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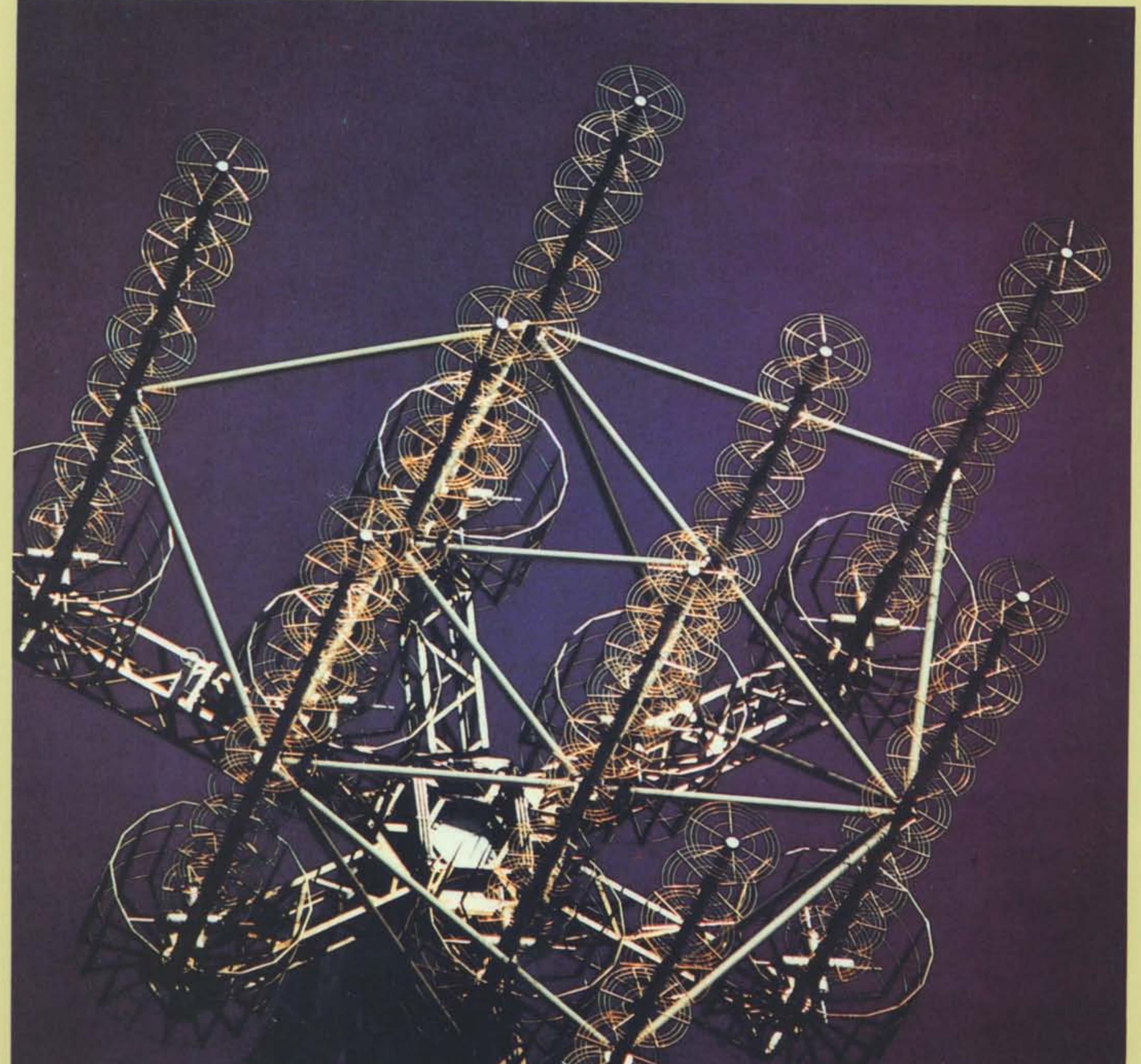

european space agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European Space Organisations: the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Ireland has signed the ESA Convention and will become a Member State upon its ratification. Austria, Canada and Norway have been granted Observer status.

In the words of the Convention: The purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems,

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of Member States. The Director General is the chief executive of the Agency and its legal representative.

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of the Spacelab Programme; the Technical Director and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC), Darmstadt, Germany.

ESRIN, Frascati, Italy.

Chairman of the Council: Mr. J. Stiernstedt (Sweden).

Director General: Mr. R. Gibson.

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée – l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) – dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, la Belgique, le Danemark, l'Espagne, la France, l'Italie, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. L'Irlande a signé la Convention de l'ESA et deviendra Etat membre de l'Agence lorsque la Convention aura été ratifiée. L'Autriche, le Canada et la Norvège bénéficient d'un statut d'observateur.

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(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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ESRIN, Frascati, Italie.

Président du Conseil: M.J. Stiernstedt (Suède).

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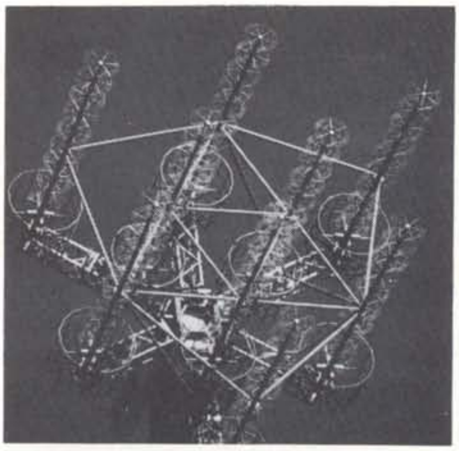

Front cover: VHF telecommand antenna used to control the IUE spacecraft from the Agency's Villafranca (Madrid) ground station.

Back cover: Electrical Demonstration Model of a satellite L-band phased-array transmitter being developed within ESA's Applied Research Programme.

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ARIANE is built in Europe by some fifty firms in 10 countries*. One industrial company puts it all together. One firm checks out all the interfaces between the numerous subsystems and components.
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ESA's Remote-Sensing Satellite Programme

C. Honvault, ESA Earth Observation Programme Department, Toulouse, France

At the present time the Agency's efforts in the field of remote sensing are concentrated in the Earthnet Programme, the remote-sensing experiments for the First Spacelab Payload (FLSP), and the preparation of a proposal for a European Remote-Sensing Satellite Programme, which includes both technology activities and system studies and instrument definition.

This article is intended to provide a brief review of studies to date, work presently under way and future plans for the Remote-Sensing Satellite Programme.

Objectives and requirements for the RSS Programme
The key mission themes for this Programme are:

- agricultural monitoring (e.g. inventory, yield prediction)
- land-use monitoring (e.g. classification and mapping)
- water-resources management (e.g. snow/ice surveys, soil moisture)
- coastal ocean surveying (e.g. sea ice, continental-shelf monitoring)
- monitoring of polar regions (e.g. Greenland, ice surveys) *
- provision of development aid (e.g. monitoring of production of biomass, disaster assessment)
- mineral resources and dynamic geology (e.g. detection of lineaments and mineral concentrations).

The specific requirements of the various applications within these themes have been studied by the Agency and this work has led to the generation of a Mission Requirements Report (MRR) for each theme. It is considered that the complete set of requirements can best be met with a set of three satellite payloads dedicated respectively to:

- land applications
- coastal ocean monitoring
- global ocean monitoring.

Attempts are, however, being made to define instruments able to play a dual role in satisfying both the coastal and global ocean monitoring requirements.

The general capabilities imposed on the payloads are:

- all-weather, day and night, illumination-independent sensing
- spatial resolution of the order of 30 m × 30 m
- correlation between microwave and optical data for interpretation purposes.

Definition studies
Two satellite system-definition studies were performed in industry until March 1979 and these are now being extended to take into account recent refinements in the definition of the various instruments. One was dedicated to the Land Applications Mission, called LASS (Land Applications Satellite System), the second to the Coastal Ocean Mission, called COMSS (Coastal Ocean Monitoring Satellite System). The constraints were:

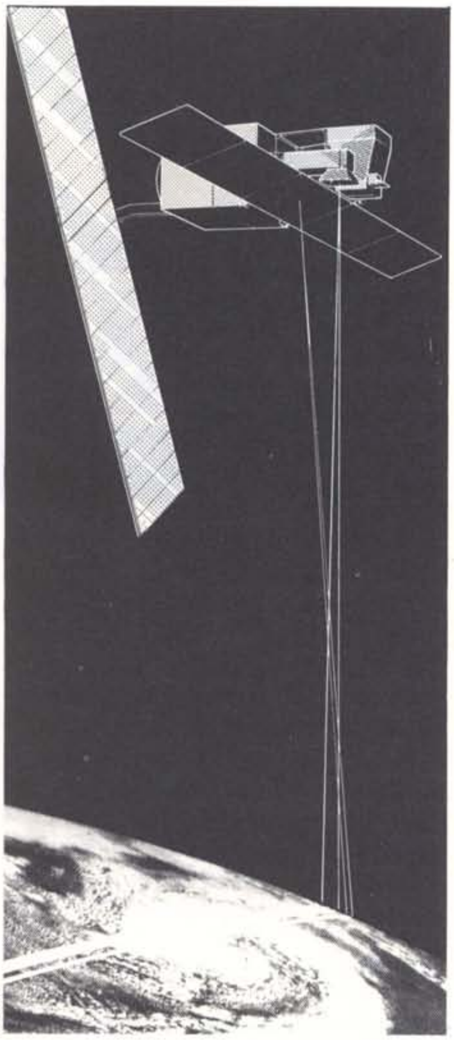
- the use of an already-designed platform called the Nominal Baseline Platform (NBP)
- a launch on Ariane-1
- the use of existing Earthnet stations adapted to the missions.

The objectives were:

- to establish a feasible baseline system concept meeting most of the mission requirements and to define its specifications and performance
- to establish development and cost plans, assuming a launch around end-1985
- to identify the critical areas in the development and the necessary growth potential and/or new concepts required to fulfil all mission requirements.

* See article Remote Sensing of Sea Ice – A Danish Project, p. 8

Figure 1 — Artist's impression of the LASS spacecraft



dornier

Table 1 – Performance characteristics foreseen for the LASS payload's synthetic-aperture radar

Spatial resolution	100 m × 100 m
Grey-level resolution	1 dB
Swath width	100 km
Look angle	20°
Minimum σ	− 18 dB
Operational frequency	5.3 GHz
Polarisation	HH or VV
DC power consumption	1.5 kW

After evaluation of the results of the two studies, with the assistance of experts from Europe and Canada, the following conclusions were reached:
- the baseline orbit is to be circular, sun-synchronous, with an altitude of about 650 km, with a measurement repeat cycle of 14 d for LASS and 3-4 d for COMSS
- the NBP as defined is suitable for the two systems
- supplementary studies were necessary prior to starting the development phase.

Elements of the LASS system
The LASS space segment is composed of the NBP and the LASS payload, while the associated ground segment consists of Earthnet for the European coverage zone, the ESA S-band tracking network, and the instrumental data-collection platforms.

The LASS payload as presently defined contains:
- An Optical Imaging Instrument (OII), tentatively based on a set of two separate instruments using the push-broom technique – a visible camera for channels 1–4 (0.52–0.90 m), panchromatic, and built around an f/5.4, 105 mm diameter dioptric lens, and an infrared camera for channels 5 and 6 (1.55–2.35 m) using an f/3 dioptric lens. A detailed definition study is presently being performed by Matra (F) with TPD/TNO and Fokker (NL).
- A Synthetic-Aperture Radar (SAR), defined by two industrial studies undertaken by Thomson-CSF (F) and Marconi Research Laboratories (UK). Both designs can be accommodated in the LASS payload. The performance characteristics are summarised in Table 1.
- An Instrument Data Telemetry System (IDTS), which will transmit the imaging information to the ground at a frequency of about 8.2 GHz, with a bit rate of about 78 Mbit/s for the OII, and 100 Mbit/s for the SAR.
- A data-collection package.

Elements of the COMSS system
The COMSS system is made up of a space segment composed of the same NBP as LASS with the COMSS payload, and the ground segment indicated for the LASS system. The COMSS payload

Table 2 – Performance characteristics defined in 1978 for the COMSS payload's synthetic-aperture radar

Spatial resolution	30 m × 30 m
Grey resolution	2.5 dB
Swath width	100 km
Look angle	20°
Minimum σ	− 18 dB
Operational frequency	5.3 GHz
Polarisation	HH or VV

defined in the feasibility study consists of:
- a SAR (see Table 2)
- an optical instrument called an Ocean Colour Monitor (OCM)
- a passive microwave radiometer called an Imaging Microwave Radiometer (IMR)
- an Instrument Data Telemetry System (IDTS), and
- a data-collection package.

In May 1979, during the joint ESA/User Representatives/Experts review of the COMSS concept, several criticisms were levelled at the SAR as presently foreseen; namely,
- spatial resolution only sufficient for high-velocity waves
- detection and tracking of icebergs and ships should use radar with large angle of incidence (e.g. 30–40°)
- greater swath width (e.g. 150–200 km) highly desirable.

The consequences of an increased angle of incidence and of widening the swath are currently being studied, but the possibilities of improving the performance of the baseline SAR are severely limited by power-supply constraints.

Ocean colour is linked to the presence and concentration of dissolved and suspended substances, which include phytoplankton, suspended sediments, and yellow substances. The OCM (Table 3) has been conceived as an improved design compared to the Coastal-Zone Colour Scanner (CZCS) now in orbit aboard NOAA's Nimbus-7 spacecraft:

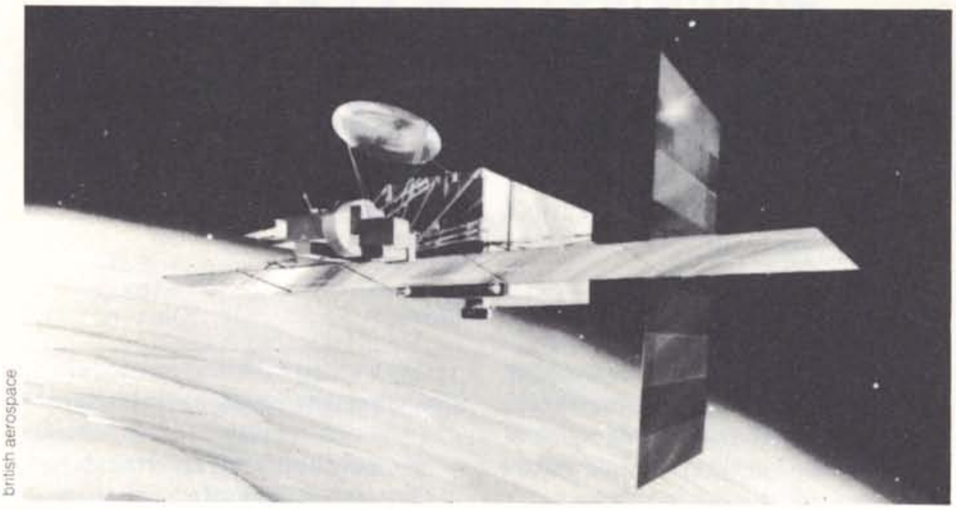


Figure 2 – Artist's impression of the COMSS spacecraft

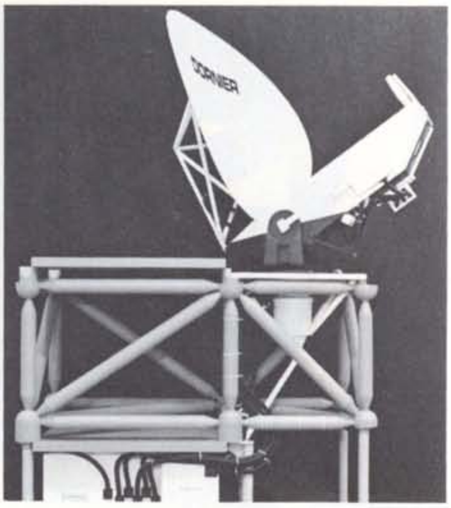


Figure 3 – Mock-up of the Microwave Remote-Sensing Experiment (MRSE) to be carried on the First Spacelab Payload (FSLP)

- Spatial resolution to be improved by a factor of 2
- Sensitivity to be improved by a factor of 10
- Atmospheric correction to be included
- Possibility to distinguish between phytoplankton and yellow substances
- Better determination of turbidity.

Table 3 – Main performance parameters of the OCM

Channel	λ (μm)	$\Delta\lambda$ (nm)	Spatial resolution (m)	Sensitivity (per cent)
1	0.415	30	800	0.05
2	0.445	30	400	0.05
3	0.500	40	400	0.05
4	0.550	40	400	0.05
5	0.600	40	400	0.05
6	0.650	40	400	0.05
7	0.750	40	400	0.05
8	1.020	40	2000	0.05
9	11.5	2 μm	400	0.2 K
10	11.0	1 μm	2000	0.05 K

The IMR (Table 4) will allow ocean-surface data to be collected day and night under almost all weather conditions. The key geophysical parameters of interest are sea surface temperature, sea surface wind, atmospheric water vapour, atmospheric liquid vapour, sea-ice-coverage parameters, and snow-cover parameters.

A multi-channel instrument is needed to resolve the various contributions to the observed radiation field with sufficient sensitivity, and an industrial study is now in progress to check the validity of the present IMR design concept. The feasibility and implications of adding a 90 GHz capability to the baseline are being investigated. This channel will be used to provide improved spatial resolution for ice mapping/measurements.

Table 4 – Main performance parameters of the IMR (H and V polarisations)

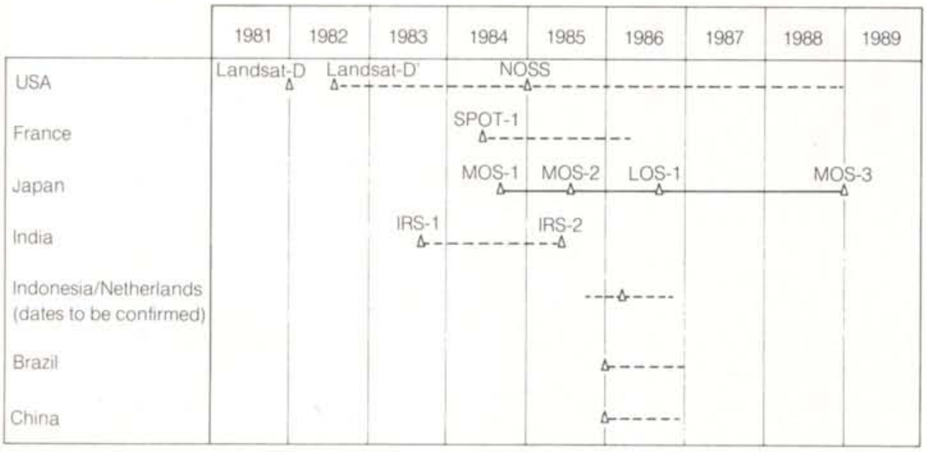
Frequencies (GHz)	Expected 3 dB footprint (km)
5.0	90 × 130
10.69	40 × 60
15.38	30 × 40
23.8	20 × 30
31.4	15 × 20
90.0	5 × 7

Evolution of the programme since May 1979

As far as the status of the satellite SARs is concerned, in addition to the specific factors mentioned above as constraints, the knowhow already secured by Germany in connection with the SAR to be flown on Spacelab has been considered. The development plan for this latter instrument presently envisages a first flight on the thirteenth Spacelab mission (SL-13) currently scheduled for 1985. In view of the time needed for post-flight data analysis, the incorporation of the results into the development phase of the satellite SAR, and the latter's integration on board the satellite, it does not seem realistic to envisage launch of a remote-sensing satellite carrying a SAR with the requisite performance characteristics before the second half of 1987.

Assuming that Europe wants to:
- make an active contribution to the world resources scene in the mid-eighties, and to be in a position to cooperate with national programmes (France, Japan, India, USA, etc.) (see Figure 4)
- meet, in terms of both quantity and quality, the growing demands of the European user community for remote-sensing products
- maintain and enhance its expertise

Figure 4 — Planned launch dates for approved/projected remote-sensing satellites



and knowhow in the various areas of remote sensing (instruments, data processing, intepretation)
- contribute to the setting up of an operational system, and
- provide assistance to the developing countries,

a 1985/86 launch is a satisfactory objective for the first European Earth-Resources Satellite, ERS-1, bearing in mind the technical and financial constraints.

In view of the growing interest of users in maritime applications missions, the Executive has selected from a number of different possible mission scenarios what seems to be the most promising one; namely an ERS-1 carrying – in addition to the OCM and IMR referred to above – a radar altimeter and a scatterometer [which might be derived from the Microwave Remote-Sensing Experiment (MRSE) to be carried on the First Spacelab Payload (FSLP); a laser reflector could be carried for orbit-determination purposes].

The radar altimeter has proved to be a useful tool for the remote sensing of the ocean (Seasat-1), and satellite altimetry has already demonstrated in particular that total ocean topography at the sub-metre level is feasible:
- altimeter data can record geoidal undulations with a degree of accuracy acceptable for earth dynamics
- the radar altimeter is capable of measuring surface slopes and hence currents with accuracies useful for oceanographic calculations
- radar altimetry can provide important surface-slope data for hydrodynamic models of large coastal-water bodies.

System studies are therefore now being undertaken by ESA with a view to:
- ascertaining the suitability of a Seasat-type altimeter for the ERS-1 system
- assessing the feasibility of implementing the radar altimeter on board the platform.

The microwave scatterometer could be a monofrequency scatterometer for wind determination, or a two-frequency scatterometer. The latter transmits two microwave frequencies in time multiplex, one of which is constant, and the other lies in the range 0.5–50 MHz, for example. Calculations deliver a cross-correlation term proportional to a component of the sea-wave spectrum, depending on look angle, depression angle and frequency difference, while rotation of the antenna gives wave direction. In this way, the long ocean wave spectrum components of waves of between 10 and 500 m can be detected. Wind velocity might also be derived from the measurement of the return signal strength at one frequency. The Microwave Remote-Sensing Experiment to be flown on the first Spacelab mission will include such a two-frequency scatterometer.

The definition studies for all of these instruments and systems will be completed by November 1980 and will provide inputs for:
- The start of the definition phase (Phase B) in 1981
- The start of the main development phase (Phases C/D) in early 1982 (development and manufacture of the spacecraft plus the setting up of an adequate ground segment for the acquisition, processing and dissemination of data and information)
- The launch and orbital operation of the first European satellite in the 1985/86 time frame
- The launch and orbital operation of a second European satellite carrying a synthetic-aperture radar (SAR) about two years later.

Conclusion

The preceding paragraphs have outlined the main European interest and objectives in spaceborne remote sensing, and have described the studies presently under way or planned which should lead to the implementation of a European remote-sensing satellite programme by the mid-1980s. Europe and, indeed, the rest of the world, with their increasing requirements for accurate and timely information on the earth's resources and environment, clearly need the new data that can be supplied by remote-sensing satellites. Although many problems still have to be resolved concerning the use of the data and the technical elements to be developed, it is firmly believed that Europe has the experience and ability to overcome them, and that remote-sensing satellites will form an important part of ESA's future space programme.

nasa image

Remote Sensing of Sea Ice – A Danish Project

P. Gudmandsen, Electromagnetics Institute, Technical University of Denmark, Lyngby, Denmark

Although Denmark has no remote-sensing programme as such, a number of institutions are studying possible applications of Landsat data in Greenland for various geophysical purposes. In this large and in many respects unexplored country, remote sensing from aircraft and satellites is likely to have great advantages over conventional geophysical exploration, particularly when one considers the severe arctic environment. This will certainly be true when remote-sensing techniques have been developed sufficiently to be used for the surveillance of dynamic features in operational systems.

Airborne sea-ice reconnaissance has been carried out in Greenland since 1959 based on visual observation by trained personnel. Because there can be dense low cloud cover in this region for more than 70% of the year, the efficiency of this approach is low when used for surveillance and mapping purposes.

Much higher efficiencies can be obtained with microwave sensors, the performance of which is largely independent of prevailing weather conditions. Consequently, the studies undertaken by the TUD Electromagnetics Institute have been particularly concerned with microwave remote-sensing techniques, with a view to developing airborne systems for sea-ice research and for underflights related to present and future satellite systems.

In our sphere, 'remote sensing' covers the observation of the earth's surface from aircraft and satellites with imaging sensors, sensors that may operate in the visual, infrared or microwave bands. In all cases the associated techniques can be divided into four phases:

- sensor design and construction
- data acquisition
- data pre-processing and image production
- image interpretation.

As part of an engineering school, it has proved a natural path for the Institute, having been drawn initially into the first of these four phases, to have progressed to the second and subsequent phases. The following paragraphs briefly describe the work that is being carried out at Lyngby and some of the results that are being obtained, together with their significance in the northern European context.

Passive microwave radiometry

Microwave radiometry relies upon the fact that every surface radiates energy even at microwave frequencies, and that this energy may be detected by very sensitive receivers called 'microwave radiometers'. The energy radiated depends upon the physical temperature of the surface and its properties. The power received by the radiometer can be expressed as $k \cdot T_B \cdot B$, where k is Boltzmann's constant, T_B the so-called 'brightness temperature', and B

Table 1 – Main characteristics of the experimental radiometers built at TUD Electromagnetics Institute

Frequency	5 GHz		17 GHz		34 GHz
Bandwidth	0.5 GHz		1 GHz		1 GHz
Noise figure	4.2 dB		5 dB		5 dB
Integration time	4	8	16	32	64 ms
Radiometric resolution	1.34	0.95	0.67	0.48	0.34 K

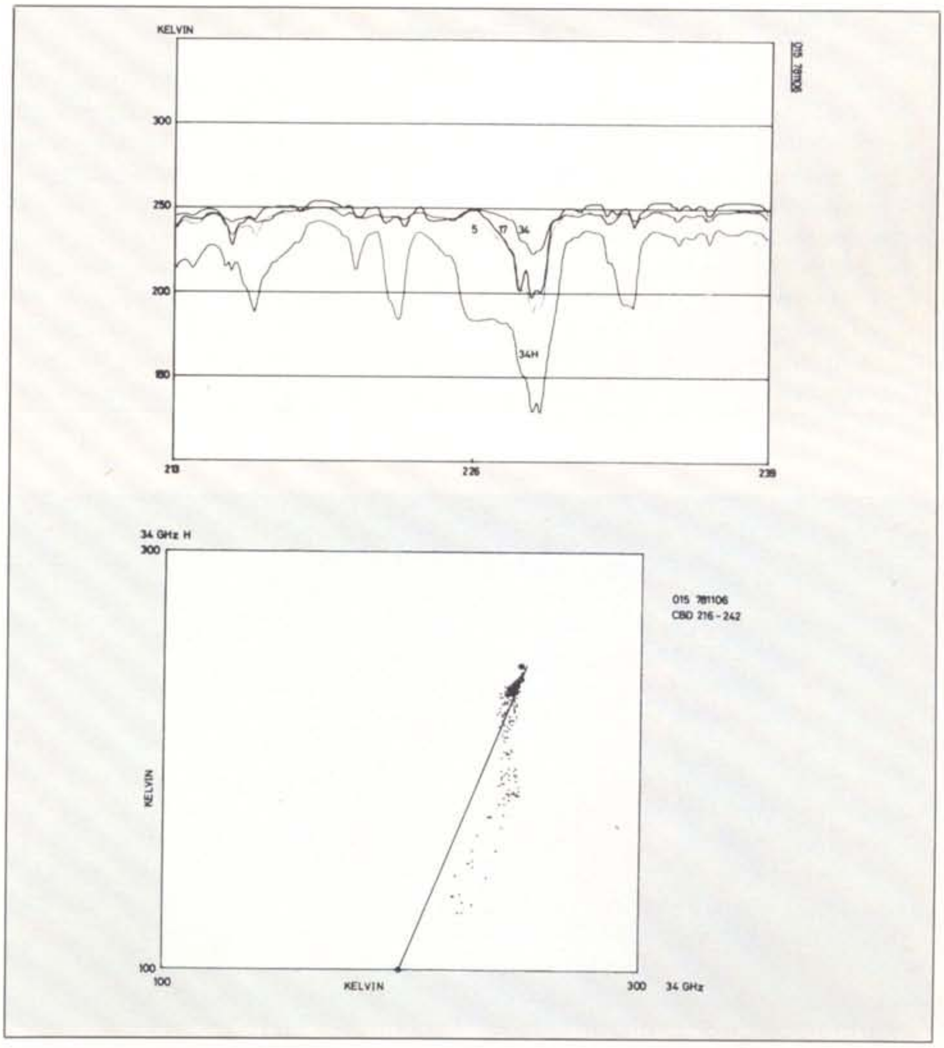
Figure 1 — Close-up of the C-130 aircraft with four radiometer horns mounted in the lower part of the paratroop door. A 2 m side-looking-radar antenna is mounted over the wheel box

Figure 2 — Four brightness temperatures (upper figure) measured with profiling radiometers at 5 GHz and 17 GHz with vertical polarisation, and at 34 GHz with vertical and horizontal polarisation (34 H). This recording was made in Melville Bay in June 1978 with first-year ice and leads, a lead being observed at position 228.

The lower figure is a correlation diagram plotting a cluster of measured brightness temperatures at 34 GHz, vertical polarisation versus horizontal. The solid line represents a simple model describing this type of ice canopy

the bandwidth of the radiometer. The brightness temperature can be expressed as $T_B = \varepsilon T$, where T is the physical temperature in Kelvin (K) and ε is the emissivity, a quantity related to the dielectric and physical properties of the surface and describing the fraction of energy actually radiated. A black body radiates all its energy, and consequently its ε is equal to one. For a plane surface, the emissivity is dependent upon the reflection coefficient of the surface, through $\varepsilon = 1 - \rho$, where ρ is the power reflection coefficient. Consequently, for a given surface there is a difference between the emissivities measured with vertically and horizontally polarised radiometer antennas. If the surface is rough, emissivity is increased and becomes a function of the degree of roughness and the reflection coefficient.

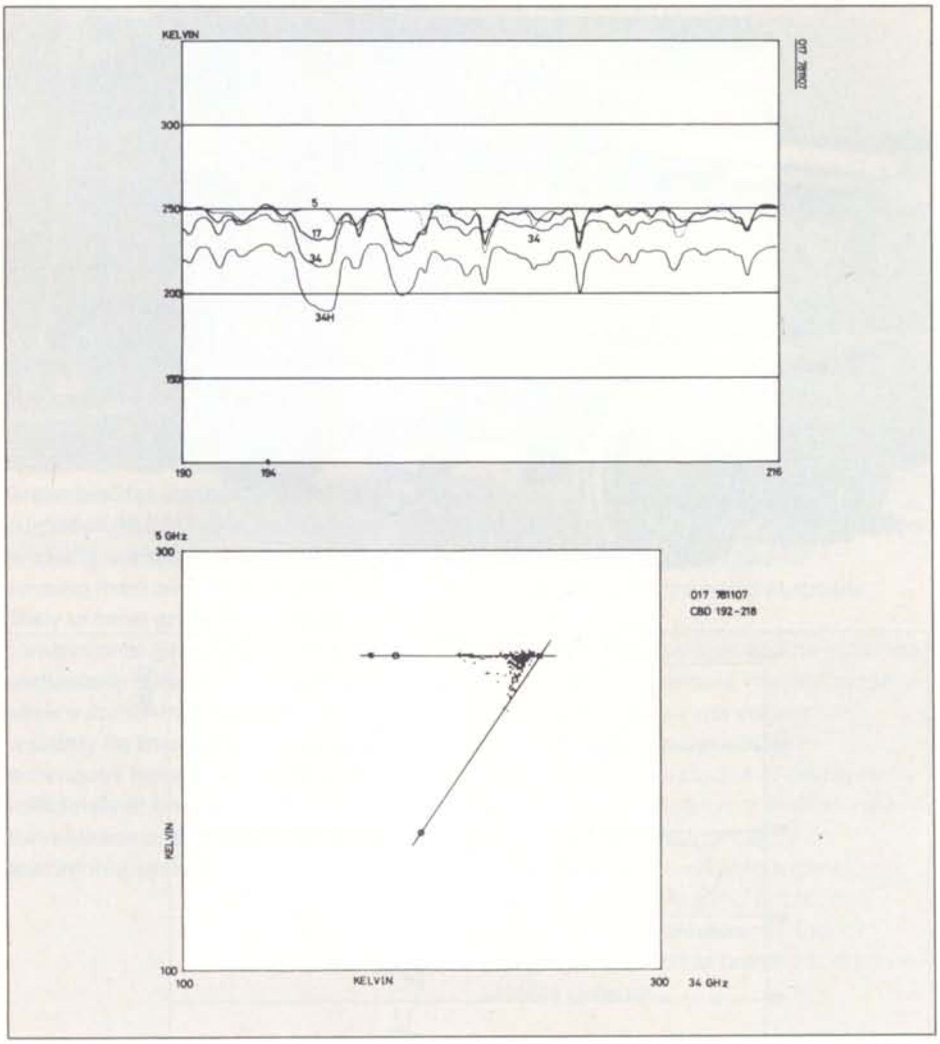
Experience shows that variations in brightness temperature are due more to variations in emissivity than to variations in physical temperature, so that radiometer techniques are useful for the classification of surfaces. In the case that the surface consists of material with low dielectric losses, the radiation at microwave frequencies may originate from below the surface, so that the measured brightness temperature depends upon the inhomogeneities in the volume below the surface in addition to the surface influence; this is called 'volume scattering', a phenomenon that can reduce brightness temperature.



The work carried out by the Institute is related to the American Nimbus-7 satellite and the forthcoming European Coastal Ocean Monitoring and Global Ocean Monitoring Satellite Systems (COMSS and GOMS). These satellites are equipped with multichannel microwave radiometers operating at five frequencies in the range of 6–37 GHz.

Owing to the limited funds available for the TUD studies, only three radiometer prototypes have been constructed, for 5, 17, and 34 GHz. A noise-injection type of

Figure 3 – This figure is similar to Figure 2 and presents data from the East Greenland Current in June 1978, where a combination of first-year ice, multiyear ice, and open water is present. The correlation diagram plots data at 5 GHz versus 34 GHz with vertical polarisation. The solid lines are derived from simple models describing this situation, the skew line representing a water/ice mixture.



radiometer was selected for its greater sensitivity, despite its greater complexity.

The main parameters of the radiometers built by the Electromagnetics Institute are given in Table 1, which shows the influence of integration time on sensitivity or radiometric resolution.

These radiometers have been used in various campaigns in Greenland. In one of them, electromagnetic radiometer horns were mounted in the paratroop door of a C-130 aircraft belonging to the Royal Danish Air Force (Fig. 1). The horns were scaled according to wavelength, to have an equal gain of 25 dB. With an angle of incidence of 50° and an altitude of 2000 m, the footprint was 375 m along and 770 m across track. The horns were vertically polarised, and an additional horn at 34 GHz was operated with horizontal polarisation, taking advantage of the multiplexing capability of the radiometer at that frequency.

Two sample recordings are shown in Figures 2 and 3 from measurements carried out in June 1978 over Melville Bay (73°30′N, 60°W), off the west coast of Greenland, and over the East Greenland Current (76°30′N, 16W), respectively. Brightness temperatures in Kelvin are given as a function of navigation numbers (i.e. position) related to the coordinates read out from the aircraft's inertial navigation system. The figures also show examples of correlation diagrams between sets of brightness temperatures observed by two radiometers.

In Melville Bay, a combination of first-year ice and water is present, the water occurring as rather narrow leads in comparison with the spatial resolution of the radiometers. Thus a lead is passed at position 228, where the brightness temperatures become low due to the low emissivity of water (Fig. 2). At this time of the year the ice is in a melting state and it can be seen that the brightness temperatures are approximately equal at the three frequencies with vertical polarisation, and there is a tendency for the 34 GHz brightness temperature to be the highest due to the wet, absorptive surface. The variations in brightness temperature are much larger with horizontal than with vertical polarisation at 34 GHz (110 K variation in contrast to 25 K). The correlation diagram shows this, but also that the variations deviate from a straight line, which results from a simple theory describing a composition of various ratios of first-year ice and open water, open water having the coordinates (100 K, 200 K).

In the East Greenland Current we find a combination of first-year ice, multiyear ice and water, the multiyear ice originating in the Arctic Ocean where it has survived several summers of melting. Figure 3 shows that with vertical polarisation there is an inversion in brightness temperatures compared with the sequence in Figure 2, with the 34 GHz brightness temperature being the lowest. This is a characteristic of multiyear ice – a good example is observed at position 196 – where volume scattering in the low-salinity ice takes place at the higher frequencies where the inhomogeneities are of the same order of magnitude as the wavelength. The horizontal line in the correlation diagram describes this phenomenon, whereas the skew line is related to various ratios of ice and water, open water having the

Figure 4 — The three-frequency radiometer system mounted on the open ramp of the C-130 aircraft with a scanning offset parabolic antenna. The aircraft is flown with the ramp open during measurements, with the antenna beams directed at 50° to the ground in a 1 Hz conical scan.

coordinates (200 K, 164 K).

In another campaign, the radiometer system was fitted with a scanning antenna mounted on the open ramp of the C-130 aircraft (Fig. 4). The antenna was an offset paraboloid reflector, illuminated by a cluster of feed horns, one for each frequency. It had a diameter of 1 m and oscillated at a frequency of 1 Hz, the footprint with a 50° angle of incidence ranging from 356 × 175 m² to 52 × 26 m².

An example of data obtained with this system is shown in Figure 5, where a brightness temperature image of a 2000 m swath under the aircraft in the marginal ice zone in Davis Strait (68°N, 56°W) in April 1979 is reproduced. In the colour scheme of this image, the brightness temperatures at the three frequencies measured simultaneously are colour-coded in 10 K steps. In the lower part of the image the pack consists of thin, wet ice, and the 5 GHz channels show that the ice concentration (area ratio of ice to water) is small and that only a few larger floes are present.

Another example is shown in Figure 6, from the East Greenland Current (65°40′N, 35°30′W). Here the 34 GHz brightness temperature is lower in general than that at the other frequencies, indicating a large proportion of multiyear ice.

The last two images have been produced on the Institute's minicomputer and represent a simple but useful way of studying the digital data acquired. In fact, each picture element represents a measured brightness temperature although on a coarse scale (only seven colours available). With appropriate changes in the scale, radiometric details can also be represented.

This latter activity forms part of an additional radiometer project related to the Institute's Nimbus-7 activities. Scanning Multichannel Microwave Radiometer (SMMR) system analyses are carried out on raw data as part of a validation process with a view to applications in the polar regions. The SMMR is a ten-channel system (five frequencies and two polarisations), so that in principle an inversion of radiometer

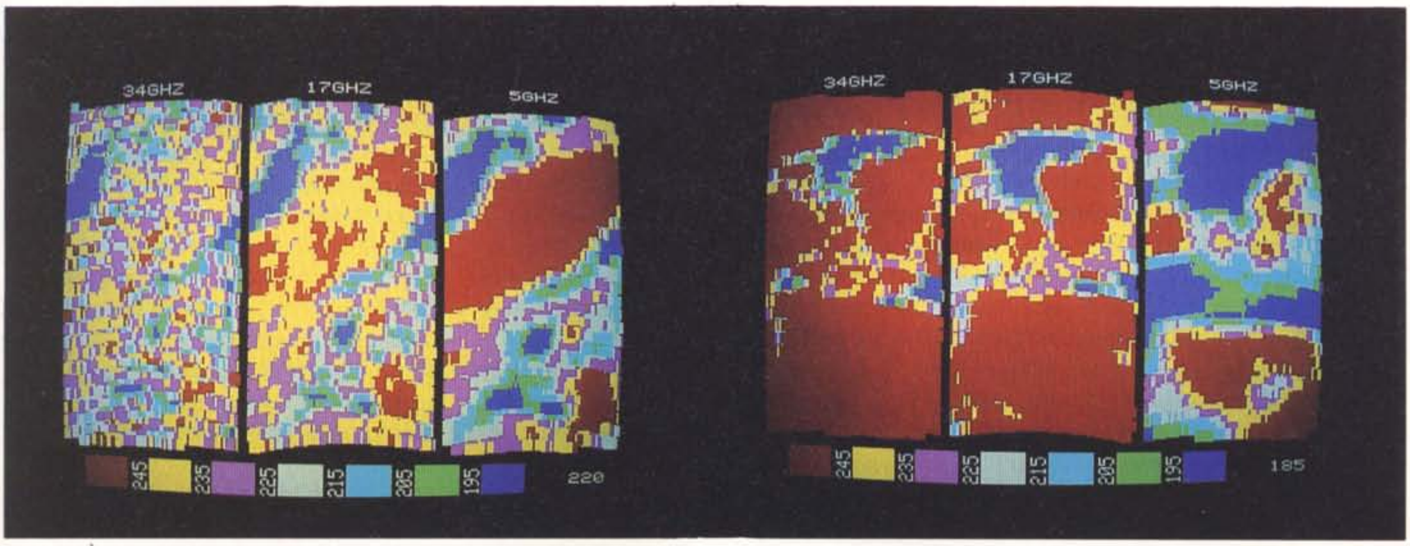
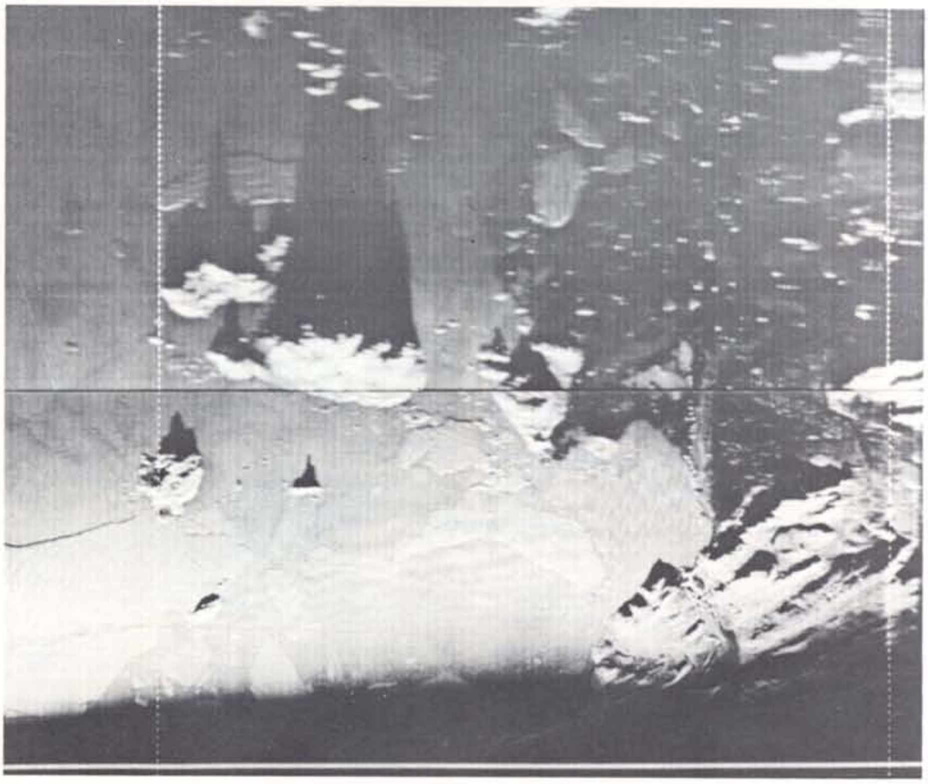


Figure 5 — Brightness temperature image obtained from measurements in the marginal ice zone in Davis Strait in April 1979. The temperatures, in steps of 10 K, are indicated by the colour scale. The blue colour represents open water or very little ice, whereas the red colour represents solid ice.

Figure 6 — Brightness temperature image from measurements in the East Greenland Current. Blue represents water and red solid ice — a large floe of multiyear ice with lower brightness temperatures at 34 GHz than at 5 GHz, for instance. The swath width is approximately 2 km.

Figure 7 – Side-looking airborne radar image recorded in July 1977 in Jøkul Bay, on the east coast of Greenland, and an oblique photograph of part of the scene taken with a hand-held camera. Ice islands with a peculiar surface pattern are surrounded by thin sea ice. Note the shadows cast by mountains.



data into geophysical data is possible when knowing the multispectral characteristics of the surfaces observed. By using a common reflector, however, the spatial resolution is different at the different frequencies, ranging from 25 km to 150 km. This presents a special problem which is being studied to see to what extent and with what accuracy the data may be valid for solving the inversion problem in a 50×50 km² cell, say, using data with a coarser resolution.

Side-looking radar

An airborne radar in side-looking mode is an active imaging instrument that illuminates the surface with pulses and detects the reflections. Every facet oriented at right angles to the look-direction of the radar contributes to the reflection from the (rough) surface, within the resolution cell determined by the pulse length and the azimuthal radiation of the antenna. An image of surface reflections is therefore obtained by sideways scanning with the emitted pulses and by moving the antenna so that a swath parallel to the flight direction is obtained, the swath width being determined by the vertical radiation pattern of the antenna.

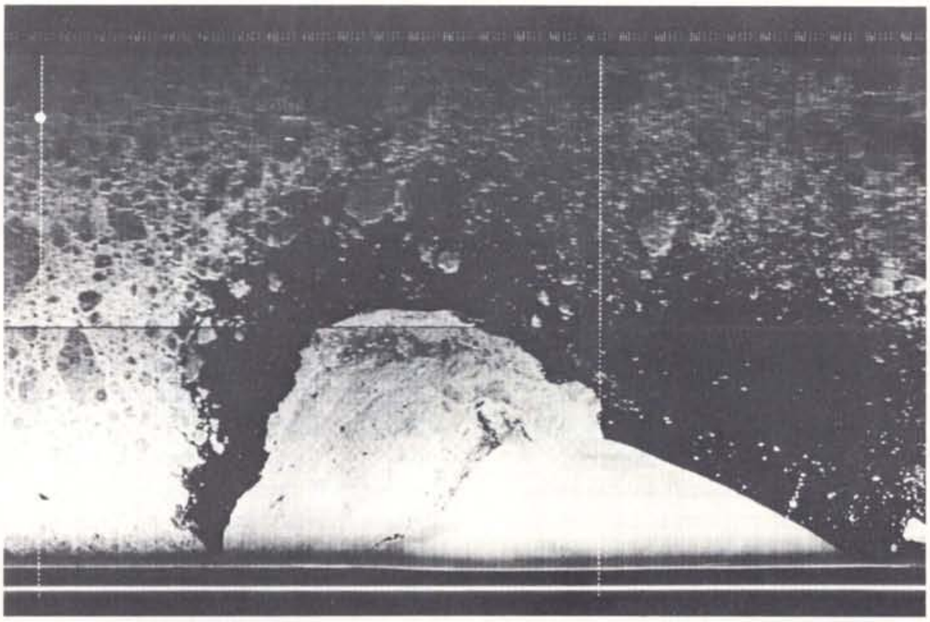
As part of the Institute's remote-sensing project a simple Side-Looking Airborne Radar (SLAR) was developed and again installed on one of the Royal Danish Air Force's C-130 aircraft. It is a commercial marine radar operating at 9.375 GHz (X-band) which has been modified electronically to suit its new application; the output circuits and the recording devices in particular have been changed. The ordinary antenna has been retained and is mounted on the aircraft's wheel housing, as can be seen in Figure 1. Thus, the radiation pattern transverse to the direction of flight extends from nadir to about 30 km, and some image distortion occurs at close range. However, with known geometries this distortion can be corrected for in a digital processing of the radar images that is presently being implemented. With the 2 m antenna the azimuthal resolution is 16 m/km, whereas the range (transverse) resolution is 9 m and is determined by the 60 ns pulse of the radar.

Figure 7 is an example of a SLAR recording in Jøkul Bay on the east coast of Greenland (70°15′N, 21°W), where large, rather thick floes with an interesting surface pattern frozen in thinner ice are observed. The image also shows the shadow effect inherent in side-looking-radar applications, shadows from island mountains, and the shadow from the thick floe from which the freeboard may be estimated. An oblique photograph is included for comparison. It was taken with a hand-held camera and is therefore not correctly aligned, but the main features of the central part of the radar image are recognisable.

Another example of radar recording is shown in Figure 8, obtained at Nordostrundingen in northeast Greenland (81°30′N, 11°15′W). On one side there is open water, with sea ice further out to sea. On the other side, shorefast ice extends 10 km from the shore. Large individual floes are apparent in the ice canopies. The variation in reflection is due partly to the surface's properties, and partly to the variation in angle of incidence from nadir (0°) out to 30 km (86°). The dotted line is a distance scale in the range direction, each step corresponding to 300 m.

As a consequence of the good results obtained, the system has now been

Figure 8 – Radar image recorded on the same flight as Figure 7 at Nordostrundingen in northeast Greenland, with shorefast ice at the ice cap in the lower part of the image and scattered sea ice, mostly multi-year ice. The dotted line is a distance scale, each step representing 300 m. The thick horizontal line at the bottom of the image is the position of the aircraft (reference line) and the thinner line is the surface contour of the terrain at nadir.



further modified and installed on an Otter aircraft belonging to Greenland Ice Services, for semi-operational use. This aircraft is equipped with two antennas, so that observations may be made on either side of the fuselage. The radar itself is equipped with an optical-fibre recorder, allowing almost real-time display of the recordings, which also include the data obtained from the Omega navigational equipment, on dry silver paper.

Experience gained with this semi-operational use of side-looking radar will form the basis for the establishment of specifications for future systems for sea-ice reconnaissance.

Conclusions

The sea-ice project described above culminated in a large-scale experiment in Davis Strait in April 1979 in connection with the Canadian SURSAT Project, in which five aircraft and a helicopter from Denmark, Canada and the United States participated. The experiment had the aim of studying and demonstrating the capabilities of different microwave sensors for sea-ice observation and also served as an underflight for Nimbus-7. It included a variety of remote-sensing equipment, such as a sophisticated X/L-band dual polarised synthetic aperture radar, a microwave scatterometer, cameras and infrared scanners, in addition to the instrumentation mentioned above.

Although very successful, the experiment provided data from only one site for one specific time of year. To be able to use microwave remote-sensing data in a future operational system, more data are needed – satellite data and underflight aircraft data as well as ground data – in order to arrive at a reliable interpretation of the satellite data in such a system.

So far we have dealt only with the observational aspects of remote sensing, which is the primary goal of these techniques. The remote-sensing data are, however, likely to be used as input for ice-dynamics models which will in turn be used for forecasting purposes. In addition to the remote-sensing data, present-day models require a number of other data that are difficult to measure remotely (wind and current and the roughness of the subsurface of floes, for example). The question therefore is: what can be done in ice dynamics with the data obtained from satellite sensors, such as ice boundaries, ice concentration, floe-size distribution, etc. and, perhaps most important, what can be derived from the temporal variation of these data? To study this question more data are needed and especially time sequences of data. The equipment and the methods described above could prove extremely useful in this respect.

Every winter about 10% of the sea surface in the northern hemisphere is covered with ice, but its extent and concentration varies widely from year to year. For a number of nations, it is therefore of great importance to monitor sea-ice conditions and to work out forecasts of impending ice situations, particularly for their shipping and fisheries. Since sea-ice considerably reduces the heat-exchange between the ocean and the atmosphere, the ice conditions are also important for climatological studies and weather forecasting. Satellite data obtained by microwave sensors of the sort described here – comparable to those that will be available on the forthcoming European remote-sensing missions (COMSS and GOMS) – are therefore likely to be of major importance for such work, assuming that we can arrive at a thorough understanding of what we observe, what can be observed, and how the data can be used reliably.

Acknowledgement

The studies presented have been carried out by a team of research engineers and research students at the Technical University of Denmark's Electromagnetics Institute over a five-year period and the success of the project is due largely to their enthusiasm and hard work. The work, which has been described in detail in a number of reports issued by the Institute, was paid for in part by the Danish Space Research Committee under yearly grants. Acknowledgements are also due to the Royal Danish Air Force, Luftgruppe Vest, and the Danish Meteorological Institute, Greenland Ice Services.

Weather Monitoring and Short-Period Forecasting Using Satellite Data

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This article discusses the use of meteorological satellite systems for weather monitoring in the context of short-period and highly local forecasts. The terms short-period and highly local do not have precise definitions in general use, but it is convenient to define them here as forecasts extending up to nine hours ahead in time and covering areas of the order of 200 km^2.

These arbitrary forecasting definitions are convenient for several reasons. Firstly they remove from further consideration the use of numerical weather-prediction techniques, since computer models appropriate to the time span defined are not yet in operational use. That is not to say that these computer techniques do not contribute to short-period forecasts, or that satellite data do not have an impact on the numerical weather predictions. Indeed, quite the contrary is true, since the short-period meso-scale forecast is normally produced with a full knowledge of the longer period synoptic-scale forecasts produced by objective numerical techniques, and these numerical forecasts include within their observational data bases information generated by the satellite system. However, their contribution is at present indirect and is therefore neglected in this article. A second reason for the choice of scales is that it enables emphasis to be placed on just one of the two classes of meteorological satellites. The two are distinguished primarily by their instrumentation and orbits, and are generally referred to as 'geostationary' and 'polar-orbiting'.

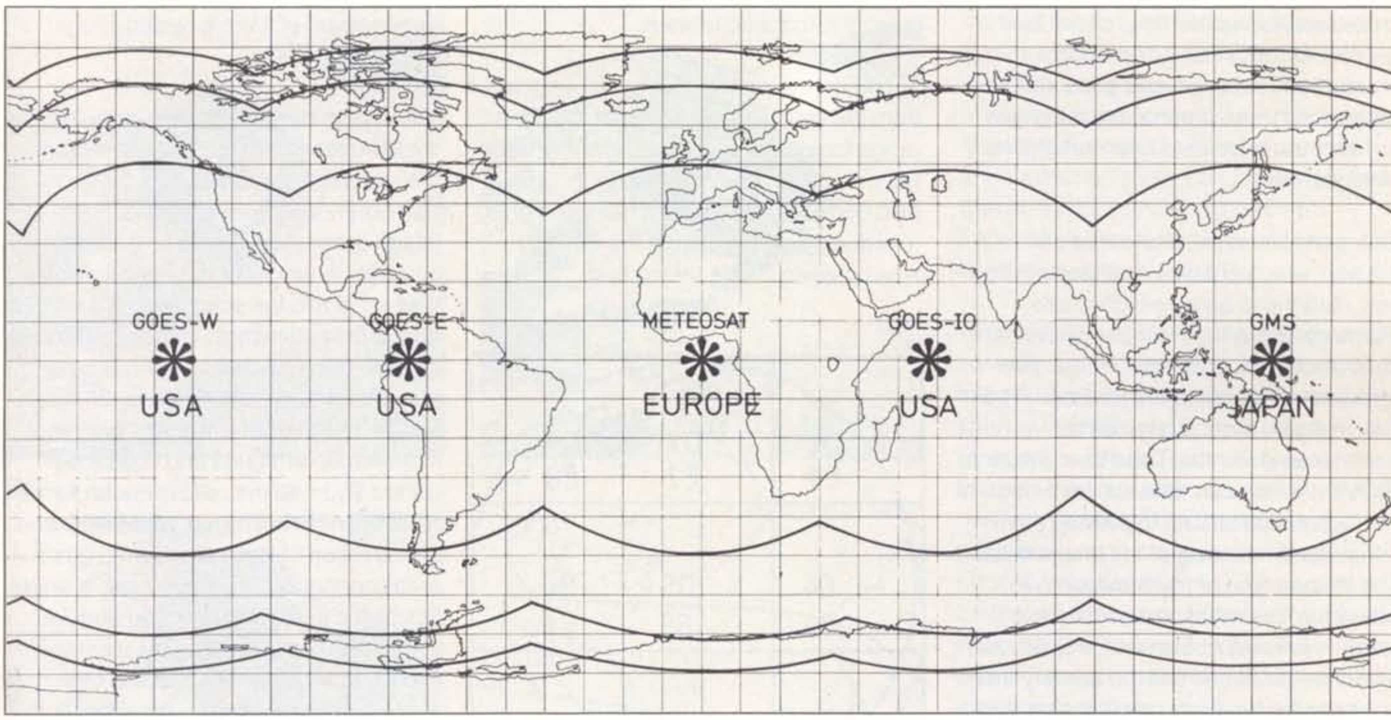
The latest generation of polar-orbiting Tiros-N meteorological satellites has a near-polar, sun-synchronous orbit with an average altitude of 854 km and an orbital period of 102 min. The ground track of the subsatellite point is such that each successive orbit is displaced westwards by about 29° in longitude, because of the earth's rotation, and the orbit is called sun-synchronous because it crosses the earth's equator at fixed *local* times each day; 0730 and 1500 in this particular case. These polar-orbiting systems are therefore characterised by twice-daily observations only (more frequent at high latitudes), and cannot be regarded as the primary satellite input for short-period forecasts as defined here, although of course the high-quality image data, acquired by virtue of their low orbit, do have a role at the particular times of day defined by the orbital parameters. Even with a system of two such satellites in complementary orbits, their function is less important than that of the other class of meteorological satellites, namely the geostationary type, of which Meteosat is an example, and consequently the polar-orbiting type is not considered in detail here.

The main characteristic of the geostationary meteorological satellite is its equatorial orbit at an altitude of 36 000 km, by virtue of which it stays more or less fixed in location relative to the earth. This fixed location enables this class of satellite to generate data for the same part of the world at very frequent intervals, such as images of the full earth disc in several spectral channels each half an hour. This high repetition rate is ideally suited to short-period forecasting, and for this reason this article concentrates on the geostationary meteorological satellites, and the Meteosat series in particular.

Finally, the choice of scale limits the discussion to an interesting and economically useful time period not yet well served by the advances in technology and techniques of the past two decades, and on which geostationary-satellite data can have a direct and positive impact.

Figure 1 – The coverage of the global system of geostationary meteorological satellites during the Global Weather Experiment (1 December 1978 to 30 November 1979). The Goes-IO (Indian Ocean) satellite was withdrawn at the end of the experiment, and Meteosat-1 suffered almost complete failure on 23 November 1979. The arcs (a), (b) and (c) on the diagram indicate, respectively, the approximate coverage areas for quantitative use of image data, qualitative use, and the communications zones

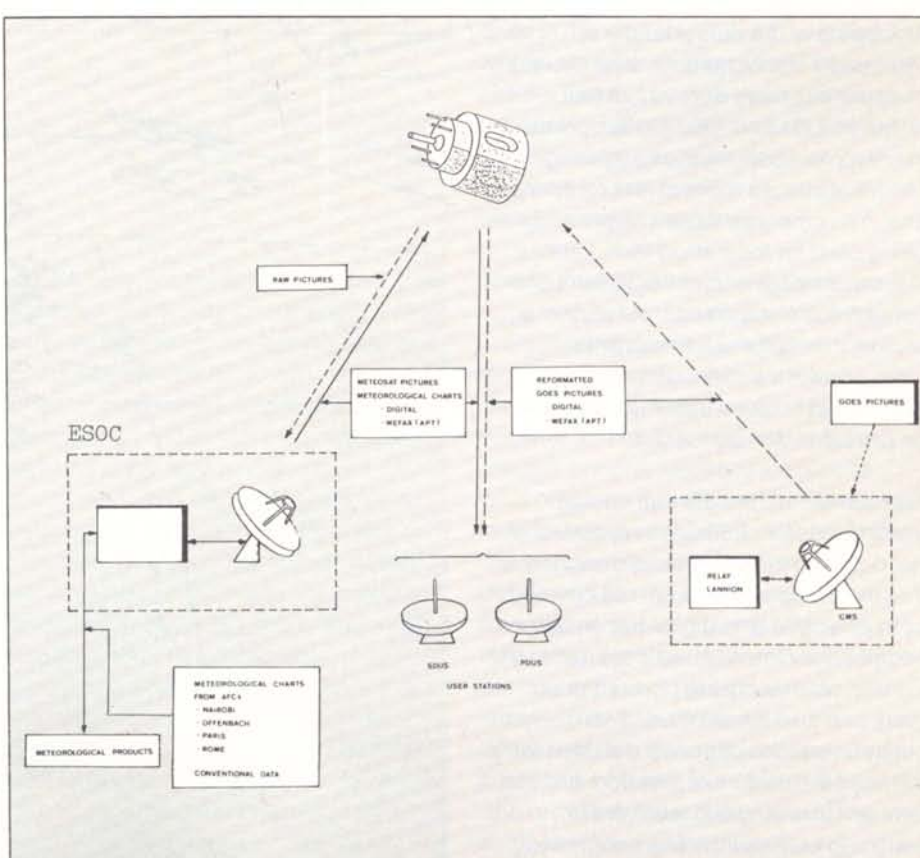
Figure 2 – The Meteosat dissemination mission. Raw images are transmitted to ESOC in Darmstadt (Germany), where they are preprocessed and sectorised before being relayed over two communications channels on Meteosat to Primary and Secondary Data User Stations



Transmitting Meteosat images to receiving stations

The radiometer carried by the Meteosat satellites has three spectral channels, in the visible band (VIS), in the thermal infrared in the so-called window channel (IR) around 11 μm, and in the so-called water-vapour channel (WV) at 6 μm. In normal operation it scans the full earth disc every half an hour, and the system generates images in digital form comprising arrays of 2500 × 2500 picture elements (pixels) for IR and WV and 5000 × 5000 pixels for VIS. Each pixel is described by an 8-bit number in the case of the IR channel, and by a 6-bit number for each of the other two channels, giving grey scales in the ranges 0–255 and 0–63, respectively.

This digital data stream is sent at a rate of 166 kbit/s to the central ground station at the European Space Operations Centre (ESOC) in Darmstadt for processing – although the signal can also be acquired by major user stations, including one in Lannion, France, and one in the Republic of South Africa. At ESOC the images are



preprocessed in order to improve their geometric, radiometric and optical properties. Coastlines and grids are added and these preprocessed images are then transmitted to user stations via Meteosat itself.

This is the Meteosat dissemination mission, which enables relatively low cost user stations to acquire high-quality image data in a more simple mode than direct reception of the raw image. Two forms of transmission are foreseen. The first, in digital form, is directed to sophisticated Primary Data User Stations (PDUSs) which can take full advantage of the digital data stream to provide local computer processing of the image data. The second type of transmission is in analogue form (Wefax) and directed towards lower-cost Secondary Data User Stations (SDUSs) where the primary use envisaged is for direct use of the images as photographs.

At the time of the partial failure of Meteosat-1 last November, after two years of operation, there were about half a dozen PDUSs and 130 SDUSs operatin in twenty-five countries, all acquiring Meteosat images more or less routinely and in many cases these images were being used for local short-term forecas The transmissions from ESOC containe not only full-disc pictures, but also imag sectors in which the full horizontal resolution for a limited area was transmitted in much less time than wou be necessary for the full disc.

The number of formats that can be transmitted from ESOC is in excess of 40 per day, and the schedule is designed sc that the European area can be covered i both analogue and digital transmissions at half hourly intervals, with the rest of the full disc normally being covered once every one and a half hours. Two distinct communications channels are used for this, and the user must therefore choose between installing two receivers or switching between the two frequencies, according to pre-published schedules, to select the required formats.

The Meteosat system has been designed from the start with the needs of the short-range forecaster very much in mind, since not only is the repetition rate high, but also considerable thought has been given to reducing to a minimum the elapsed time between image taking and transmission of the processed image format from ESOC.

The system has in fact been optimised for the European user, and for this reason the standard chain of events for each half-hourly image is as follows. Start image generation at time t=0 at the southern extremity of the earth's disc. At time t=20 min the scanning reaches 30°N and shortly afterwards covers Europe. By t=25 min the full disc image has been acquired and preprocessed by ESOC, and by t=35 min the image is being cut into sectors with grids and coastlines added. By t=48 min, all European formats have been retransmitted from ESOC and transmission of formats covering other areas continues. Thus, even with a simple SDUS, the European user can acquire image segments showing the local scene every half an hour within 28 min of that scene being observed by the spacecraft, and with the considerable advantage of having superimposed coastlines to help locate the meteorological phenomena.

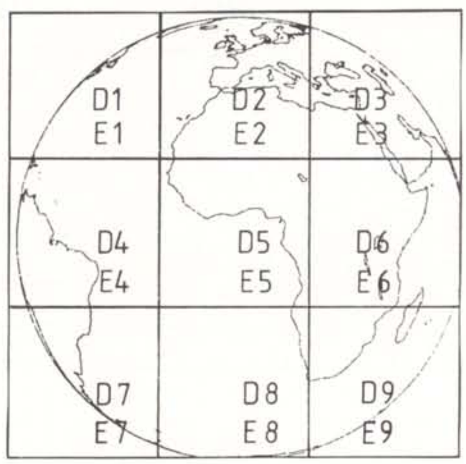


Figure 3 — An example of the way in which the full earth's disc is cut into sectors before retransmission from ESOC. With these sectors IR and WV images can be sent with full horizontal resolution as an analogue transmission (Wefax). Each of the nine formats utilises nearly 4 min of transmission time. If VIS data is sent in these formats, it is transmitted with half the available resolution

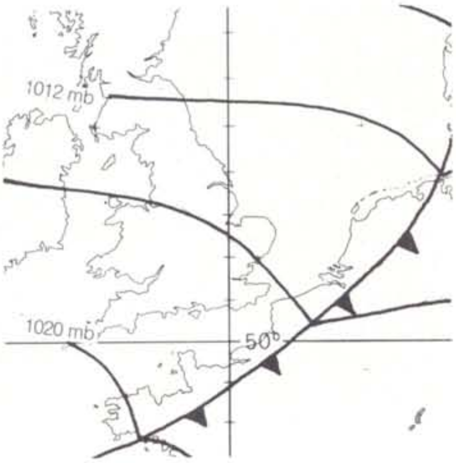
Figure 4 — Part of an infrared European sector, transmitted from ESOC with coastlines added, and received by the Swiss meteorological service

Figure 5 — Samples from a sequence of Meteosat-1 images for 21 August 1979. (5a) at 0800 UT show clear sky over most of southern England, with a sharply delineated cold front over Kent. By 1130 UT (5b), the front is over the Straights of Dover, and much of southern England is covered with small convective cloud, while the colder sea remains cloud-free. At 1630 UT (5c), the front has moved further south east and the cloud over the UK is dissipating. A cyclonic vortex north of Scotland is clearly apparent in all three images, and the corresponding synoptic analysis for 12 UT is shown in (5d)

(a)

(b)

(c)



(d)

monitor the progress of synoptic-scale features, such as cyclones, frontal systems, anticyclones and jet streams – all of which set the scene for the meso-scale forecasts with which we are concerned, and indeed on some occasions may be the most important single piece of information that one can extract from the satellite images.

An example is shown in Figure 5 in which samples from a sequence of Meteosat-1 images illustrate the progression of a sharply defined cold front across the Straights of Dover. Such a sequence enables the forecaster to locate the front precisely, as well as to monitor its progress, and in particular to detect velocity changes that may be insignificant on the synoptic scale but which are vitally important on the meso-scale. The sequence also shows the location of the associated cyclone and illustrates the diurnal variation in small convective cloud over south east England, where clear skies in the morning (Fig. 5a) give way to almost continuous cloud cover of a cellular nature by noon over land, while the cooler sea areas stay cloud-free. By late afternoon the cloud cover is once more starting to disperse as a clearer area forms over central England.

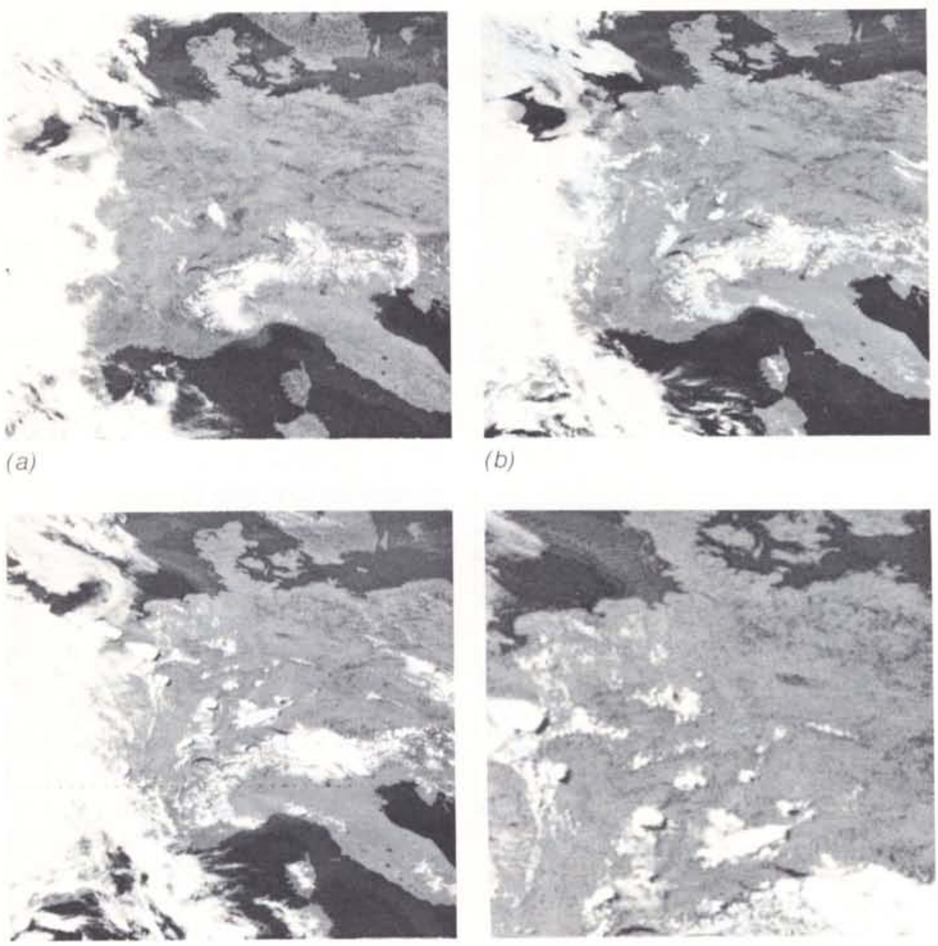
Reception and use of the image data

After transmission from ESOC, a very wide range of possibilities exist for the use of these image data. So far in Europe, until the failure of Meteosat-1, they have been used simply as images, that is as pictures of cloud formations and weather systems as viewed from space, although there are plans to use the images in more objective ways in the future, after Meteosat-2 becomes available later this year. Thus the main user requirement has been simply for some means of visualising the image. The means for doing this range from Polaroid photographs of oscilloscope displays at the simplest, to systems that include computers to remap the image into new and more convenient projections for display on TV screens. Computer processing is not limited to the PDUS, since several organisations have adopted a technique whereby the analogue Wefax transmissions to SDUSs are digitised and computer-processed. Nor is it necessary for each user to have a dedicated antenna and radio receiver, since several meteorological services have these components at a central site and distribute the images by landline, with or without local processing, to forecasting offices at various locations. Such systems have already been installed in the United Kingdom and in Switzerland.

The images pass eventually, by one means or another, into the hands of the local forecaster, who uses them to identify and monitor the weather systems that affect the area and time scales under consideration. One can use them to

This diurnal variation of a subsynoptic scale feature is shown more dramatically in Figure 6, where the development of large areas of thunderstorms over Germany is clearly portrayed. The frequent and readily available satellite imagery not only identifies the precise location of the thunder-cloud masses, but can also be used to estimate rainfall. On this occasion the rapid growth of the clouds and the low temperature of their summits, as revealed by the Meteosat infrared images, are a clear indication of the occurrence of heavy convective storms. This was confirmed by the network of conventional stations, which could not, however, delineate the extent and growth of these features with the same precision as the sequence of satellite images. The latter also shows

Figure 6 — A set of Meteosat-1 images for 31 May 1979 showing the development of intense convective cloud masses over Germany. In (6a) (time 0900 UT) Germany and Poland are almost free of cloud and the progressive development of the storm clouds at 1130 UT (6b) and 1430 UT (6c) is clearly visible. (6d) is a computer-generated enlargement of part of the area shown in (6c). In all images the snow-covered Alps are clearly visible, as are the lakes of southern Germany



(a) (b) (c) (d)

clearly that the frontal cloud system to the west was on this occasion very slow moving over the West German borders, but was advancing rapidly eastwards over the Mediterranean.

In addition to the above phenomena, satellite images can also be used to monitor cloud clusters and vorticity centres, as well as mountain waves, and in the tropics tropical storms and hurricanes and the inter-tropical convergence zone.

The data-collection system

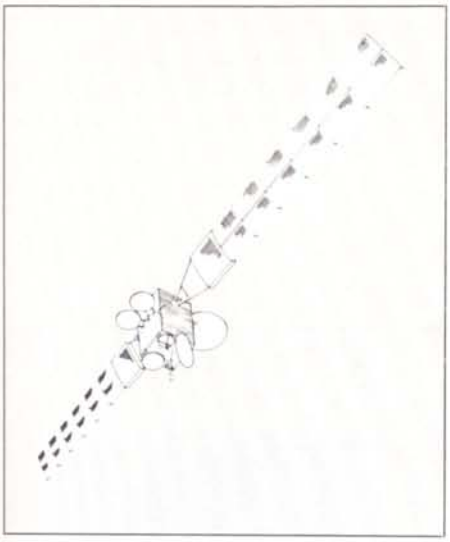
In addition to the imagery system, Meteosat, in common with most other meteorological satellites, supports a data-collection system, The 66 communication channels available for this purpose enable automatic or semi-automatic stations to transmit environmental data to ESOC for relay to the user community. The system has been described in detail in ESA Bulletin No. 21 (February 1980, pp 44-48).

Future developments

With the very rapid growth in user stations to over 130 in the two years following the launch of Meteosat-1, the meteorological community within Meteosat's coverage zone has been newly exposed to the potential of a geostationary satellite for improving short-period forecasts. As has been discussed, the main use so far has been in the application of individual images in photographic form, but several services are in the process of introducing systems that will allow the advantages of these frequent high-quality images to be more fully exploited. In many cases this involves the use of video display systems, usually linked to a computer so that the image data ingested can be subjected to a range of enhancements to make them more suited to the task. Using such local facilities with Meteosat-2, the forecaster will be able to use interactive techniques to: access the required image; zoom in to the area(s) of interest; animate sequences of images; superimpose different images or channels (e.g. VIS plus IR); merge satellite images with other data; and enhance they grey scales by level-slicing and contrast-stretching.

All of these facilities are under evaluation or are being implemented in several countries, including France, Germany, Switzerland and the United Kingdom, and they can dramatically improve the information that the forecaster can extract from the image data. Of particular relevance is the use of animated image sequences in which the development and movement of weather systems are vividly displayed. An obvious extension of this is to use the computer and pattern-recognition techniques, or human and interactive techniques, to extend the sequence into the future by extrapolation, or by merging with short-period meso-scale numerical forecasts when these become available operationally. Other possibilities exist for merging the satellite data with other inputs, and an ambitious scheme has already been devised in the United Kingdom for combining image data with data from weather radars, which are themselves calibrated against standard rain gauges, to permit detailed mapping and forecasting of meso-scale rain areas on a scale of from one to six hours.

All of these ideas will require several more years of development and pre-operational trials before the full capability of the satellite system can be exploited. Meanwhile the images produced on simple recorders are obviously of great benefit to the local forecaster, and provide him with a new and exciting tool.



Preliminary Study of a Satellite Business-Communication System for Europe

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Some preliminary results have recently become available from an on-going trend analysis study covering, among other topics, the cost-effectiveness of space systems dedicated to private communications services for business organisations in Europe compared with terrestrial communication systems. The analysis takes into account the aims and operational characteristics of the Satellite Business System (SBS) project currently being implemented in the USA. The demographics of the business organisations have been analysed using case histories to investigate the specific features that determine the pattern of communication use in Europe. Although today's requirements for private business networks do not yet justify dedicated space systems, the European PTTs and the telecommunication suppliers are already experimenting and carrying out trials to assess the market for a variety of innovative services.

In the context of a trend-analysis study on future space communication systems started in 1978 to specify technology goals and their priorities for the period 1985–1995, ESA commissioned the international consultancy firm Arthur D. Little to look at the cost-effectiveness of space communication systems, compared to terrestrial communication systems, for a number of identified future applications and services.

In the case of Europe, special attention has been paid to private communication services for business organisations in the light of their potential implementation via space or terrestrial communication systems. This particular service/region combination was investigated with the aim of providing insight into the type of services that the business environment needs, quantifying the user requirements for such services, and drawing up performance parameters.

Background

The development of domestic satellite systems in the USA shows a trend towards increasing specialisation in their use. Traditional telephony traffic and television signal transmission are giving way to various types of data traffic aiding provision of communication services to the American business community. These new trends are being reflected in the design of the satellite systems, which increasingly utilise digital transmission techniques in conjunction with small earth stations.

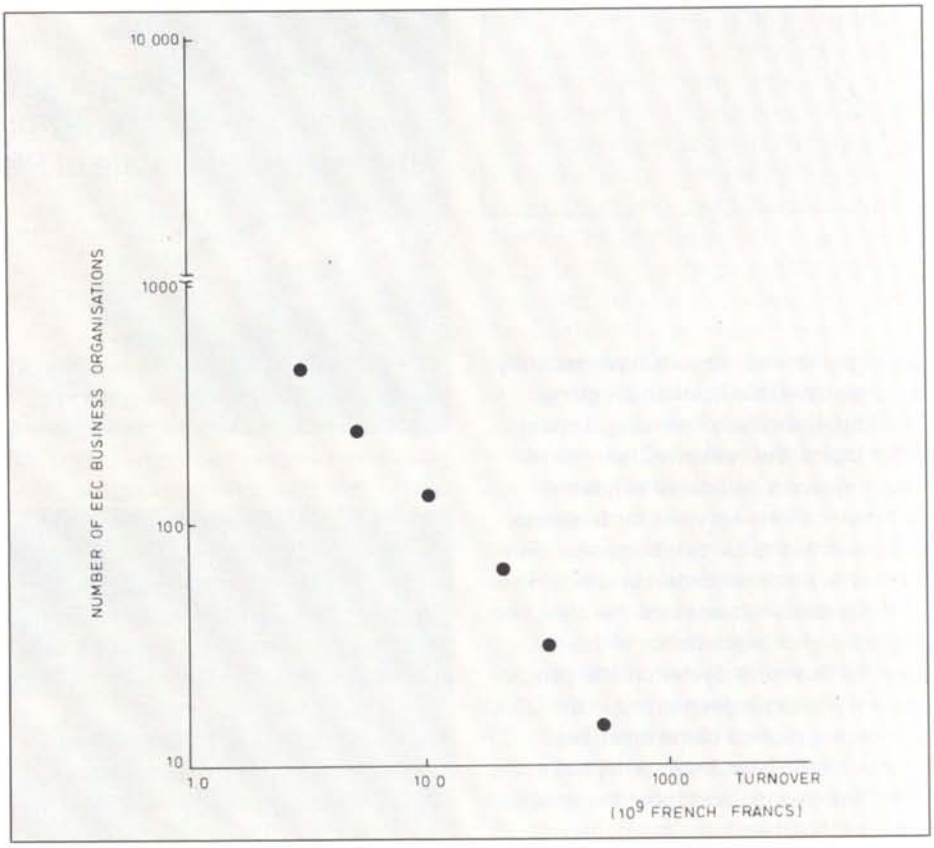
The latest developments in the USA have influenced the European telecommunications administrations to consider the introduction of similar systems in Europe. Several business communications systems are already being planned which are largely dependent on satellite links. However, institutional and regulatory conditions in Europe call for the specific adaptation of such systems to the European environment.

Europe has a well-developed infrastructure of telecommunications networks, but these rely on predominantly analogue techniques selected mainly for the telephony traffic. Within the networks, access to higher capacity transmission paths is possible and services such as 48 kbit/s and video links are relatively common on a private leased-circuit basis, but they are expensive to provide, especially for international connections.

Digital techniques are starting to be used more and more in European networks. The problems in the near term are that special equipment is required to gain access to the digital transmission network and the network itself will not be sufficiently widespread to ensure a digital path over the whole length of some connections.

The introduction of digital transmissions and Stored Program Controlled (SPC) exchanges will gradually form an Integrated Digital Network (IDN) that, when extended to the user over digital access and enhanced with appropriate service features, will develop into an Integrated Service Digital Network (ISDN) of high potential. Most business-

Figure 1 – Statistical distribution of European companies in terms of turnover



communication needs should be satisfied by such a network, with the exception perhaps of wideband video services. In this context, the principal advantage of the satellite system is its ability to provide wideband data or video-conference facilities anywhere within the satellite's coverage zone. Moreover, satellite facilities can be made available very quickly, whereas the complete range of terrestrial facilities will not become fully available for a decade or so. In the meantime a satellite system can be competitive not only for megabit/second data and video services over long distances, but also when there are only a comparatively small number of users.

System-assessment parameters

The target group of potential users for a space communication system providing private and leased-line services can be identified by examining the following parameters:

- the expected annual fixed and running costs of the system to a user: comparing these with the telecommunications budget of a cross-section of organisations reveals the minimum size of a potential user who can afford to use such a system
- the cost of the system compared with that of terrestrial (distance dependent) tariffs reveals the economic break-even distance for a satellite data service with terrestrial rates for chosen bandwidth links
- the demographics of multisite organisations and the spacing of the sites reveals the number of candidates for which a space system is the most cost-effective solution
- an examination of the pattern of information flow in the office environment shows the types of services required and provides an indication of the expected traffic
- an examination of non-cost factors such as vulnerability, reliability, confidence in a new technology, PTT regulations, etc., is an indicator of possible attitudes towards a space-based solution.

Table 1 – Business organisations in the European Economic Community with an annual turnover exceeding 600 million French francs in 1977 (source Arthur D. Little)

France	360
West Germany	336
United Kingdom	306
Netherlands	73
Belgium	62
Italy	50
Luxembourg, Denmark and Ireland	24
Total	1211

Depending on the industrial segment and the style of corporate management, business organisations spend between 0.5% and 5% of their annual turnover on telecommunications. The average is around 1%, and it is growing 4–5% faster than total turnover.

The minimum configuration for a single organisation would of course be two earth stations, which means that the total annual charge for the earth segment would probably amount to about 500 kAU (3 million French francs). It can further be assumed that any business organisation would be prepared to grant 25% to 50% of its total telecommunications budget to space communications for reasons of redundancy.

Within the European Economic Community (EEC) there are approximately 1200 business organisations with an annual turnover (1977) in excess of 600 million French francs (Table 1). This total includes nationalised industries and services, but does not include government administrative units. The nearest equivalent statistic for the USA is the 1006

Figure 2 – Video-conferencing, one of the many possible business-communication applications that can be explored with L-Sat

public companies with total sales in 1977 in excess of 275 million US dollars. This is an important guideline for a European equivalent of the SBS project, as the latter hopes to draw its customer base, at least initially, from the top 1000 US corporations. It should, however, be recognised that certain important parameters differ greatly between the USA and the EEC. For example, the USA is a single national entity, distances there are greater, and telecommunications have a higher priority.

Clearly our estimates should be treated with care as they are based on several assumptions that may prove inaccurate for the 1985–1995 period with which we are concerned. An idea of the sensitivity of the estimates to errors in the underlying assumptions can be gained by considering the demographics of large organisations in Europe, the number of which is approximately inversely proportional to their annual turnover (Fig. 1). Thus if the estimate of the cost of owning and operating a space communication facility is too low by a factor of two, the number of potential users will be one half of the estimated figure. Conversely, the market size could theoretically be doubled if the cost of ownership were halved.

Roles of the satellite link

As has been said, the roles that the satellite link can play in Europe have to take into account the capabilities of the developing infrastructure of terrestrial networks. In fact, the finding of suitable near-term and future roles for the space link in Europe is closely related to the evolution of data-processing systems.

The satellite link has a number of distinct advantages:

- ability to provide wideband data or video-conference facilities anywhere within the coverage of the satellite, even for a small percentage of the time
- operational flexibility in circuit utilisation (network reconfigurability, multiple destination)
- ability to offer a comprehensive set of services
- possibility of rapid extension of the network
- small number of link elements: two earth stations and one spacecraft
- potentially very low data error rate.

Two disadvantages are the high costs of the earth segment and of the space segment. The high cost of the earth segment may limit the number of earth stations to those locations that can serve users with a large data requirement, or to users who consider it of paramount importance to have access occasionally to high-data-rate or video-conferencing facilities. One means of reducing the cost to each user is to encourage them to share a common earth station serving a substantial area. This solution, however, entails a need for high-speed dedicated terrestrial links to users, which is one of the things that the satellite system is supposed to avoid.

The high cost of the space-segment capacity is especially relevant to the cost of voice transmission. Small earth stations usually use a satellite repeater with about 25% of the efficiency achieved with the large earth stations that are used for normal international services, and even when the cost of the national terrestrial links is included the conventional method is still cheaper than using small earth stations for voice traffic. On the other hand, the costs of the space-segment capacity for data transmission are lower than current terrestrial transmission costs over long distances when using analogue equipment.

The present terrestrial networks in Europe can handle data rates up to 2.4 kbit/s (switched), 9.6 kbit/s (leased) and voice communications. Services requiring speeds up to about 50 kbit/s can be provided only on a leased-circuit basis and as a consequence of the existing analogue equipment they are expensive. Above 50 kbit/s, special arrangements have to be made, and in the event that data are transmitted on analogue equipment the costs are very high.

Table 2 — Site diversity of French business organisations as a function of turnover (source Arthur D. Little)

Annual turnover 10^9FF	Number of companies		Number of sites						
			Distance from HQ to site (km)					Foreign sites	
	Separate	Single	<130	130-310	310-500	500-1000	>1000	European	Other
30	4	–	27	18	17	6	–	15	4
20	6	–	50	26	45	15	–	20	7
10	12	–	91	43	68	21	–	40	39
5	24	–	133	62	89	34	–	45	45
3	40	6	176	86	107	44	–	48	46
1	100	18	317	194	174	66	–	64	57
0.6	130	31	388	237	190	74	–	73	73

Leased or switched services with data rates of up to 64 kbit/s, and probably multiples of this, will be available throughout European networks when digital switching is introduced. The development of the ISDN will permit all business applications requiring speeds in this range to be serviced, but the ISDN will only be put to full use when fibre-optics lines or other wideband communications technologies are commonly available on local networks. At that time, the cost of digital signal transmission should fall significantly, because 64 kbit/s will then correspond to one voice channel, instead of the present 9.6 kbit/s.

By considering the relative suitabilities of satellite and terrestrial facilities in the short and long term, the following scenario can be envisaged.

The introduction of satellite systems providing special data services in Europe could be started by transferring the internal-level line networks of large business organisations to the satellite system. The earth stations would be located close to the users, allowing them to access the satellite network not only at the basic rate of a pulse-code-modulated or delta-coded voice channel, but also via various high-speed data ports. The initial system would consist uniquely of a satellite network that would gradually become integrated with the developing terrestrial ISDN.

In the long term, the role of the satellite network would change from being the primary communication medium to an integral component of the ISDN. The satellite system would continue to complement the features of the growing terrestrial infrastructure of this network, for example by providing only those services to which it is especially suited and by meeting the needs of those users ready to pay an additional charge in order to have a comprehensive communications facility via a single earth station close to their premises. The development of video-conferencing requirements will largely determine the extent of satellite use in the long term, as it is the one service where satellites are always likely to have the edge over terrestrial networks, especially over very long distances.

Demographics

Arthur D. Little's files of case histories on the telecommunications of major European organisations include about 100 of the 1211 European organisations with high enough turnover. The key findings of the analysis of these case histories, and of the official demographic data are:

- Some 80% of the largest European organisations are in Germany, France and the United Kingdom. Only 5% are in Ireland, Denmark and Luxembourg.
- Organisations are almost totally nationally based and those few that

Table 3 — Primary industrial activities of top business organisations in the European Economic Community (annual turnovers greater than 600 million French francs in 1977)

Industrial sector	Number of companies
Retailing	215
Food	117
Building	103
Mechanical engineering	103
Electrical engineering	91
Chemicals	88
Services	75
Steel and metals	59
Public services	50
Transport	49
Automotive	44
Petroleum	42
Textiles	33
Paper	31
Non-ferrous metals	26
Printing	17
Glass	17
Rubber	16
Mining	13
Aircraft	13
Shipbuilding	9
Total	1211

operate across national boundaries do so through autonomous local subsidiaries, with little communication back to headquarters.
- No single case history reveals an establishment that has a primary group leased line longer than 130 km.
- Only a small number of leased lines are in the range of 130 – 300 km, and so the bandwidth required over 130 km only marginally exceeds that for over 300 km (see example for France, Table 2).
- In France the organisation headquarters are centred almost exclusively on Paris and operational sites tend to be concentrated in the major cities. In the other European countries the operational sites are more evenly distributed.
- The 1211 largest business organisations in Europe account for 25% of all employees and for more than half of all leased lines.

The case histories are also useful for investigating the pattern of communication use within an organisation. Voice accounts for by far the biggest use of bandwidth in a business organisation. Typically in a working day every office worker will receive one telephone call from outside the organisation, will make one call outside the organisation and have one internal call. Each call typically lasts about 2 min. Around 70% of the calls will be made in the periods 9.30 – 11.30 am and 14.30 – 15.30 pm. In a typical headquarters branch of 1000 office staff, there are 500 telephone extensions connected to a PABX with some 70 external ports. Assuming 64 kbit/s voice channels (for space communication systems), the total bit consumption per day in voice traffic is 2.3×10^{10} bit, equivalent to a data rate of around 2 Mbit/s during the three busiest hours of the day (to satisfy queuing constraints the actual bandwidth capacity has to be more than twice this). One third of this will be internal traffic, mainly within the originating site; about 1% of the internal traffic will be between sites more than 130 km apart.

As regards data transmission, some 100 managers receive some 30 sheets of computer output, a total of 130 Mbit. At this level, data represents some 0.5% of voice traffic and it is difficult to conceive how data could grow two orders of magnitude to reach near parity with voice traffic. On the other hand, text could conceivably grow to a significant level; if the 20 sheets of ordinary A4 text that the average manager receives each day were facsimile transmitted, they would represent the same level of traffic as the voice communications. Arthur D. Little believes that communicating word processors and facsimile will grow in market penetration, so that by 1990 around 10 – 20% of 'mail' will be transmitted electronically. This will represent a significant fraction of the office communications bandwidth, but voice systems will still predominate.

Another factor that emerges from the analysis of case histories is that the communications usage depends on the industry sector. Telecommunications, and in particular leased lines, are concentrated in those industries where:
- time scales involved in their processes are short, i.e. where time is money;
- the processes are office-labour intensive.

Banks, insurance brokers and finance houses, for example, tend to be big users, as do retail/wholesale chains and some manufacturing industries where coordination between different sites is important (mechanical engineering, consumer products, automotive). A breakdown of European companies by industry sector is shown in Table 3.

Although government organisations could be big users, their public accountability and their status as large employers mean that they cannot easily introduce telecommunications (or any other form of office automation) that constitute 'expensive luxuries' in the eyes of the general public. Also, government workers are obliged to leave a clear audit trail, usually on paper, to satisfy public accountability, and this can be difficult with electronic communication systems.

Conclusions

The analysis that has been presented here is based on the services currently provided to business organisations, including telephone, telex, datal and textual transmission. Based on the estimated minimum cost of a business organisation gaining access to such services, there are only a limited number of European organisations that could afford such access, and their total existing and projected future requirements for such services would not justify a space-based solution.

The biggest problem is identifying those services that will be successful and therefore ought to be offered. The European PTTs and the telecommunications suppliers are experimenting and carrying out trials to assess the market for a variety of innovative services. A space communication system does have the advantage of flexibility in terms of bandwidth utilisation and in the location of the sites to which services are required. For this reason space systems are attractive to PTTs and to the telecommunications suppliers. The provision of L-Sat will allow the potential services to be explored more fully and a more concrete appraisal to be made of the real market opportunities. Some of the services suggested have the potential to change current bandwidth usage substantially, and also the traffic patterns of communications within business organisations.

Technology Trends and Development Objectives for Future Communications Satellite Payloads*

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Pursuit of preparedness for future space missions both within the Agency and within European industry is the major task of ESA's Technology Programme. The Advanced Systems Technology Programme (ASTP) running at ESTEC is largely responsible for the identification and provision of the technological advances needed to realise the fixed, mobile and broadcast communications payloads that will be flown on the operational European communications spacecraft of the late 1980s and 1990s. This article explains some of the facets of the ASTP and the process by which future technological requirements can be derived from the evolutionary trends apparent in space communications today.

* Based on a paper presented at the 8th AIAA Communications Satellite Conference.

Background

The Agency's ECS and Marecs satellites will establish operational domestic and maritime communications satellite services for the 1980s based on spacecraft and payload technology developed in Europe and tested successfully over a number of years on Symphonie, Sirio and OTS. This concentration of effort in the implementation of ECS, Marecs and the other forthcoming European commercial systems such as Telecom-1 and TV-Sat in France and Germany brings with it a risk of diverting too many resources away from the critical development of competitive new technologies for the complex and demanding payloads for the satellite systems that will take over at the end of the decade.

When it was decided in the early 1970s to undertake a European Communications Satellite Programme, the choice of such advanced technologies as three-axis stabilisation and the use of frequencies above 10 GHz was supported by a specialised technology programme and by a parallel mission-modelling effort. That this was the right approach is now being demonstrated by the implementation of European operational systems with these features and in the export of technologies that are being used on Intelsat-V and on American satellites.

Europe clearly has sufficient industrial resources and access to large enough markets to justify such development programmes. Because of their specialised nature and the large investments required, however, careful choice of mission objectives and degree of technology advancement to be pursued is essential if the chances of later utilisation in economically viable systems are to be maximised. In other words, it will not be sufficient to attempt a gradual upgrading of the technologies or to wait for requirements to appear from mission analyses; rather these two parallel processes must be made to proceed interactively and the results assessed on the basis of criteria of competitiveness with ground and non-European space-communications systems.

On the other hand, the limited resources available within the basic technological research programmes of ESA and national space organisations are by necessity widely spread over many research activities, which are sometimes limited to just an assessment of new technologies or a preliminary demonstration of technical feasibility.

It is for these reasons that a specialised Advanced Systems Technology Programme (ASTP) was started in 1978 as a fundamental element of the Agency's Communications Satellite Programme, and the ASTP is expected to run for at least four to five years, with an average funding of about 6 MAU* per year.

Adequate scope is being given within the ASTP to the interaction of systems and mission analysis and technology developments by working within the one Programme on three main areas:

* 1 AU = ± 1.2 $US (1979 rate)

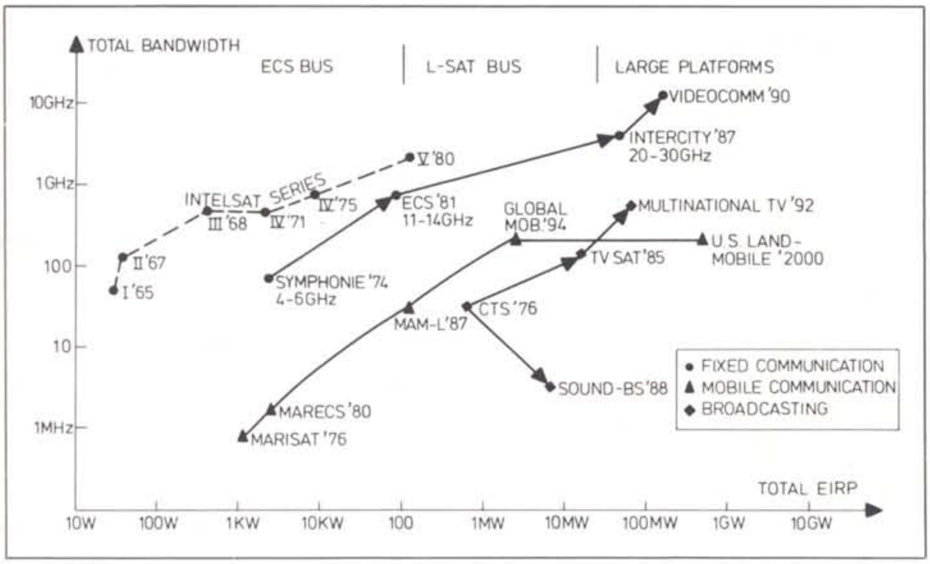


Figure 1 — Bandwidth/total EIRP trends for past and future communications spacecraft payloads

Figure 2 — The Multibeam Array Model (MAM) antenna, an 18-element, 19-beam phased array developed for mobile communications satellites

- analysis and design of telecommunications systems and associated spacecraft configurations, an important part of this category of activities consisting of experimentation in satellite telecommunications, with propagation and transmission experiments
- telecommunications technology and equipment for satellite payloads and ground stations
- technology and equipment for other spacecraft subsystems (platforms).

Furthermore, in view of applications in operational programmes, it is planned to develop selected equipment within the ASTP to the point of demonstration of flight worthiness, and some components to full flight qualification.

Trends in payload performance
Extrapolation from past achievements, when based on sound knowledge of the user's requirements, can provide a first reasonable approach to technology forecasting. Bearing in mind, however, that any final system implementation will not be based on continuing development, but on space qualification of selected technologies, attention must be paid to the definition of successive generations of technology giving adequate performance improvements and lifetimes, to allow development and qualification costs to be recovered.

The evolution of payload technology in the successive series of Intelsat satellites can be taken as an example in this context. The most important communications performance parameters are plotted in Figure 1: the vertical scale gives total bandwidth, the horizontal scale the total effective isotropic radiated power (EIRP) as the sum of the EIRPs of the active repeaters. It can be seen that there have been relatively small performance increments between the Intelsat series, largely because of the need to follow very rapid expansions in traffic in a system calling for large space-segment investments in combination with rigid standardisation of ground-segment parameters. In the progression from Intelsat-I to Intelsat-IV, increased antenna gain and spacecraft available power led from power-limited to bandwidth-limited systems. Frequency re-use and introduction of the new 14/11 GHz frequency bands have since led, from Intelsat-IV to Intelsat-V, to a more than twofold increase in the number of repeaters and an increase in total bandwidth.

From the toroidal patterns of the Intelsat-I and II antennas, through the despun earth-coverage antennas of Intelsat-III and the spot beams of Intelsats-IV and IVa, to the six separate and reconfigurable coverage beams of Intelsat-V, the maximum antenna gain has been increased by more than 30 dB (one thousand times), thereby providing the largest single contribution to the EIRP and capacity increases. Dividing the coverage into separate zones and channelising the available bandwidth has, however, led to problems in interconnecting the many repeaters, a total of 27 on Intelsat-V. On this last satellite static reconfiguration by ground command is provided for following traffic pattern changes, to allow some flexibility in interconnection.

Dynamic switching on board the satellite to route each channel to its destination, as in a ground switching centre, represents the quantum jump to be expected in the next generations of communications satellites.

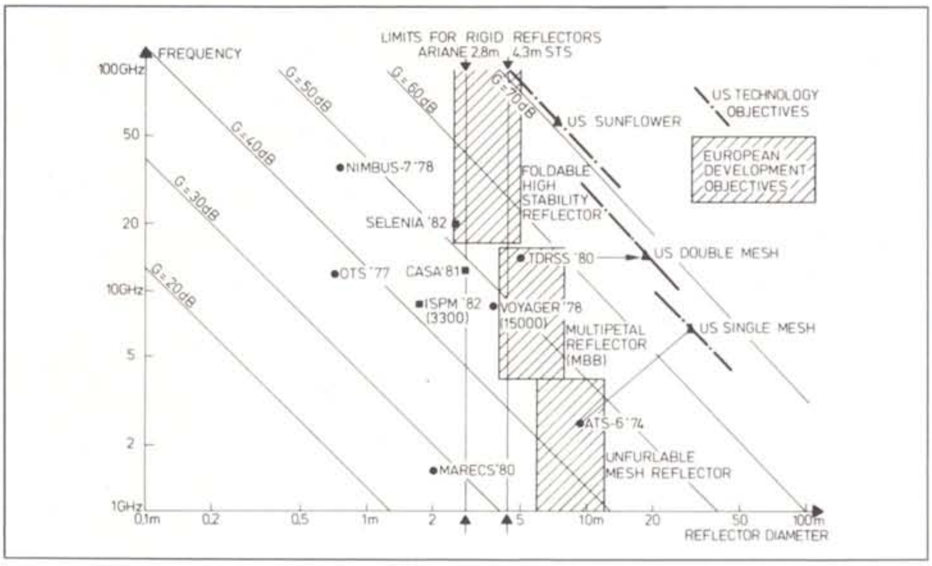
Fixed communications
The pattern of technology development for fixed communications payloads in Europe is not unlike that for Intelsat, except that because of the smaller resources available the successive

satellite generations have been more widely spaced in time, leading to more substantial performance improvements between generations. After Symphonie in 1974 with two repeaters at 6/4 GHz, ECS in 1981 will have nine active repeaters (out of a total of twelve) operating at 14/11 GHz; bandwidth, installed power and antenna gain have increased by an order of magnitude.

The next generation of spacecraft being prepared with the support of the ASTP development programme for the late 1980s is aimed at providing intercity trunk services at 30/20 GHz, with some twenty repeaters and a total bandwidth approaching 5 GHz. Total transmit power will be increased by a further order of magnitude and antenna gain will be raised to some 55 dB by using high-precision reflectors. On-board switching [satellite-switched time-division multiple access (SS TDMA)] of the demodulated signals is foreseen to allow interconnection of the regenerative repeaters. The result is a dramatic improvement in the EIRP to compensate for the increased propagation losses, and to allow substantially smaller ground stations to be used in city centres.

The following generation of satellites foreseen for videocommunications for the mid-1990s will push this trend still further, relying on rooftop terminals in an effort to support the large increase in capacity that will be required by the implementation of high-capacity data links, teleconferencing and videophones. With a further order of magnitude increase in total transmitted power and antenna gain and fully deployable multipetal reflector antennas, more than one thousand digital video channels could be transmitted from a single satellite. Typical coverage of one European country will very probably be achieved with clusters of some fifty beams, each accessed by tens of channels. Not only will on-board digital switching take place in baseband, but high-speed processing could be used for demultiplexing and demodulation, and

Figure 3 — Development trends in terms of operating frequency and diameter for communications spacecraft reflector antennas. Numbers in brackets indicate diameter/tolerance (rms).
- ● = *qualified*
- ▪ = *under development*
- ▲ = *studies.*



subsequent multiplexing after switching, as is presently done in electronic telephone exchanges.

Mobile communications

The same type of trend analysis can be applied to satellite payloads for mobile communications. Because of the many small terminals in this application the number of satellite channels needed is much higher, each with a rather narrow bandwidth and high EIRP density. ESA's Marecs satellite delivers more than twice the total EIRP of the Marisats, largely because of its shaped-beam antenna, and with its linear transmitter it can provide 35 channels to the present standard Inmarsat ship terminals.

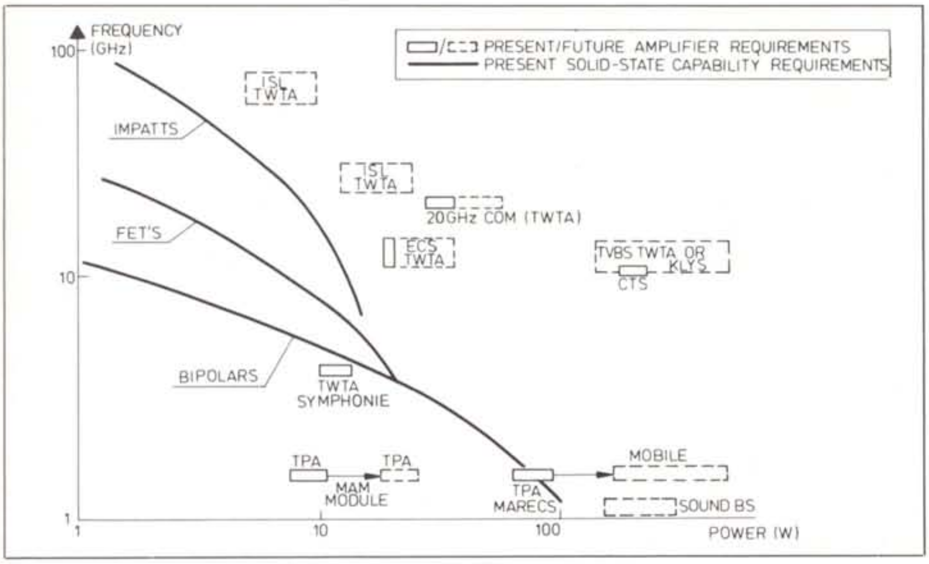
A substantial capacity improvement could be obtained by using multibeam antennas; 440 channels could be transmitted with the phased array technology demonstrated in the MAM programme (Fig. 2). However, for some time to come such large capacities will find a market only if much cheaper terminals are introduced.

A third generation of mobile communications satellites in the 1990s will need extensive frequency re-use to provide a 'global' service to a very large population of smaller terminals. The 30 MHz of bandwidth in the L-band allocated to maritime and aeronautical communications at present can support 600 channels. With maximum frequency re-use (every third beam in a triangular lattice) in a cluster of 91 beams, with what is achievable with impending technologies and an array-fed reflector antenna, one might expect a maximum of 18 000 channels to be available. In that case the system will be sharply interference limited, and with the low-directivity antennas on the small mobile terminals the design of access, modulation and coding schemes will be a major problem.

The most difficult task, however, will once more be the interconnection of the several thousand channels, with the consequent complexity, mass and reliability problems of the routing and switching equipment.

The very presence of these problems would seem to indicate that the evolution to very powerful systems for mobiles outlined in some American studies will not be realised before the late 1990s, the constraints lying not only in transmission capacity development, but even more so in the communication and switching-system design problems.

Figure 4 — Satellite power amplifier performances for existing spacecraft compared with future European objectives



Broadcasting
Two types of satellite television broadcasting missions are presently planned and have agreed frequency allocations: direct television broadcasting at 12 GHz, and educational and community television broadcasting at 2.6 GHz.

The parameters for the 12 GHz downlink in Europe were established at the 1977 World Administrative Radio Conference (WARC), and this has fostered user interest, with several European countries already studying the introduction of a direct broadcast service by the mid-1980s. Payload hardware is already becoming available as a result of national and ESA's own satellite pre-development work and a large Ariane-launched platform will adequately support such payloads.

Television broadcasting is essentially a national service and by far the largest part of the investment will be in the ground segment and in the programming. Nevertheless, with the advent of larger platforms and the need for small coverage areas, multinational satellites carrying composite communications payloads might already appear in the early 1990s.

The Agency's ASTP is responsible for providing a number of the critical technology advances that will be needed, including:
- antenna-pointing systems and RF sensing, to achieve the requisite accuracy and stability, particularly for multimission spacecraft
- special antenna feeds and pattern-prediction techniques, to meet the very stringent side-lobe and cross-polarisation requirements
- high-power klystrons and advanced cathodes
- high-voltage technologies and solutions to high microwave power handling problems in switches, filters, etc.

Furthermore, a particular effort is to be dedicated to uplink systems analysis, where the problems of planning and allocating frequencies must be tackled from a global viewpoint, taking potential interference with other services into account.

Educational and community television broadcasting services have been allocated 120 MHz in the 2.6 GHz band, and are to be used mainly in developing countries for public services with relatively broad coverage areas and few television channels. Transmitted power will be of the order of 100 W per channel and the satellite antennas will be 1–3 m in diameter.

Unfortunately satellite sound broadcasting was not allocated a specific frequency at the 1979 WARC but experimentation was recommended in the 1.5 GHz band. System design work has already shown that 6–7 m unfurlable reflector antennas and 200–400 W transmitters will be needed here.

NASA's ATS-6 satellite, which has demonstrated the required technologies, can be considered a forerunner for both missions. However, the potential market in developing countries and the technology commonality with mobile communications would suggest that further European development efforts and possibly even experimental missions are worthwhile.

Development objectives
Some of the development objectives to be met in preparing for future communications satellite payloads are already evident from the above resumé of performance trends. Clearly, more bandwidth will eventually be needed to support the growth in capacity. The increased frequency allocations for space communications provided at the recent WARC and the move to 30/20 GHz for fixed services should provide sufficient bandwidth until the end of the century, provided good use is made of available frequencies and of the geostationary orbit by extensive frequency re-use. The increased transmission capacity will be supported by higher satellite EIRPs and receiving sensitivities.

Antennas
The main contribution here will come from larger reflectors based on more easily built, lightweight deployable structures (Fig. 3). The United States has a marked lead in the deployable-reflector technology needed to accommodate the large antennas in the limited space available on today's launchers. ESA plans

to develop an engineering model by 1985 for unfurlable antennas with mesh reflectors with 6–12 m diameters, working at up to 4 GHz. For higher frequencies, a deployable reflector with rigid petals or double mesh will be required to achieve the necessary surface accuracy. NASA's TDRSS satellites will fly such technology in 1981.

Offset-fed reflectors will be required to achieve high polarisation purity and good side-lobe control, although these will be heavier and more expensive to manufacture than front-fed types. The ASTP programme covers development by the CASA (Spain) and Selenia (Italy) companies of rigid carbon-fibre reflectors capable of operating at frequencies above 10 GHz. It should be possible to extend this technology in the mid-1980s to millimetre waves and antenna diameters approaching 4 m, with composite reflectors on truss supporting structures.

A clear trend is also identifiable in the development of antenna feeds, with single feeds being used for spot beams and clusters of feeds for side-lobe control and beam-contouring. The USA also currently has a substantial technological lead in this area, having already flown such antennas on Intelsat-IVa. Coverage with multiple beams and beam re-configurability with extensive frequency re-use call for the development of large feed arrays for illuminating offset reflectors.

These designs favour the use of active feed arrays, each feed incorporating amplifiers for receive and transmit functions. In this respect ESA is well placed, with its MAM phased-array technology developed for mobile communications (L-band) representing a good starting point (Fig. 2).

Microwave amplifiers
Figure 4 summarises the performance of existing satellite power amplifiers for transmitters, and the European development objectives. Not surprisingly the projected increases in power levels for microwave tubes are not very large, since as has been pointed out the greatest contribution to higher EIRPs is expected to come from the antennas. It is likely that solid-state transmitters will be used more and more, particularly those based on field-effect transistor (FET) amplifiers, which are capable of increasingly higher powers and frequencies and are well suited to antenna-feed-array application. Only for the higher powers used for broadcasting and the millimetre wave frequencies used for intersatellite links will tubes continue to dominate the field and call for further substantial development effort.

Signal processors
Though it is still extremely difficult to present trends and objectives, the largest R and D effort for future communications satellites is likely to be required in the fields of on-board signal processing, switching and traffic routing. The evolution of these technologies from simple filter banks to digital processors is illustrated in Table 1.

Table 1 – Evolution of communications routing capability for fixed services

	Year	Interconnected links	Techniques	Signal rates Mbit/s
Intelsat-I	1965	2	Duplex with single access in each repeater	
Intelsat-II	1967	2	Frequency division multiple access (FDMA)	
Intelsat-IV	1971	12	FDMA and SPADE system with demand assignment	
Intelsat-V	1980	27	FDMA and SPADE, with reconfigurable interconnection of repeaters	
ECS	1982	9	Time division multiple access (TDMA) with frequency hopping	120
Advanced Westar	1982	4 × 4	Satellite-switched TDMA with microwave switching	225
ASTP switch-matrix development	1982	16 × 16	Baseband switching of digital signals	60
Bell Laboratories' experimental payload	1983	100 × 100	Antennas with scanning beams and TDMA	600
Intercity trunk satellite	late 1980s	20 × 20	Baseband digital switching	360
Videocommunications	mid-1990s	1000 × 1000	?	8

Only on considering the close integration required with the ground segment when designing the overall communications network is it possible to understand the rather slow operational implementation of such new techniques as TDMA, which has been under development for many years.

The true step to on-board switching for the dynamic interconnection of repeater channels is still to come, even on American satellites. Whatever technique is chosen for its implementation, the increased complexity with the large numbers of channels will pose formidable problems of volume, mass and particularly reliability, aside from the fundamental question of achieving greater integration with the ground networks; hence the question marks shown in Table 1. The only certainties are that a lot of research and development are required, and that the transfer of switching and traffic-routing functions to the satellite is ultimately unavoidable, but it is likely to be rather slow in coming about.

Impact on spacecraft configuration
The previous paragraphs have outlined very briefly the forecast communications mission requirements and the main technological payload development objectives derived from them. These payloads must fly on suitable geostationary platforms, for which the basic development objective is the one of improving the available resources in terms of mass, power in sunlight and eclipse, thermal and mechanical environment, pointing accuracy and orbital stationkeeping.

The wide range of payload requirements to be expected would suggest that there are benefits to be derived from having a series of platforms available with different ranges of capabilities (Fig. 1). Europe already has one family of platforms available based on OTS, compatible with an Ariane double launch, and already being re-used on two ESA missions, for ECS and Marecs, and also in the French Telecom-1 project.

For direct television broadcasting, development of a larger spacecraft platform making use of Ariane's maximum capability is required, and this is one goal of the Agency's L-Sat project.

These two families of European platforms should prove adequate for the next generation of communications missions, and their development and further improvement is one of the ASTP's most important objectives.

In defining a long-term payload technology programme and extrapolating to larger platforms, however, a number of important considerations cannot be ignored:

- The escalation of payload requirements for future missions in terms of mass, power, sizes of antennas, and numbers of repeaters. Already some multinational TV-broadcasting missions, like the one studied for Scandinavia, cannot be fully implemented on a single Ariane-launchable platform, and the same applies to the Intelsat-VI generation if that is to be of the 'large capacity' class.
- The combining of different missions on the same satellite is being pursued whenever organisational constraints allow. The latest Intelsat-V models will be used for at least three types of services i.e. mobile, fixed international and domestic with leased repeaters. Similarly, Insat, Arabsat and Telecom-1 are all multi-mission satellites.
- The reduction in ground-terminal antenna sizes for economic and mission-associated reasons, reduces the available angular discrimination needed for protection against interference in frequency re-use from separate orbital positions, and this must be compensated by increased discrimination in coverage from larger satellite antenna systems.

However, one cannot take for granted any immediate step to such solutions as the gigantic Orbital Antenna Farms already being proposed in USA. Optimum spectrum and orbital utilisation will make it necessary to exploit available orbital discrimination with separate satellites as long as the earth station is investment-constrained and to limit interference with other ground systems. Moreover, the development and implementation effort, and in particular the launch costs, are not continuous functions of platform size. Going beyond the capacities of Ariane and the Shuttle, for example, will require rendezvous missions in combination with space-construction technologies that are as yet only in a very preliminary study stage.

Nevertheless, there is clearly justification for at least definition studies of a new family of large geostationary platforms, to exploit the benefits of economies of scale in the cost of providing spacecraft resources: solar and eclipse power, telemetry, telecommand and ground control systems (TTC), accurate orbital station-keeping and at least rough three-axis pointing, larger antenna structures, etc.

Large flexible solar arrays, high-capacity batteries, high-capacity and distributed data-handling systems, accurate ranging and electric spacecraft propulsion are among the advanced platform technologies that will be called for.

In the payload and communications systems areas the introduction of a number of important innovations can already be foreseen:

- the re-use of a common large antenna reflector for several missions, possibly by dichroic or polarisation beam splitting to various repeater feed arrays
- the extensive use of regenerative repeaters to make possible digital interconnection between different payloads, isolation of up and downlinks and synchronisation
- the use for interconnection of optical technologies to reduce mass and EMC problems and to allow larger switching matrices
- the sharing with mobile and broadcasting services of up and downlinks and shore stations installed for fixed services
- the introduction of high-capacity intersatellite links, using millimetre waves, and possibly lasers.

The need to prepare these advanced technologies as long-term development objectives in the framework of the Technological Research Programme is therefore quite clear.

The 1979 World Administrative Radio Conference – An Observer's View

G.F. Block, Technology, Industry and Infrastructure Department, Directorate of Planning and Future Programmes, ESA, Paris

The 1979 WARC, held in Geneva from 24 September to 6 December 1979, had the mandate to 'review and, where necessary, revise the ITU radio regulations'. The outcome of this eleven-week Conference was therefore of paramount importance for ESA's future programmes. In view of the fact that at the WARC itself the Agency – as an international organisation – would only enjoy observer status, the main emphasis had to be on the preparatory work, that is on motivating as many ESA Member-State Administrations as possible, as early as practicable, to take the Agency's frequency requirements into account in preparing their National Position Papers for the 1979 Conference.

The preparatory phase

Preparations for the WARC were started within the ESA Executive as long ago as the summer of 1975, with the definition of the Agency's strategy for achieving its main objectives, namely the allocation of adequate frequency bands to space services.

In the summer of 1976, the Executive presented to its relevant governing body for approval a general strategy paper covering ESA's involvement in the preparations for the 1979 Conference. This proposal was based on the clear understanding that the preparation for and execution of the 1979 WARC was to be the responsibility of the individual Member State Administrations, and the main thrust of the Agency's preparatory activities was therefore concentrated on further concerting national positions regarding those radio-communication services that are not yet well organised internationally from a frequency-management standpoint:

- the space-operations service
- the space-research service
- the meteorological satellite service, and
- the earth-exploration service.

The other radio-communication services of interest to the Agency, namely:

- the fixed satellite service
- the mobile (aeronautical, land, maritime) satellite services, and
- the broadcasting satellite service,

were considered to be generally well taken care of by the Administrations themselves and unsolicited interventions by ESA were to be avoided. Any preparatory activity by the Agency concerning the latter services was consequently restricted to cases where ESA's assistance was specifically requested by Member-State Administrations.

Subsequently, the ESA Executive prepared the first version of its 'ESA Position Paper for the WARC 1979', in which it laid down and justified in detail its future frequency requirements, concentrating for the reasons given on the four radio-communication services identified above.

Most ESA Member States responded favourably to the Executive's proposal for a discussion of its Position Paper, either with their national Administrations or their space agencies, depending on the particular national arrangement for preparing for the 1979 Conference. Between November 1976 and May 1978, three bilateral discussion cycles were held, each resulting in a revised version of the ESA Position Paper. Finally, to align its views also with those of non-Member States active in space and with whom ESA maintains technical relations, the Executive initiated an active exchange of views with NASA (USA), NASDA (Japan), INPE (Brazil), ISRO (India), Telcom Australia and the Canadian Department of Communications.

These discussion cycles led to a gradual alignment of positions between the Executive and ESA Member-State Administrations – as well as some non-Member-State Administrations – with the result that a number of Administrations

Figure 1 — Assembled delegates to the 1979 WARC

took substantial parts of the ESA Position Paper into account in formulating their national proposals for the Conference, tempered of course by their national priorities vis-à-vis other (terrestrial) radio-communication services.

Shortly before the opening of the 1979 WARC, the ESA Executive organised a meeting, in July 1979, of frequency managers from its Member-State space agencies and from those space agencies with whom previous exchanges of views had taken place. This meeting not only reviewed the situation of space services in the light of national positions for the 1979 WARC (these were circulated by the ITU Secretariat between May and September), but also asked the ESA Executive to continue convening meetings of this kind at the WARC itself for 'on the spot' coordination, which the Agency gladly accepted to do.

The Conference itself

During the Conference ESA convened meetings once or twice per week – as required – of its Member-State space agencies; these were also attended regularly by delegates from the national space agencies of Argentina (CNIE), Brazil (INPE), Canada, India (ISRO), Japan (NASDA) and the USA (NASA). (In the ordinary course of its affairs, ESA maintains close technical relations with these non-Member-State space agencies.) Many of the decisions in the areas of space research, space operations, meteorological satellite services and earth-exploration satellite services (such as allocation of the 2 GHz bands worldwide, allocation of frequencies to active and passive sensors, etc.) can be credited to the work of this group.

At the end of the Conference, the group's members unanimously agreed to continue this work in the future, because of its continued importance for coordination of frequency matters, consolidation of preparatory work for CCIR and future WARCs, etc. The creation of this 'Space Frequency Coordination Group' can therefore be regarded as a completely unforeseen, but nevertheless welcome, byproduct of the 1979 WARC, and the Agency can be pleased with the role it was called upon to play, a role that allowed it to help in the difficult process of finding compromise solutions, acceptable if not to all, then at least to the great majority.

The results of eleven weeks of work

In the following paragraphs, the results of the 1979 WARC of key importance for the various space radio-communication services are reviewed in the light of the Agency's proposals and/or objectives.

Space-operations services

The ESA programme encompasses spacecraft operating in a wide spectrum of fields (fixed and mobile satellites, broadcasting satellites, meteorological satellites, space-research satellites, etc.). The great majority of them are geostationary and consequently require an injection- and transfer-orbit support network that typically consists of four stations around the world. It would be uneconomic to implement such a support network for each of the radio-communication services (i.e. for a variety of different frequency bands), and it is considerably more attractive to operate them at least for the launch and early orbit phases in the frequency bands allocated to the space-operations service. At present ESA uses the VHF space-operations bands (137–138/148–149.9 MHz) for this purpose, but because of the particular technical characteristics of VHF (propagation, antenna radiation patterns, crowding in the geostationary orbit) it is planned to move to the UHF in the early 1980s.

In its efforts to ensure economy in the operation of future generations of spacecraft, as well as in the associated ground support, ESA favours for its ground-support network a solution based on the use of a single frequency band. The optimum solution was consequently to allocate to the space-operations service the same bands proposed for other satellite services, namely 2200–2290 MHz/2025–2110 MHz. After lengthy discussions during the WARC, a very satisfactory solution was found, paving the way for space and terrestrial services to share the 2 GHz band.

Space-research service

The trend in ESA's space-research programme is increasingly towards larger

Figure 2 – Chairman of the 1979 WARC, Mr. Roberto J.P. Severini of Argentina (first from left)

spacecraft, with data rates and/or performance requirements in excess of those offered by the VHF bands that have been used so extensively in the past. Consequently, all of ESA's currently approved spacecraft – both those already launched and those that will be launched between now and 1983 – operate in the 2025–2110 MHz/2200–2290 MHz bands (Geos-1 and 2, ISEE-2, Exosat, ISPM).

The decision of the WARC was to make the 2 GHz bands available also to the space-research service from 1 January 1982. This will allow the Agency to operate its scientific spacecraft with the same network that is also used for the launch and early orbit phases of its geostationary applications satellites, i.e. with the same frequencies used by the space-operations service, leading to more efficient and less expensive ground support.

Meteorological satellite service
There is already a notable shortage of available bandwidth in this domain and, although Meteosat-1 could still be reasonably accommodated, severe problems were expected for second-generation meteorological spacecraft with increased performance parameters, and with an increasing number of independent satellite systems competing for bandwidth in the frequency spectrum.

Another very important requirement frequently voiced by the meteorological offices is for less expensive reception equipment both for land use and for ships. The power flux density limitations that presently govern the sharing between the meteorological satellite service and terrestrial users, particularly in the 1670–1700 MHz band, prohibit the satellite designer from providing the meteorologist with an adequate power flux density at the earth's surface, leading to additional spending by the meteorologists on more sophisticated reception equipment.

With this in mind, for the 1979 WARC ESA had proposed two amendments to the existing frequency allocation around 1700 MHz: a 10 MHz increase in bandwidth, and exclusive allocation of a 10 MHz slot in the band to small low-cost earth terminals.

The Conference did in fact agree to expand the existing frequency band to 1710 MHz, but 41 countries did not endorse the exclusive 10 MHz band. Consequently, meteorologists will not be able to work with smaller stations than they operate now, which may mean unnecessarily high costs, particularly for the meteorological offices of the less developed countries that wish to equip themselves with receiving facilities for meteorological satellites for the first time.

Earth-exploration service
European activities in this area presently consist mainly of data acquisition from NASA spacecraft, but plans for active participation by Europe with its own earth-observation satellites in the early 1980s are now taking shape. Consequently there was great interest prior to the 1979 WARC in securing a considerable improvement in the associated frequency allocations, both for the space-to-earth telemetry links, and for the spacecraft's active and passive (microwave) sensors.

The absence in the previous ITU Radio Regulations of any frequency allocations for active sensors and very few for passive sensors at frequencies above 50 GHz, as well as rather inadequate provisions for space-to-earth data transmission in Regions 1 and 3, called for urgent action at the 1979 Conference. ESA had consequently formulated a detailed proposal for new or improved frequency allocations for this radio-communication service.

The Conference not only went along with the proposals that ESA had asked its Member States to submit, and which were also supported by the national positions of some of the countries mentioned earlier, but in a number of cases allocated frequency bands beyond what was asked. This success has to be credited in part to the support leant to these proposals by the less developed countries, who clearly recognised the importance of this issue for their future economic development.

Fixed and mobile satellite services
While ESA had not, as has already been explained, formulated any proposal for these radio-communication services, the Agency's observers at the Conference followed developments very closely.

The main frequency bands of interest to the Agency are the 4/6 GHz, 11/14 GHz and 20/30 GHz bands of the fixed satellite service and the 1500/1600 MHz band of the mobile satellite service.

The new WARC frequency allocations for the 4/6 GHz bands will increase the bandwidth available in both directions (uplink and downlink) from 700 MHz to 1100 MHz. ESA had hoped that a small part of the total available bandwidth would have been allocated on an exclusive basis, which would have greatly facilitated the use of small earth stations.

The allocation situation has also been improved in the 11/14 GHz bands, the total bandwidth available in both directions now being 1 GHz, instead of the previous 500 MHz. Unfortunately, the earth-to-space band is split into two 500 MHz blocks, which makes their effective use somewhat more difficult. Here also there is no exclusive allocation for small earth terminals.

The frequency-allocation situation in the 20/30 GHz bands has remained unchanged as far as the bandwidths available to space services before and after the Conference are concerned.

Finally, the 1979 WARC has distributed the 1500/1600 MHz band more equitably between the maritime and aeronautical mobile satellite services. With the Aerosat project shelved and with Marisats already operating and a whole host of new maritime satellite projects on the horizon, among them ESA's Marecs series, the Conference revised these frequency allocations so that in future each of the mobile satellite services will have a 14 MHz band in both directions, plus a 1 MHz band (also in both directions) for joint use for distress and safety operations. ESA is pleased with this revision.

Broadcasting satellite service
The 1979 WARC was expected to allocate the future earth-to-space frequency bands for *satellite television broadcasting*. There was some concern before the Conference regarding this issue as no clear tendency in favour of one or another band could be identified in the national proposals. The final outcome was, however, better than expected: because no common position could be reached, a compromise solution had to be accepted, allocating three frequency bands instead of one. Two of these (10.7–11.7 GHz and 17.3–18.1 GHz) are shared with the space-to-earth links of the fixed satellite service. The third, and at the same time most controversial band of 14.0–14.8 GHz, on which agreement was only reached after lengthy and often heated discussions, will be shared in the 14.0–14.5 GHz portion with earth-to-space links of the fixed satellite service. This may lead to very difficult sharing situations for some arcs of the geostationary orbit. The use of the 14.0–14.8 GHz band will be restricted to countries outside Europe. The Agency has plans to use the 17.3–18.1 GHz bands for its broadcasting satellite programme.

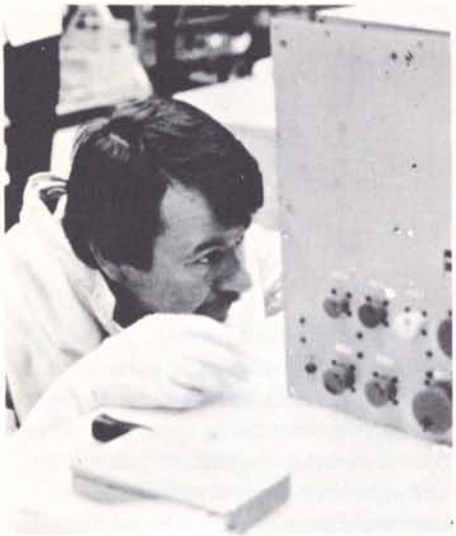
Several national position documents to the Conference contained proposals for allocating a frequency band to *satellite sound broadcasting*, with two regions of the frequency spectrum being considered; one around 800 MHz, and one between 1429 and 1525 MHz. The first of these bands was dropped early in the Conference, while the second received strong support from the less developed countries, but was strongly opposed by the European Administrations. As a compromise, a Resolution was drafted and accepted which recognises that such a service could be accommodated in the 1429–1525 MHz band and that a future Administrative Radio Conference could be entrusted with introducing this service into the Table of Frequencies and at the same time with re-accommodating those services presently using this band. This solution, though not ideal, is sufficient for the Agency's needs at this moment, and its efforts will be concentrated on this part of the spectrum.

Summarising the impression ESA observers took home regarding the results for the fixed, mobile and broadcasting satellite services, which are certainly much more controversial radiocommunication services than the four others considered above, one can say that most of ESA's objectives were met. However, from the point of view of global cooperation and foresight the 1979 WARC was somewhat disappointing, with several questions resolved to the satisfaction of a majority, but leaving a dissatisfied minority.

Future outlook
The 1979 WARC, long anticipated and prepared for over many years, may be over but the work of evaluating its results and their impact goes on, the Conference having left behind a heritage of new WARCs and RARCs (Regional Administrative Radio Conferences), with more limited mandates, many of which will nevertheless be of great importance to ESA. The WARCs deal with radio-communication problems for all three ITU Regions, i.e. worldwide, and the next one for space services, with the mandate to consider the 'Use of the geostationary satellite orbit and planning of the services using it', will be convened in two parts, with the first session taking place not later than 1984, and the second 12-18 months later.

The next RARC, the mandates of which are restricted to radio-communications in only one or two of the ITU regions, will be held in early 1983 and will deal with 'The detailed planning of the broadcasting satellite service in the 12 GHz band and associated uplinks in Region 2'. A second RARC planned for late 1983 will endeavour to find the 'missing links', its mandate being 'For planning uplinks in broadcasting satellites operating in the 12 GHz band in Regions 1 and 3'.

Conclusion
While the two RARCs will certainly be of great importance to ESA, it is the next WARC that will command particular interest. It is the results of this Conference that will determine whether space-communications systems will be allowed to expand to the benefit of all mankind, or whether a more restrictive planning approach might jeopardise all future efforts towards the optimal use of this most important orbit. A lot of work remains to be done before this next WARC opens in 1984 and ESA again looks forward to making whatever contribution it can to this important task.



The Competitiveness of European Space Industry

G. Dondi, Industrial Policy Department, Directorate of Administration, ESA, Paris

The space industry is being presented in Europe as one of the growth industries of the future. The opportunities are certainly there, and the latent technological expertise to exploit them is also present. On the other hand, European space industry is not alone in coveting the new opportunities. Given this predicament, it is only natural to ask 'will European space industry be competitive in the commercial markets for space systems in the 1980s?'

Introduction

Three concepts in the title of this article merit a word or two of elaboration:
- What is meant by the term 'competitiveness'?
- What is included under the general label of 'space industry'?
- What may be considered 'European'?

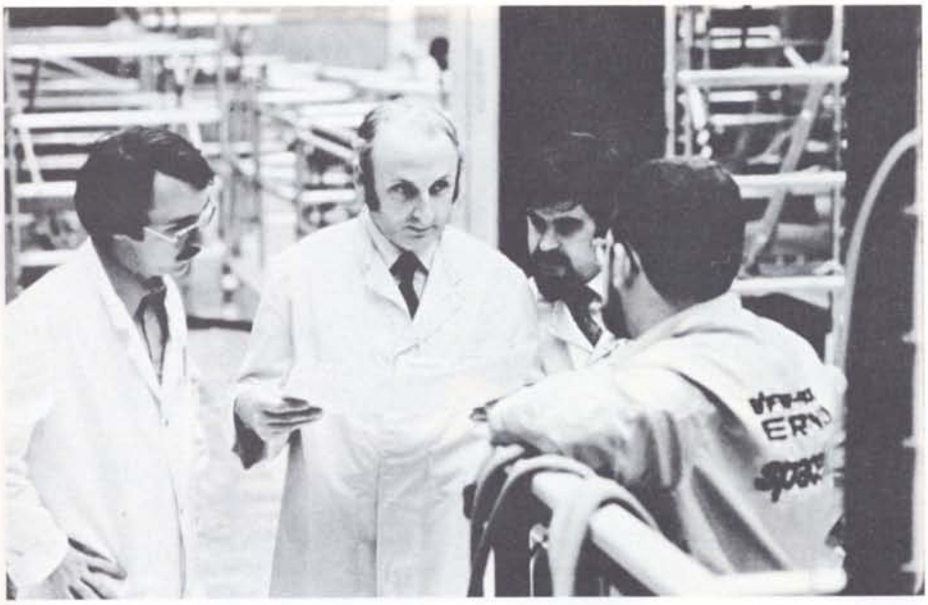
'Competitiveness' immediately implies an idea of confrontation, and more specifically commercial confrontation in an open market. If, for example, two offers are presented for manufacture of a piece of equipment, the awarding of a contract will depend on a comparative evaluation of the two offers based on:
- technical quality
- cost
- delivery time
- political support (which may be direct, e.g. by suitable intervention at the decision-making level, or indirect, e.g. by providing attractive financing terms for a project with outside support).

Two offers for a specific tender action may be considered competitive if:
- the requirements of the customer are met (or if, at least, a sufficiently strong case is made to show the customer that the requirements met by the offer submitted cover his 'real' requirements!)
- the advantages of both offers vis-à-vis the various evaluation criteria balance out in an overall comparison.

Competitiveness so defined is related to a specific situation in a specific environment, at a given time.

A wider perspective can also be taken by considering the competitiveness of the 'industry of a country'. One country's industry can be considered competitive vis-à-vis that of another if during repeated confrontations in open markets the offers submitted by the firms of the two countries have a comparable probability of winning the contracts at stake. To judge the competitiveness of the space industries of two countries, or of two groups of countries, therefore:
- the confrontations considered must cover a number of cases
- the confrontations should not be influenced by political considerations introducing a very strong bias in the buyer towards one of the solutions (e.g. governmental markets that impose 'buy national' clauses)
- the probability of each contender getting an order should be comparable (not necessarily equal); the total number of awards in the series of confrontations should therefore also be comparable (not necessarily equal).

'Space industry' may be defined as the specific space-related capability and potential of the firms active in:
- rocket propulsion systems (missiles, rockets, space transportation systems, and associated components)
- space hardware (spacecraft and payloads, and related spaceborne equipment and components)
- ground equipment for supporting space missions: tracking and telemetry stations;control stations; data receiving stations



(telecommunications, meteorology, earth observation, etc.); environmental testing equipment, checkout equipment, etc.
- supporting services for space activities, such as maintenance and operation of ground infrastructure, and technical assistance of various types.

The term 'European' when applied to 'space industry' may give rise to some ambiguity because the geographical entity of Europe does not correspond to the group of countries belonging to ESA, and because European space industries can include European subsidiaries of non-European firms.

European space industry will therefore be defined here as embracing those industries active in the space field within western Europe, and those firms controlled by non-European interests are included only if they have manufacturing facilities in western Europe.

Assessment of the competition
How can the problem of the competitiveness of European space industry be formulated? Clearly there are two elements to consider:
- firstly, competitiveness with whom? i.e. which parties are in competition?
- secondly, competitiveness for what? i.e. what are the markets in which competition may be expected to play a role?

To answer the first question, it is clear that the world's space industry may be considered concentrated in five main domains:
- US space industry
- USSR space industry
- European space industry
- Japanese space industry
- other countries' space industries.

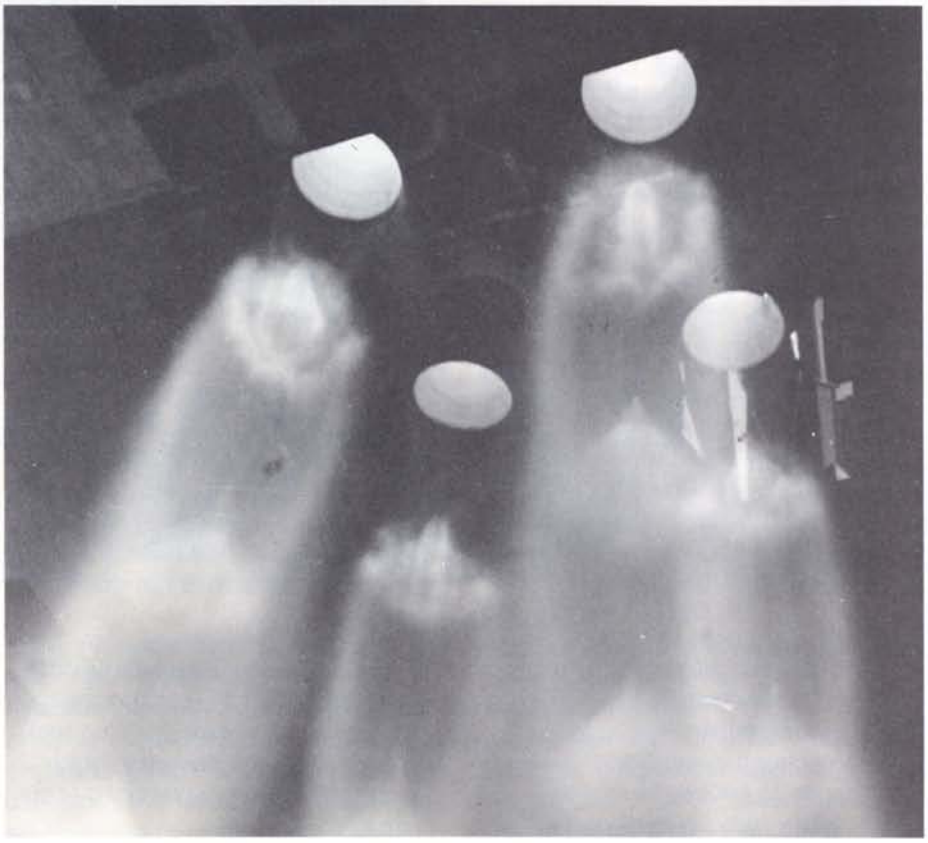
The first four groupings include the major space powers, namely those countries or groups of countries capable of providing complete space systems, i.e. space transportation systems, spacecraft systems and related ground-support equipment and operations, for all types of missions. The last category includes countries that have only a limited space capability (lack of rocket propulsion systems, or possibility of supporting only a limited number of missions, etc.).

Within Europe, some countries certainly have the capability to provide complete space systems nationally, but have voluntarily decided to undertake their major space programmes on a cooperative European basis. Some of the 'other countries' have space industries that can already provide complete space systems (China and India), but not for all types of missions. Also, some of the 'other countries' have a space industry that is well developed in specific fields, such as telecommunications and earth observation in Canada, even if they cannot provide complete space systems.

The investments in space activities in the USA and the USSR in the last twenty years have been at least an order of magnitude greater than those in Europe; it is therefore not surprising that these two countries lead the others both in numbers of achievements and in the number and quality of developed space technologies.

The USSR is apparently only marginally interested in offering its space capabilities to other countries for commercial purposes, with Russian space 'exports' so far taking the form of:
- military assistance to allied countries; mainly through 'services' based on space systems controlled by the USSR
- supply of launch services for scientific satellites in a very limited number of cases (the USSR as a member of INMARSAT has recently indicated its willingness to launch one of the Agency's Marecs spacecraft).

The USA's space industry, by contrast, has been very active in supporting the space needs of other countries through:
- on-request launch services (by NASA)
- cooperative scientific missions with other countries/groups of countries (via NASA)
- cooperative data-acquisition missions (via NASA)
- commercial delivery of complete space systems (by industry)
- transfer of technical assistance and knowhow (by NASA and industry).



In the early days, European space industry benefited from the transfer of knowhow from the American space programmes. In the last ten years, however, a certain number of European initiatives in space research and development, the timing of these initiatives, and the simultaneous contraction of the American space programmes have contributed to a gradual build-up of European capabilities to a point where in some segments of the space market there is direct competition between American and European industries.

Japanese space industry has certain similarities with that of Europe, with two significant differences:
- space activities in Japan were begun slightly later than in Europe and have received lower budgets
- the support and technology transfer from the USA has been more important than in Europe, especially in the field of launcher development.

The Japanese industry has not yet reached the stage of marketing complete space systems commercially, but it is nevertheless already well represented in the commercial domain.

In summary, then, Europe's space industry has principally to compete on international markets with American space industry, with confrontations in specific areas where European products and services may be particularly competitive. Competition from Japan has also to be reckoned with, and may be expected to be especially fierce in those fields where European space industry is also particularly active, such as telecommunications and ground stations.

Assessment of potential space markets
Markets for space systems can be analysed from three different standpoints:

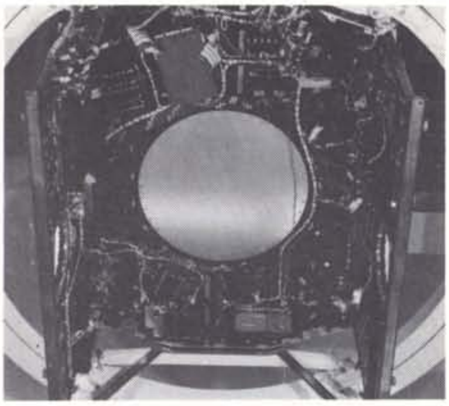
1. The end product to be supplied:
- space transportation systems
- spacecraft
- ground stations
- support systems, etc.

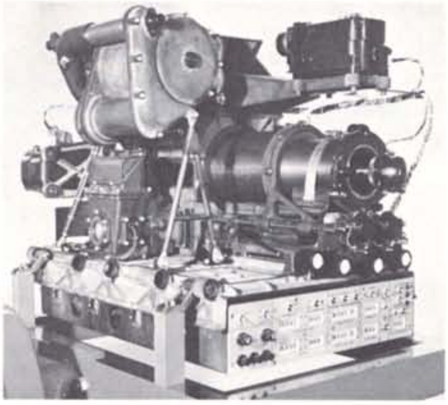
2. The missions to be satisfied:
- civil missions – scientific research, earth observation and meteorology, telecommunications, etc.
- military missions – observation, positioning, telecommunications, etc.

3. The sponsor financing the activity:
- government institutions – national (NASA, NOAA, DOD, CNES, DFVLR, etc.), international (NASA, NATO)
- commercial institutions – national or domestic (WESTAR, TELSAT, SBS, etc.), international (INTELSAT, INMARSAT).

This last classification is perhaps the one that can most usefully be retained in the context of our appraisal. Up to now, space activities have mainly been sponsored by government institutions, national or international, and as a consequence the space market has largely been a captive one. Current trends indicate that the part of the market sponsored by commercial institutions, and therefore more likely to be open to commercial competition, should increase in the eighties in both absolute and relative terms. This is a clear indication that space activities are evolving from an experimental phase oriented mainly towards technology development and prestige undertakings, towards practical applications in which cost-effectiveness will play a major role.

A word of caution is nevertheless necessary:
- this trend will be felt by industry towards the second half of the eighties only, and
- commercial space ventures for domestic satellite systems can be expected to be open to competition





only in those countries that do not possess, or have only limited space capabilities.

Clearly, each of the major space powers will in principle cater for is own space needs. Confrontation between the various space industries will therefore take place

- essentially in catering for the applications missions of countries not having a space industry or having a space industry that cannot provide complete space systems,
- marginally in covering the needs of other major 'space countries' more competitively (the major factor is cost, but delivery time, reliability, adaptability to mission requirements, etc. can also play a role).

Commercial competition will therefore mainly be limited to applications-oriented missions and in terms of end products will involve:

- space transportation systems (expendable launchers, re-usable systems)
- spacecraft for applications missions (mainly telecommunications, earth observation)
- ground stations and equipment to support applications missions (fixed stations, mobile stations).

Judgement of competitiveness

There are two questions to be answered here:

- Is European space industry capable of competing with the United States and Japanese space industries in the commercial space markets of the eighties?
- Which are the favourable and unfavourable elements that may play a role in this commercial competition?

Two different approaches are possible in dealing with this problem, one analytical, and one qualitative.

Taking the analytical approach first, one can analyse space industry experience and capabilities, assess space industry costs taking into account the tender actions in which they have participated, and extrapolate and compare trends. Clearly, the main limitation in this approach lies in the difficulties encountered in acquiring reliable and comparable data for recent projects, so that any conclusion derived runs the risk of being based on very limited evidence.

The other approach, by contrast, is based on the qualitative analysis of informed 'opinions', collecting opinions on 'competitiveness' from interested parties (both on themselves and on competitors), and comparing those opinions in an attempt to extract some common elements. In this case, the input data are much easier to obtain, but the information is often incomplete (i.e. focused on limited aspects of a problem), biased (i.e. focused on factors of interest only to a particular party), expressing fears or hopes rather than facts, or inferring causality where only a temporal succession of events exists. The reliability of the basic information is, then, to say the least, doubtful, but nevertheless it is thought that the process is useful for composing an integrated picture of the competitiveness problem and for providing a feeling for possible actions that may be needed.

The European and American viewpoints

When discussing the competitiveness of space industry the dialogue usually falls into a pattern whereby the strong points of the competitors are first underlined, and sometimes overrated, the weak points of one's own position are revealed, and finally some remedial actions are suggested, usually in the form of direct or indirect increases in public support for space activities.

Evidence presented in this way is, of course, not completely objective. On the other hand, analysing this same type of evidence from two direct competitors, in our case representing the European and American viewpoints, can provide a reasonably balanced insight into the problem.

The case for the competitiveness of European space industry as presented by its supporters and the case presented by supporters of American space industry are summarised in Tables 1 and 2.

Conclusion

The points of view listed in Tables 1 and 2, all of which have either been extracted from the recent literature or have been expressed by representatives of European and American space industry, allow one to arrive at a broad synthesis of the situation. It can be deduced that American space industry acquired a recognised technological lead following the space programmes of the 1960s, culminating in the Apollo project. Commercially, it has exploited this technological lead well into the 1970s, trading off economic solutions against

Table 1 – Space industry competitiveness – the European viewpoint

1. Why is the American space industry competitive?

1.1 The American space industry is supported by a very important natural market (military and civil space markets, which complement the NASA and DOD R&D markets). Consequently:
- space products may be planned in small series, with obvious cost advantages
- military R and D support has been instrumental in developing technologies/equipment that now benefit civil space programmes.

1.2 The international situation has automatically favoured the American space industry:
- the cost of manpower in Europe in the last five years has increased much more rapidly than in the United States
- the devaluation of the dollar has given an additional edge to American products.

1.3 The marketing approach of American firms is very effective:
- American aerospace firms are already represented worldwide, and the marginal additional cost for space marketing is negligible
- the worldwide logistic support of the American embassies to their commercial missions is well known
- because of their size American firms can easily supply 'complete services', working with a limited number of subcontractors; in addition they are often able to offer hardware already 'proven' in previous programmes.

1.4 The technical approach of American firms tends to be conservative vis-à-vis commercial customers; this fosters low cost and high reliability.

1.5 American management methods allow very efficient handling of space projects:
- there is usually strong management by a prime contractor which dwarfs the subcontractors, and the latter are selected purely on technical-performance and cost grounds
- American firms are more flexible than their European counterparts in adapting their staffing to the load factor of their installations.

2. Why is European space industry's competitiveness limited?

2.1 European space firms have been accustomed until recently to supplying a 'protected' market:
- national and bilateral programmes generate 'captive' markets
- ESA programmes generate a market in which competition is limited by the 'buy European' policy.

2.2 The European space effort is dispersed over a large number of firms in different countries; the industrial management structures are therefore heavier, slower to react and, in the final analysis, less efficient than the corresponding management structures in America.

2.3 Firms that have shown initiative in the commercialisation of space activities have relied more on political support for ad hoc trials than on systematic and in-depth marketing actions.

3. What could be done to improve the competitiveness of European space industry?

3.1 The importance of the common European programmes sponsored by ESA should be increased, placing the accent on:
- applications programmes leading to the demonstration of systems or components that have a foreseeable commercial interest
- research and development effort, to be concentrated on areas where European independence is vital or where a European technical lead may be ensured.

3.2 European space industry should attempt to supply complete services and not only individual system elements; production of competitive hardware is a particularly strong feature of the American industry; European industry, on the other hand, may be particularly competitive and logistically better placed to supply associate services; it is important therefore to avoid the 'piece-meal' approach starting with hardware items, because the subsequent support services tend to follow from the same source.

3.3 An effort should be made towards standardisation in its various forms (standard equipment or components, adoption of functional and interface standards, etc.) to reduce costs.

technological innovation. But now American industry sees this favoured position becoming endangered on two grounds:

- The lower priority granted to space activities by the US Government in the 1970s has had an effect both on the development of new technologies and on the enthusiasm for tackling challenging new projects oriented towards the commercial exploitation of space.
- The European and Japanese space industries are growing increasingly independent, being sufficiently mature to take full responsibility for complex space projects, if necessary in competition with their US counterparts.

The European industry itself, on the other hand, though it feels confident, is aware of a number of prevailing limitations:
- The need for cost containment is recognised

Table 2 – Space industry competitiveness – the American viewpoint

1. How can the progress and increased competitiveness of European space industry be explained?

1.1 Research and development efforts in Europe are particularly efficient for several reasons:
- the R and D community is smaller and geographically more concentrated than in the USA, making communications easier
- social planning, i.e. government support of R and D efforts with long-term perspectives, to avoid unemployment, is a way of life in Europe. This can be costly in the short term but is beneficial in the long term
- R and D efforts are more directly guided and harmonised by governments, with active participation by universities
- the prestige of R and D scientific staff is much higher in Europe than in the USA.

1.2 The concentration of the European space industry has brought about a rationalisation of efforts at various levels:
- concentration of R and D effort
- definition of common programmes at European level
- concentration of development effort in areas assured of profitability in the international market place
- definition of integrated industrial structures at European level.

1.3 European firms have been active and effective in technology exchange within Europe and in adopting US developed technologies put at their disposal; at the same time they are rather jealously guarding their own advanced technologies whenever they find themselves in a strong position, thereby keeping their lead more efficiently than their American counterparts.

1.4 European firms routinely rely on political support at the highest level to promote their products commercially:
- commercial missions are often lead by political personalities
- international commercial ventures are often financed from government-sponsored sources under preferential conditions.

1.5 The marketing efforts of European space firms are beginning to show results particularly in countries where an American presence is not politically welcome.

2. What are the reasons for the gradual erosion of the American lead in space activities?

2.1 Lack of support for space programmes after the Apollo era is responsible for some of the ground gained by competitors.
- the gradual drain on R and D resources in the space telecommunications field has allowed European industry to become technically competitive there
- the limited means put at the disposal of the Shuttle programme has generated delays which, together with the premature decision to phase out conventional launchers, has pushed customers towards Ariane

2.2 Productivity gains in American industry (particularly the aerospace industry) have been lower than in Europe in the last few years

2.3 Management and organisational methods have progressed more rapidly in the European aerospace industry in the last few years; in particular, Europeans know how to manage complex, multinational projects, which are becoming the rule in the international market place.

3. What could be done to improve the competitiveness of the American space industry?

3.1 Increased funds should be allocated to American space programmes, pursuing in particular:
- operational utilisation of the Shuttle and optimisation of future space missions around it
- development of new telecommunications and observation systems by investing in the associated R and D activities
- new and ambitious missions in the scientific field and in the field of 'space industrialisation' (building of space stations for telecommunications, power generation, etc.).

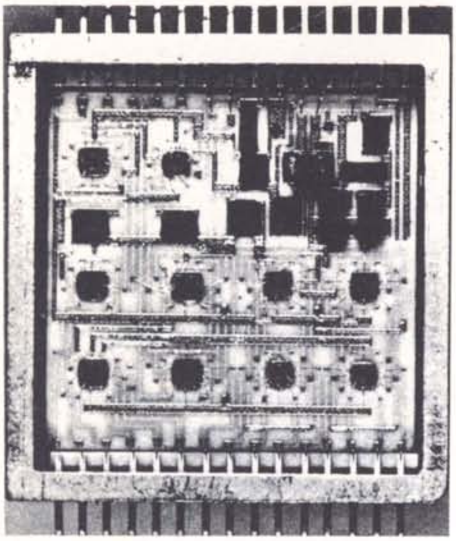
3.2 Appropriate structures should be set up within the US government to promote exports in the aerospace sector (a Trade Representative was appointed in December 1979 to pursue these matters).

3.3 Appropriate actions (mainly at R and D level) are required from the Federal Government in fields closely connected with the aerospace industry to improve the industry's competitiveness, e.g.
- in the electronics industry exports still exceed imports, but there is a reverse tendency for integrated circuits, computers and telecommunications equipment
- adoption of advanced manufacturing technology in the American aerospace industry should be stimulated.

3.4 International cooperation between American and European space industries is another means of ensuring market share and product quality without abandoning the principle of competition; specialisation should replace cut-throat competition, leading to more effective results overall for the end user.

- Competition with American space industry is seen not so much as a general challenge, but rather as an opportunity to exploit specific advantages in areas where Europe has an apparent advantage
- Competitiveness is seen not as a fillip for ruthless commercial battles, but rather as a basis on which to compete on equal terms with American companies in exploiting the space markets of the future.

As far as the measures proposed for increasing the competitiveness of the respective space industries are concerned, there is a striking similarity between the measures advocated by the industry's European and American supporters. It is, of course, difficult to judge how much these measures are dictated by the true needs of the final users of space systems and how much by the fear of being outmanoeuvred by the competition.



Architecture of On-Board Data-Handling Systems for ESA Satellites

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The limited number of ESA satellite missions and the associated geographical-distribution constraints call for rationalisation and some degree of standardisation in data-handling interfaces and architecture. The on-board data-handling (OBDH) system studied as part of ESA's Technological Research Programme links centralised facilities via a data bus to various types of remote terminals for data acquisition, distribution and processing. The data-handling units of the subsystem are standardised at functional and interface level, which avoids recurring development and user-education costs from one space mission to the next while still retaining sufficient freedom to facilitate industrial competition and technological evolution.

Each successive generation of spacecraft brings increased requirements in terms of data rates, attitude measurements and control, on-board processing and physical size. As spacecraft become more complex, it only remains feasible to build them cost-effectively if the interfaces for power, signal and data flow, etc. between the various elements are clearly designed from the outset. This is particularly the case for the data-handling subsystem, which has to communicate with the payload and other subsystems developed by different European contractors. To be able, therefore, to proceed with the parallel development of the various subsystems and payloads with minimum risk of incompatibility or duplication of effort, all on-board software and signal interfaces must be rationalised and required to comply with well-defined standards. Moreover, by standardising commonly used subsystems one can expect cost savings due to the reduction in development and qualification effort, and even more so due to simplification of the integration and re-utilisation of both equipment and proven test and operational procedures.

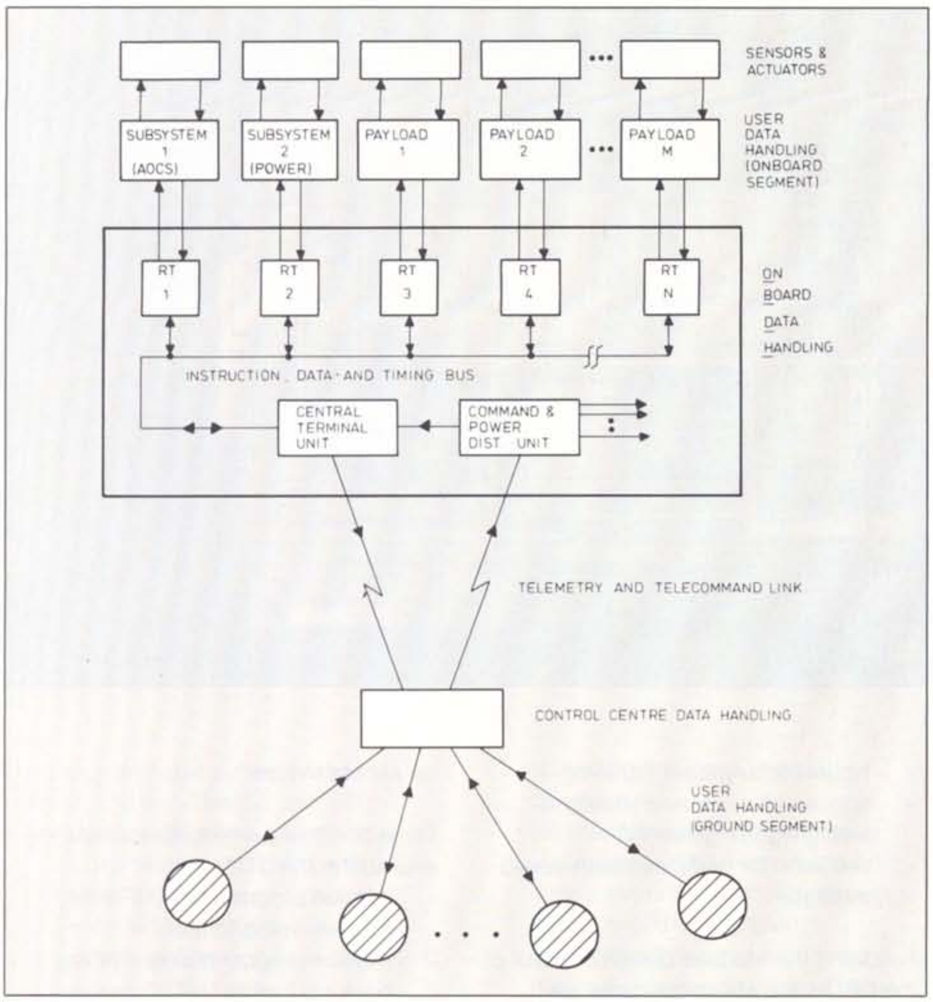
Although, theoretically, the greatest cost-effectiveness can be achieved by using standard units, it must be stressed that before such a goal can be achieved one must take into account such factors as the comparatively small number of spacecraft involved, the long development cycles and the industrial-policy/geographical-distribution constraints, which are a very important feature of European space activities and which limit the cost-effectiveness of hardware-unit standardisation.

The conclusion therefore is that, although the advance of digital technology and particularly the advent of LSIs (large-scale integrations) would make it possible to employ general-purpose multi-mission (standard) hardware, the rate of technological progress coupled with the low mission frequency would bring problems of rapid obsolescence for standardised units and of lack of flexibility in the optimisation of cost, geographical distribution and equipment availability.

The OBDH system developed by ESA under the Technological Research Programme, and outlined in the following paragraphs, attempts to solve these problems by specifying and standardising the data-handling units of the subsystem at functional and interface level only. In this way, the initial investments in system-level development (hardware and software) and user education are not a recurring expenditure, but freedom for industrial competition and technological evolution still remains. The data-handling requirements of the different ESA missions to be accommodated are so varied that the requisite degree of standardisation can be achieved only with a modular system capable of assuming different configurations, so as to minimise lack of performance or overdesign.

In addition to remote terminals for the acquisition and distribution of data, the ESA OBDH system contains a number of autonomous, task-dedicated peripheral processors which are connected by a standard interface to the central facilities

Figure 1 – Simplified block diagram of the ESA OBDH subsystem and its role in user data flow



via a data bus. The modular system structure allows expansion for both reliability and/or performance improvement, while the task autonomy of the peripherals both allows the user to optimise the design for particular requirements and eases test and integration problems.

General system description

The system rationale is that by distributing commanding, data-acquisition and processing capabilities within the various subsystems, experiments and payloads, major simplifications in software, data traffic, interfaces, testing and operation result compared with centralised processing systems. However, to achieve these simplifications it is necessary to *standardise the design of the hardware*, software and communications interfaces, and basic command and housekeeping processing functions in the central terminal unit. The key features of the ESA OBDH are:

- The command and data-distribution functions and the data-acquisition functions are implemented using standard interfaces, standard remote terminals and standard procedures.
- The transfers to and from the remote terminals are implemented via a serial data bus, thus helping to minimise spacecraft wiring loom problems and, in particular, allowing the spacecraft to be integrated and tested as separate modules.
- The system is modular, to permit the same basic building blocks to be used for many spacecraft, thus permitting standard subsystems configurations, testing and operating procedures.
- The processing required for spacecraft management and control is completely separate from the payload data processing, the former being implemented as a standard function of the central unit, the latter either in optional user-dedicated modules in the central unit or at the periphery using intelligent terminals.
- The system is supported by a comprehensive infrastructure for testing at unit, subsystem and spacecraft level and for software development.

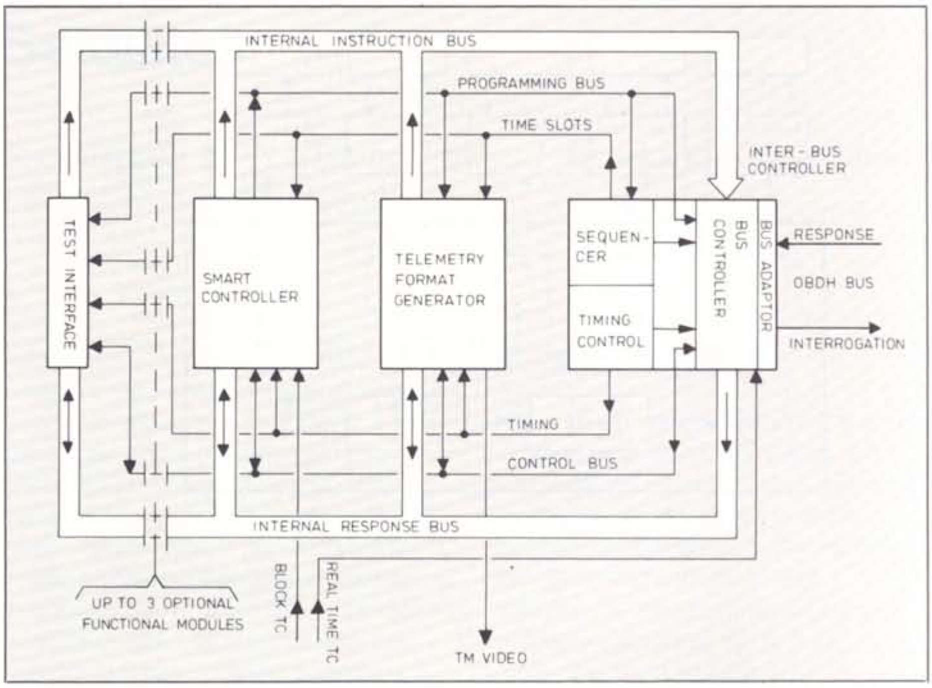
Functions and building blocks of the OBDH

The functions of the ESA OBDH subsystem shown in Figure 1 are:

- to receive and decode telecommands from the ground, and distribute them to the spacecraft subsystems
- to gather and encode spacecraft data (payload and housekeeping data) and send it, duly formatted, to the telemetry transmitter
- to provide for on-board command and housekeeping data processing (spacecraft management and control)
- to generate the on-board time reference, and distribute timing signals to spacecraft subsystems
- to provide an optional capability for user-dedicated processing and data formatting
- to provide event datation for users.

The OBDH subsystem uses a time multiplexing principle that permits the use of a single data-transfer medium or data bus which feeds remote terminals (maximum of 31) from a central unit. The remote terminals are responsible for the distribution of operational commands and data to other subsystems, and for the acquisition of data from those subsystems.

Figure 2 — Simplified block diagram of the basic central terminal unit (CTU)



The central unit provides the telemetry output for the RF downlink and receives command instructions decoded from the RF uplink. Commands and data are transferred between the remote and central units of the OBDH subsystem in specific time slots.

The data bus
The data bus is implemented as a redundant set of lines; each set is a full-duplex system composed of two one-way buses, for interrogation and response.

The interrogation bus provides a dedicated transmission path from the central unit to all the remote terminals. Interrogation instructions in serial form are sent continuously over the bus in order to feed the remote terminals with commands, data and operating clock pulses.

The response bus provides a common transmission path for responses (if any) originated at remote terminals and going to the central unit or, if specified by the central unit, a data path for transfers between two suitable remote units (maximum response rate 15 625 words/s).

Messages to be exchanged in the data bus are allocated according to predefined time slots in such a way that the central unit always controls the source, destination and nature of the data involved.

The various units are coupled to the data bus by transformers housed in bus couplers, which are an integral part of the data-bus harness.

The central terminal unit (CTU)
The CTU is the central controller of the OBDH subsystem in that it provides time-shared access to the data bus for the acquisition of data and the distribution of commands and/or data. Its functions are:
- command handling, either from the ground or programmed on board
- spacecraft data gathering and formatting for downlink telemetry
- housekeeping-data handling
- spacecraft clock reference and timing signals generation
- provision for dedicated high-speed interface.

Following the modular design concept of the OBDH, the above functions are performed by modules connected via an internal bus system (Fig. 2).

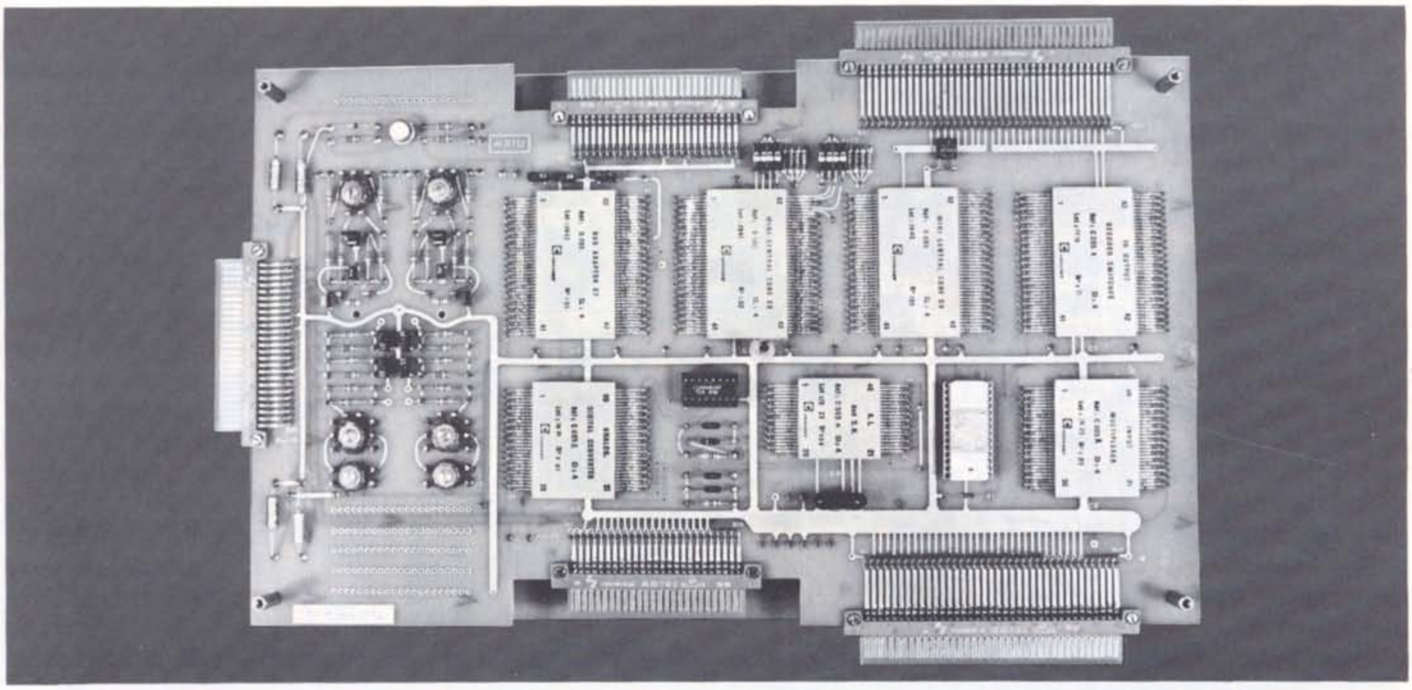
The bus controller handles the timing of the whole unit, the traffic along the internal bus system, and the time-shared access to the external OBDH data bus. The last two functions are implemented by granting bus access (internal and external) to one of the 'active' modules of the CTU at a time, and the bus controller can handle up to seven modules.

The telemetry format generator provides the on-board transmitter with a PCM signal according to the ESA PCM Telemetry Standard and merges user telemetry data, internal telemetry data originating from the various modules of the CTU, and high-speed telemetry from the dedicated interface of the CTU, into a serial data stream.

Three command-selectable formats are available in the CTU:
- mission programmable (PROM) housekeeping format
- mission programmable (PROM) back-up format
- in-flight programmable (RAM) operational format.

The smart controller is a processor-based module with access to all channels of the subsystem and is responsible for:
- command handling for reprogramming memories in the CTU, in the user's equipment and for the generation of time and/or data-dependent commands (i.e. time tagging, command expansion and scheduling etc.)
- housekeeping handling, including limit checking, status summary, snap-shot acquisition for trouble shooting, etc.
- combination of the above two functions to implement closed-loop control.

Figure 3 – Breadboard of a mini remote terminal unit (RTU)



The programmable pulses module is optional and provides the user with:
- pulses issued with a command programmable time delay with respect to a reference signal generated by the user
- synchronisation signals at command programmable rates.

The optional dedicated format generator module provides the user with an in-flight programmable (RAM) acquisition sequence delivering to a dedicated interface data collected from the OBDH subsystem.

Remote terminals
These units perform the data acquisition and distribution function at the user interface on the standard OBDH input/output terminals which allow access to or from the data bus. To meet the different users' requirements, three types of remote terminals are available.

The functions of the remote terminal unit (RTU) are:
- remote acquisition and multiplexing of analogue and digital data (including analogue to digital conversion)
- remote distribution of commands (pulses and 16 bit memory loads)
- remote event datation with respect to the on-board time reference
- remote distribution of broadcast pulses (i.e. pulses distributed at the same time by all terminals irrespective of their address) at suitable telemetry-related rates.

The mini-RTU provides, in a highly miniaturised form (Fig. 3), a subset of the above functions with limited capability in the maximum number of input/output channels. The mini-RTU can exist either as a stand-alone unit or integrated in the relevant subsystem or payload.

The intelligent terminal unit (ITU) provides local acquisition, distribution and processing of data and supports the high-level interface (protocol) with the executive of the CTU processor.

The command and power distribution unit (CPDU)
The CPDU is an internally redundant unit performing:
- demodulation and bit synchronisation of the uplink telecommand signal
- frame verification, validation and execution
- distribution of up to 96 high-power priority commands
- distribution of four 24-bit serial load commands
- configuration control of the OBDH subsystem by switching and distributing the AC input power to the various OBDH units.

Technology employed
Having considered criteria like maturity, LSI capability, dissipation, reliability, radiation hardness, availability, cost and speed of operation, C-MOS semiconductor technology has been selected for most functions. Magnetic bubble memories are the technology choice for mass storage.

Most well-defined, fixed and repetitive

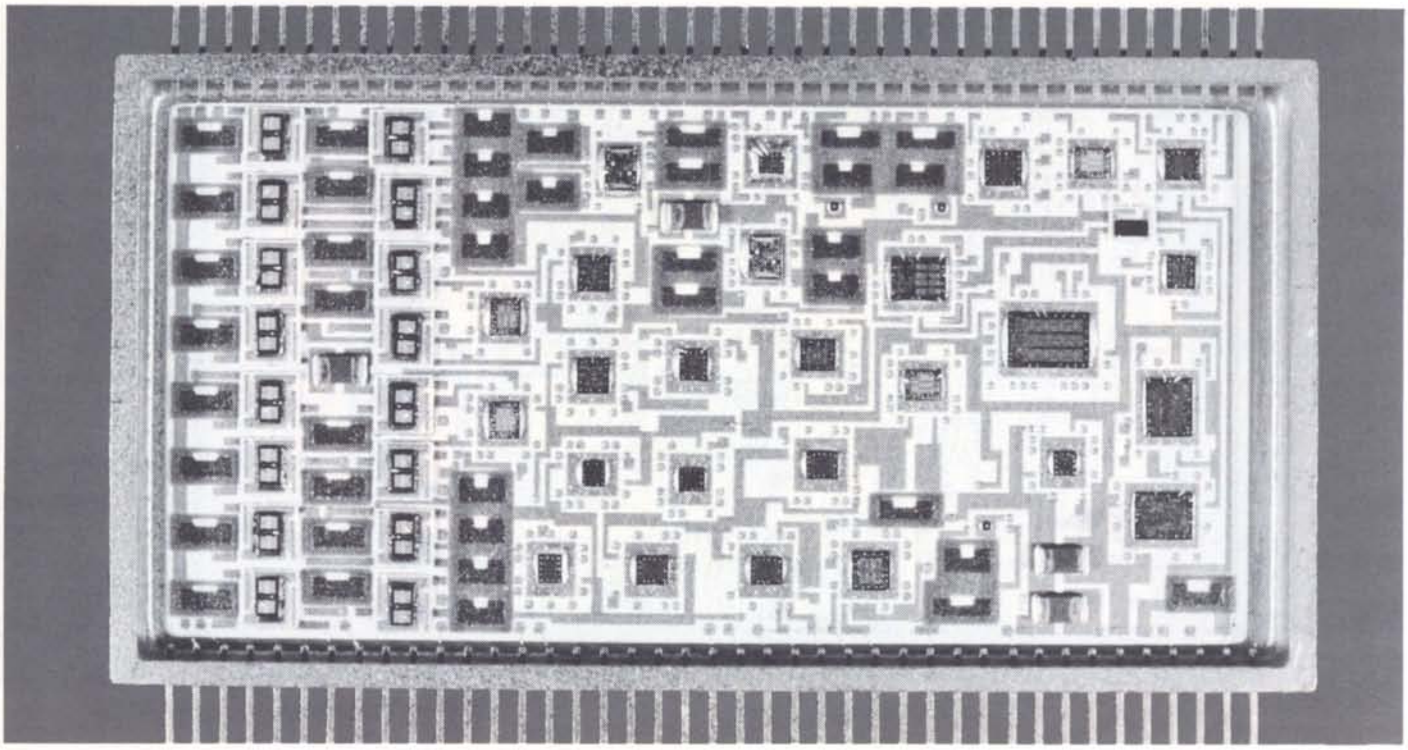


Figure 4 — Bus adaptor hybrid for the OBDH

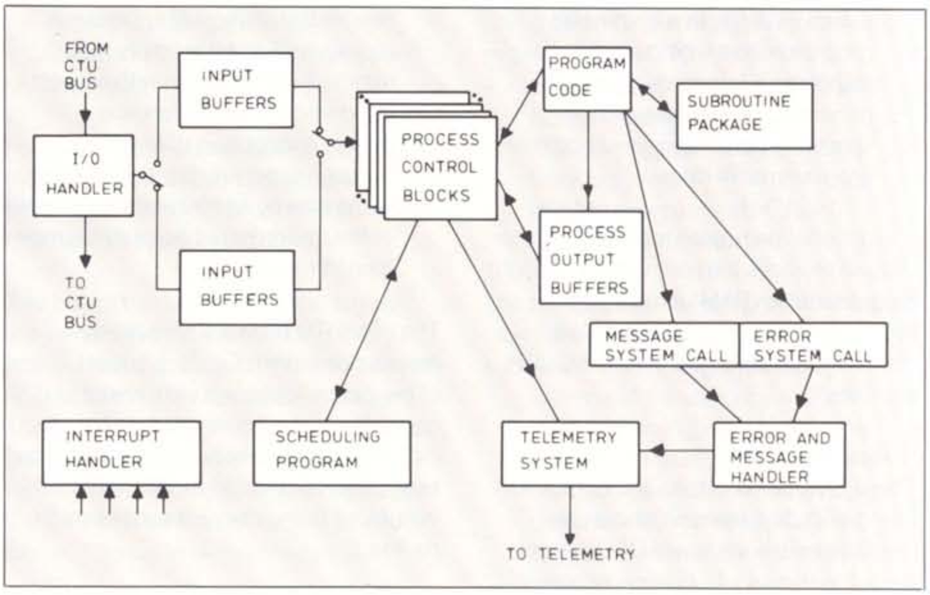


Figure 5 — Organisation of the overall OBDH software system

functions like input/output interfaces, analogue input multiplexers, output buffers and memories have been integrated in hybrid packages, with resulting improvements in mass, volume and reliability (Fig. 4).

All OBDH units are modular, so that performance can easily be tailored to requirements. A modular packaging scheme is used, in which modules of standard sizes and construction are stacked together to form a unit with easy add-on capability.

Software

The basic structure of the software system to run the smart controller of the CTU (Fig. 5) is characterised by a modular system executive with simple data structures for interfacing the software modules. The applications software consists basically of the implementation of special data-processing algorithms. Data from an input buffer is processed and the result placed in an output buffer. The real-time executive ensures that the data processing runs at the correct time and that the resultant data are despatched to their correct destination. It can perform this task for a number of such activities and correlate the total actions of the system in time.

Provisions are made for scheduling and asynchronous processes.

The interfaces of the various modules of applications software with the executive and the information required by the

Table 1 — OBDH performance

Telemetry	wire-path and telecommand selectable up to 250 kbit/s
Dump bit rate	up to 1 Mbit/s using high-speed dedicated interface
Timing	distribution of 250 kHz clock; format, frame, TM word pulses and real-time, interrupt through the data bus via remote terminals
Distribution of ground-generated commands	20 per second (CTU will accept up to 125 per second)
Distribution of CTU-generated commands	up to 7750 per second
Acquisition of data words for TM or CTU use	up to 15 625 per second
TM formats	three telecommand selectable formats: – housekeeping (PROM) – back-up (PROM) – operational (RAM)

Table 2 — Summary of ESA OBDH unit characteristics

Unit	Mass (kg)	Power (W)	Remark	Delivery
CPDU engineering model	3	1.5 6	standby max	end 1979
CTU engineering model	2	5	basic CTU	mid-1980
Standard RTU engineering model	3	0.4 1.5	standby max	early 1980
Standard mini-RTU breadboard	0.3	0.35 1.2	standby max	delivered
Standard mini-RTU engineering model	0.1	0.35 1.2	standby max	end 1980
ITU engineering model	2	5	–	mid-1980
Data bus	–	–	–	delivered
60 Mbit mass store (bubble memory)	10	3 min 18 peak	R=0.9 after 5 y	June 1981
Mechanical model of packaging scheme	–	–	–	delivered

modules about their own resources (e.g. output buffers) are concentrated in progress control blocks (PCBs).

The net result is that the designer of applications programs is provided with a well-defined software environment, thus relieving him of most problems related with computer input/output.

OBDH performance

Table 1 gives a summary of OBDH performance. The figures shown are maxima for each of the functions. Due to the modularity and flexibility of the OBDH system, its actual overall performance will vary according to the mission-specific organisation of the subsystem, i.e. number and type of units, mode of operation, etc.

Implementation of the OBDH subsystem

Although the goal is to standardise the data-handling subsystem and the units that compose it at functional and interface level only, a design-proving system must be developed to access the feasibility of the design goals. The hardware and software development of the units is being carried out under the Agency's Technological Research Programme, and involves nine contracts with six firms in five different countries.

A breadboard model of the OBDH has been delivered to ESA and was integrated in 1978. Table 2 summarises the characteristics of the OBDH units, with an indication of the expected delivery dates. Integration of these units with a view to evaluating and characterising their performance for hardware and software configurations representative of the most typical ESA spacecraft missions, will start in mid-1980 and will be completed in 1981.

OBDH operational configurations

The requisite performance (number of channels, data throughput, bit rates, etc.) for a particular application is achieved mainly by equipping the OBDH with a number of basic components and then adding a suitable number of accessory modules. Reliability is achieved by duplicating the CTU, the data bus and the RTUs as required.

These features of the OBDH give the system designer the freedom necessary to tailor the subsystem configuration to the data-handling requirements of a given space mission, as the following examples for three different classes of satellite illustrate.

Table 3 — Key features of three typical satellite data-handling configurations realised with the ESA OBDH system

Simple telecommunications satellite	Simple scientific satellite	Complex earth-resources or scientific satellite
CPDU (self-redundant)	CPDU (self-redundant)	CPDU (self-redundant)
One redundant data bus	One redundant data bus	Two redundant data buses
One CTU active One CTU backup	One CTU active One CTU backup	One CTU active One CTU backup
Each CTU contains: – bus controller and spacecraft clock – telemetry-format generator	Each CTU contains: – bus controller and spacecraft clock – telemetry-format generator	Each CTU contains: – bus controller and spacecraft clock – telemetry-format generator with high-speed dump capability
– smart controller – special timing	– smart controller – special timing – AOCS controller	– smart controller – AOCS controller – powerful processing module (16 bit microprocessor) – drivers for additional redundant data bus
One RTU* for service module	One RTU* for subsystems	– One mini-RTU* for each of the main components
One RTU* for payload	One mini-RTU* for AOCS One mini-RTU* for each experiment	One mini-RTU* for each major component of subsystem (RF, thermal, power, etc.) One mini-RTU* for each experiment with centralised processing and control One ITU* for each experiment with local processing and control
	One optional redundant bubble-mass memory 40–100 Mbit as required	One redundant bubble-mass memory, 40–100 Mbit as required

* These units may be duplicated to meet reliability requirements.

Telecommunication satellites
In this case a 'bare-bone' configuration will suffice and the only processing done by the OBDH is the telecommand and telemetry handling. The system is somewhat centralised, with only two RTUs, and most of the telemetry is raw data, with some processed floating-format data generated by the smart controller for status reporting, compressed housekeeping and telecommand verification.

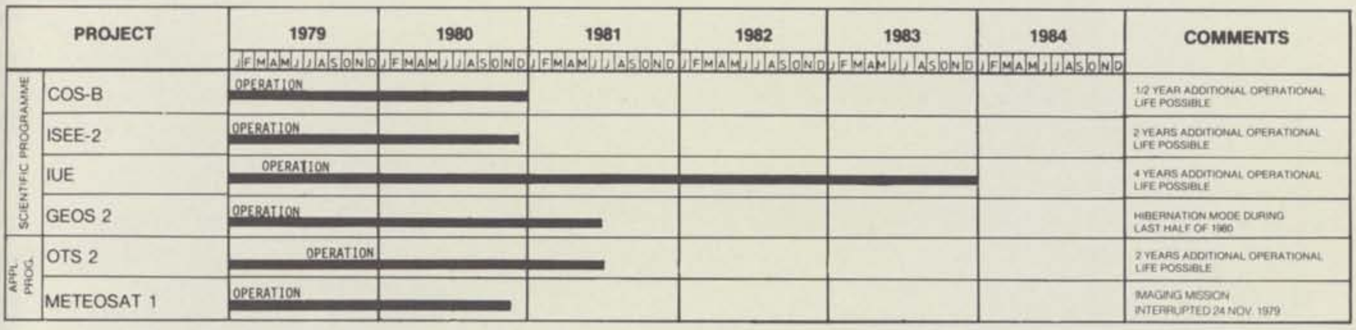
Scientific satellites (three-axis stabilised)
In this case a more sophisticated OBDH has to be used including an additional processing module in the CTU to perform attitude and orbit control functions. A mass store is necessary if there is no uninterrupted coverage from the ground. AOCS safety modes are implemented via hardware in the AOCS system. Most of the telemetry is raw data (real-time or playback from mass store) with some processed floating-format data generated by the smart controller and the AOCS controller. Data acquisition/distribution is fully decentralised and extensive use is made of mini-RTUs.

Complex earth-resources or scientific satellites
In this case the OBDH is fully deployed. The CTU, in addition to the smart controller and an AOCS controller, contains a powerful processing module for scientific data reduction and/or payload control. Mass storage is required to compensate for the low coverage from the ground station due to its limited availability and/or the short duration of each pass over the station. Moreover, some decentralised preprocessing of data is performed using the intelligent terminal unit (ITU) and two completely separated data buses (each of them redundant) are used for spacecraft subsystems and payload.

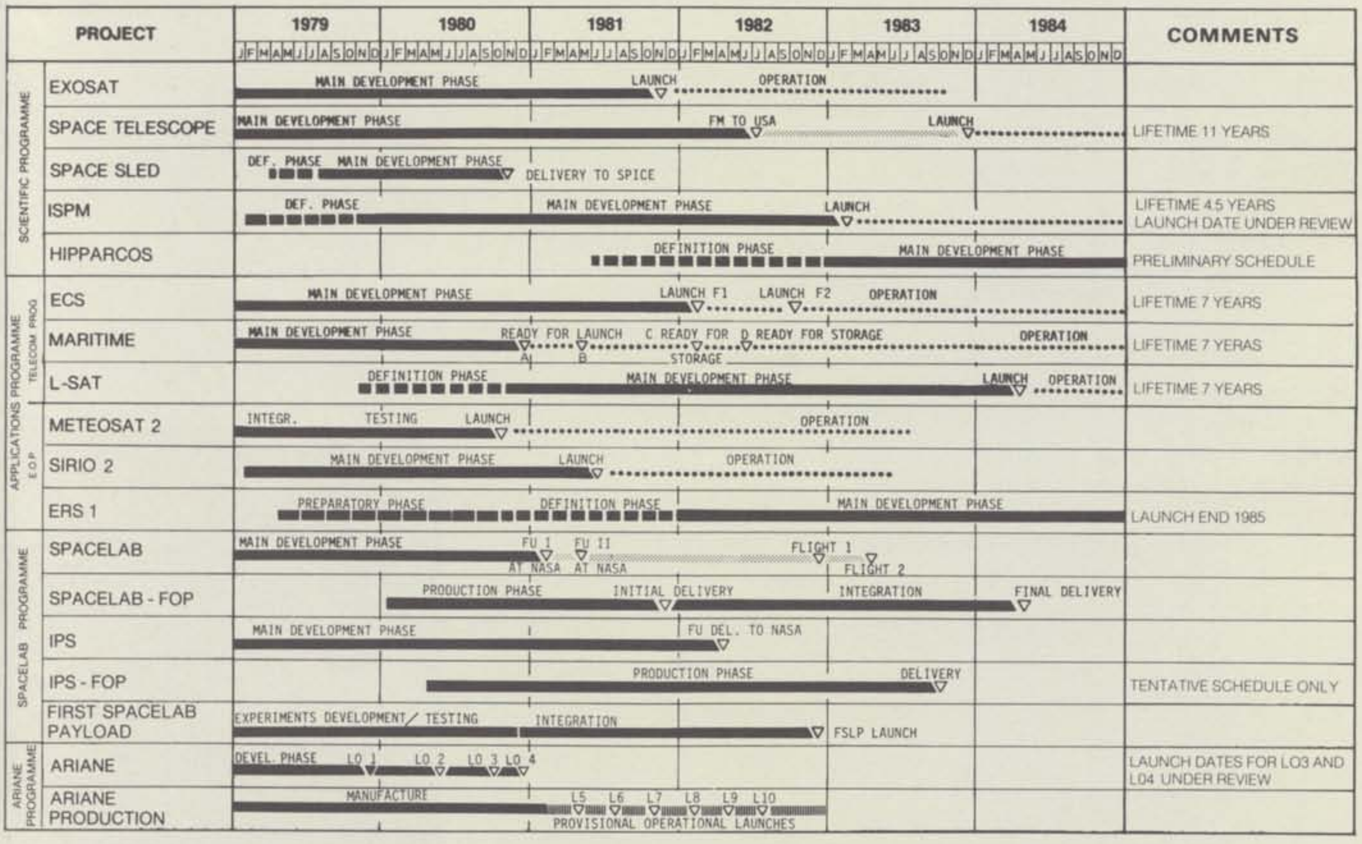
No interaction is possible between RTUs of the payload and those of the spacecraft subsystems. Most of the telemetry contains a playback of processed floating-format data generated by the various processors in the CTU and stored in the mass store.

Programmes under Development and Operations*
Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status as per end February 1980/Bar chart valid per end March 1980.

Bien que le planning ci-dessus soit valide jusqu'à fin mars 1980, la situation des projets décrits dans les pages qui suivent s'arrête à la fin février 1980.

Cos-B

Voilà près de cinq ans que Cos-B est exploité avec succès et continue de fonctionner conformément aux prévisions. L'utilisation des 'consommables' se maintient à un niveau qui autorise la poursuite des opérations au moins jusqu'à fin 1980. Aux termes des arrangements conclus la poursuite de la mission sous la forme d'un projet spécial, il n'y a plus de scientifique représentant les expérimentateurs à l'ESOC. Au contraire, les résultats de l'analyse scientifique des échantillons de données sont imprimés à distance à l'ESTEC afin d'être examinés par le responsable scientifique du projet dans les deux ou trois jours suivant leur acquisition. Cette façon de procéder n'est réalisable que grâce au fonctionnement régulier du matériel embarqué et à l'expérience acquise par le personnel de l'ESOC dans l'exploitation du satellite et le traitement des données.

Ces derniers temps les observations ont été axées sur la recherche de réponses à des questions non élucidées et sur la poursuite de découvertes résultant de l'analyse de données acquises précédemment. Les trois observations suivantes, dernières en date, méritent d'être citées:
- *la région d'Ophiucus, où une source de rayons gamma découverte précédemment a été associée à un complexe nébuleux local (à l'échelle de la Galaxie);*
- *le radio-pulsar PSR 1822-09, dont une étude antérieure a été suivie de mesures radio simultanées effectuées par la division 'Radiophysique' de l'Australian Commonwealth Scientific and Industrial Research Organisation;*
- *la région de Corona Australis, qui a permis l'étude simultanée d'un autre complexe nébuleux et de l'une des deux sources de rayons gamma qui ont été découvertes à des latitudes supérieures à 20° par rapport à l'équateur galactique et qui se prêtent donc très bien à une association avec des objets extragalactiques.*

Pour l'analyse de la masse de données déjà disponibles, l'attention s'est portée sur l'étude d'une éventuelle variabilité à long terme de l'émission gamma provenant de certaines régions du disque galactique. Ce travail exige une étude minutieuse de la variation, en fonction du temps, de la sensibilité de l'expérience et du niveau de la composante de bruit de fond de l'intensité mesurée. On constate pour la première une faible diminution (associée à un affaiblissement graduel du rendement de la formation d'étincelles dans la chambre à étincelles) qui peut être aisément corrigée. Cet effet est contrebalancé par une chute importante du niveau du bruit de fond, due à une modulation plus intense des rayons cosmiques avec l'approche du maximum solaire.

Geos

Geos-1

Lors d'une récente tentative de remise en marche du satellite à des fins scientifiques, on a constaté que la batterie embarquée s'est dégradée au point d'être désormais inutilisable. En outre, la puissance délivrée par le réseau est tombée à une valeur inférieure à 50 W. Il s'ensuit qu'il n'y a plus d'énergie pour assurer le fonctionnement de la charge utile, partant, plus de possibilité d'exécuter une mission scientifique valable. On prévoit de réaliser une dernière expérience technologique puis de stopper les commandes au sol.

Geos-2

Ce satellite poursuit avec succès sa mission avec ses sept expériences toujours en fonctionnement. Le magnétomètre à noyau saturé (S-331) continue de fournir une composante de champ magnétique fiable dans le sens de l'axe de rotation. Cette lecture, combinée aux résultats fournis par le magnétomètre à bobine exploratrice (S-300) et l'expérience de résonance (S-300), permet d'obtenir des données de champ magnétique de bonne qualité.

Entre le début de septembre et la mi-octobre 1979, Geos-2 est resté stationnaire à 37° de longitude Est, où il a été utilisé en soutien d'une campagne de fusées émettrices de baryum effectuée de Kiruna. Le satellite a ensuite été mis à poste à 15° de longitude pour procéder à des observations de l'équateur géomagnétique. Depuis le début de janvier, il est replacé à 37° de longitude Est où il est utilisé en soutien d'une campagne d'observation conduite par un certain nombre de scientifiques français. La durée de vie officielle du satellite s'achève le 30 juin. Il entrera alors dans une période d'hibernation de six mois et sera remis en activité début 1981 pour travailler en liaison avec l'installation EISCAT.

ISEE

La mission continue de se dérouler normalement. En fin 1979, ISEE-2 a effectué une longue série de manoeuvres avec pour triple objectif de réduire les fluctuations de la vitesse de rotation dues à l'action exercée par les longues antennes sur le corps du satellite, d'amener l'axe de rotation du satellite dans le plan de l'écliptique pour l'étalonnage du magnétomètre et de réaligner les orbites d'ISEE-1 et d'ISEE-2 qui tendaient à s'écarter l'une de l'autre. Le système de commande d'orientation et de correction d'orbite (AOCS) a fonctionné correctement et les manoeuvres ont été parfaitement réussies. Il reste à bord suffisamment de gaz pour plusieurs années de manoeuvres de correction d'espacement.

Comme en rendait compte le précédent Bulletin, la première panne totale d'expérience de la mission ISEE-1 s'est produite le 11 septembre 1979 avec la perte de l'alimentation de l'expérience pour les particules de moyenne énergie (Williams, NOAA). On suppose actuellement que cette défaillance est due à un blocage de la plate-forme entraînée par un moteur pas-à-pas. En ce qui concerne ISEE-3, il est maintenant évident que des problèmes de conception se posent pour l'un de ses instruments pour les particules solaires, qui n'est plus en mesure de distinguer des isotopes voisins. Aucune dégradation notable n'est

Le véhicule spatial Geos-2

The Geos-2 spacecraft

Cos-B

Cos-B is now approaching five years of successful operation and continues to perform nominally. Consumption of consumables remains at a level compatible with continued operation at least to the end of 1980. Under the arrangements for continuation cf the mission as a special project there is no longer a scientist representing the experimenters in ESOC. Instead the results of the scientific analysis of samples of the data are printed remotely in ESTEC for examination by the Project Scientist within two or three days of acquisition. This is only practicable because of the consistent performance of the experiment and the accumulated experience of the operations and data-processing staff in ESOC.

Recent observations have been directed towards answering questions and pursuing discoveries that have arisen from the analysis of earlier data. This is demonstrated by the three latest observations:

- the Ophiucus region, where a gamma-ray source discovered in an earlier observation has been associated with a 'local' (on a galactic scale) cloud complex;
- the radio pulsar PSR1822-09, an earlier study of which is being followed up with simultaneous radio measurements by the Radiophysics Division of the Australian Commonwealth Scientific and Industrial Research Organisation;
- the Corona Australis region, which permits a simultaneous study of another cloud complex and of one of the two gamma-ray sources that have been found at latitudes more than 20° from the galactic equator and are therefore strong candidates for association with extragalactic objects.

In the analysis of the extensive data already available attention has been devoted to the investigation of possible long-term variability in the gamma-ray emission from certain regions of the galactic disc. This requires a careful study of the variation of both the sensitivity of the experiment and of the level of the background component of the measured intensity. The former shows a small reduction (associated with a gradual lowering of the efficiency of spark formation in the spark chamber) for which a correction can be easily applied. It is offset by a significant fall in the background level, due to increased modulation of cosmic rays with the approach of the solar maximum.

Geos

Geos-1

During a recent attempt to reactivate this spacecraft for scientific purposes, it was found that the on-board battery has degraded such that it can no longer be used. In addition, the solar-array output power has dropped below 50 W. This means there is no more power for payload operation, and a sensible scientific mission is no longer possible. It is planned to carry out one last technological experiment and then to terminate ground-control actions.

Geos-2

This spacecraft is continuing its successful mission with all seven experiments operational. The fluxgate magnetometer (S-331) still delivers a reliable magnetic-field component in the spin-axis direction. This reading, combined with the output from both the search-coil magnetometer (S-300) and the resonance sounder (S-300), leads to good-quality magnetic-field data.

From early September through mid-October 1979, Geos-2 was stationary at 37°E and supported a barium-release rocket campaign carried out from Kiruna. The spacecraft was then moved to a longitude of 15° to carry out observations at the geomagnetic equator. Since early January, it has been back at 37° and is supporting a ground-observations campaign being conducted by a number of scientists from France. The official life of Geos-2 will end on 30 June and the spacecraft will then enter a six-month hibernation period. It will be reactivated in early 1981 to operate in conjunction with the EISCAT facility.

ISEE

The mission continues to run smoothly. An extensive series of manoeuvres were carried out with ISEE-2 in late 1979 with the three objectives of reducing the spin ripple caused by interaction of the long antennas with the spacecraft body, turning the spin vector into the ecliptic plane for magnetometer calibration, and aligning the orbits of ISEE-1 and ISEE-2, which were drifting apart. The attitude and orbit control system (AOCS) operated nominally and the manoeuvres were entirely successful. Enough gas remains for several more years of separation adjustments.

As reported in the last Bulletin, the first complete experiment failure of the mission occurred on 11 September, when the medium-energy particle experiment of Williams (NOAA) lost its power supply. It is now suspected that the stepping platform jammed. It is now evident also that one solar-particle instrument on ISEE-3 has design problems and is not able to resolve adjacent isotopes. There has been no noticeable degradation on ISEE-2 since the last report.

After the initial consolidation period, significant physics is now flowing from the mission. Forty-five per cent of the publications rely crucially on the binocular vision of ISEE-1 and 2.

A ten-month extension of ISEE-2 operations has been requested from ESA.

IUE

The three agencies involved in the IUE project have received 424 proposals for observing programmes for IUE's third year of observations; 171 of these were directed to ESA, calling for four times more observing time than was actually available. The selection committee, finding many of these proposals to be excellent, accepted 121, but were forced to cut greatly the time available to each proposer. Scheduling for the third year is now under way.

At a three-agency meeting in Villafranca in November, the following agreements were made:

- A power-management programme was agreed to prolong the lifetimes of the batteries as far as is consistent with a minimum risk to current observations
- Improvements to the operational and image-processing software would continue, to enhance the value of IUE
- Procedures to correct an error in the intensity calibration of the short-wave camera were agreed. A correction algorithm developed by ESA at Villafranca for low dispersion will be published and high-dispersion images will be reprocessed at the

signalée au sujet d'ISEE-2 depuis le dernier rapport.

Après la période de mise en place initiale, la mission fournit maintenant de façon continue des données d'un contenu physique appréciable. Quarante-cinq pour cent des publications tablent de façon critique sur la vision binoculaire assurée par ISEE-1 et 2.

Il a été demandé à l'ESA de prolonger les opérations d'ISEE-2 pour une période de dix mois.

IUE

Les trois organismes participant au projet IUE ont reçu 424 propositions de programmes d'observations pour la troisième année, dont 171 adressées à l'ESA, représentant 4 fois le temps d'observation à sa disposition. Le comité de sélection, jugeant un grand nombre de ces propositions excellentes, en a accepté 121, mais a été contraint de réduire sévèrement le temps attribué à chacune d'elles. La programmation pour la troisième année est maintenant engagée.

Au cours d'une réunion des trois organismes qui s'est tenue à Villafranca en novembre, des accords sont intervenus sur les points suivants:

- *Un programme de gestion de l'énergie destiné à prolonger les durées de vie des batteries dans toute la mesure compatible avec un minimum de risque pour les observations en cours a été établi.*
- *Des perfectionnements du logiciel opérationnel et du logiciel de traitement image continueront de renforcer l'intérêt de ce satellite.*
- *On a adopté des mesures destinées à corriger une erreur d'étalonnage en intensité de la chambre de prise de vues ondes courtes. Un algorithme correcteur, mis au point par l'ESA à Villafranca pour obtenir une faible dispersion, sera publié et les images présentant une importante dispersion seront soumises à un nouveau traitement dans les stations sol.*
- *La publication des images incorrectement traitées du fait de ce problème sera suspendue pendant six mois après la rectification des données ou la publication de l'algorithme correcteur, de façon à protéger les droits des observateurs initiaux.*

Une équipe d'observateurs britanniques a déjà utilisé ses données IUE pour démontrer l'existence d'un disque de gaz chaud à partir duquel une accrétion se produit sur la nova naine UW Hydri, ce qui coïncide parfaitement avec la théorie selon laquelle le flux devrait varier en fonction de la racine cubique de la fréquence. Cette preuve d'un 'disque d'accrétion' est importante du fait qu'il se produit vraisemblablement des phénomènes similaires dans les quasars et les sources de rayons X.

Ainsi que le signale un autre article du présent Bulletin (voir page 74), des observations de la comète brillante de Bradfield ont été effectuées en janvier, en collaboration avec des observateurs britanniques et américains; elles ont à nouveau démontré l'aptitude unique d'IUE à réagir rapidement à des événements astronomiques imprévus.

OTS

OTS continue de fonctionner normalement et tous ses systèmes sont en bon état.

Le satellite est utilisé de façon intensive. L'Administration française des PTT a demandé à prolonger d'un an, jusqu'en juin 1981, ses expériences de transmission de la télévision avec la Tunisie, et elle souhaite utiliser le canal 2 pour des expériences entre Pleumeur-Bodou et Gomez en préparation de Télécom-1. L'Administration irlandaise a également demandé à pouvoir réaliser avec le satellite une expérience de transmission entre le sol irlandais et des plates-formes pétrolières en mer. L'Administration française des PTT a 'd'autre part' sollicité l'autorisation de transmettre les Jeux olympiques par le satellite et d'entamer une expérience de transmission de données entre l'URSS et la France. Toutes ces propositions sont actuellement examinées par le Conseil d'ECS.

A la suite de l'ouverture du terminal STELLA au CERN le 6 mars, les préparatifs sont en cours pour la démonstration de transmission de données entre Genève et le Royaume-Uni. (voir page 73).

Exosat

Satellite

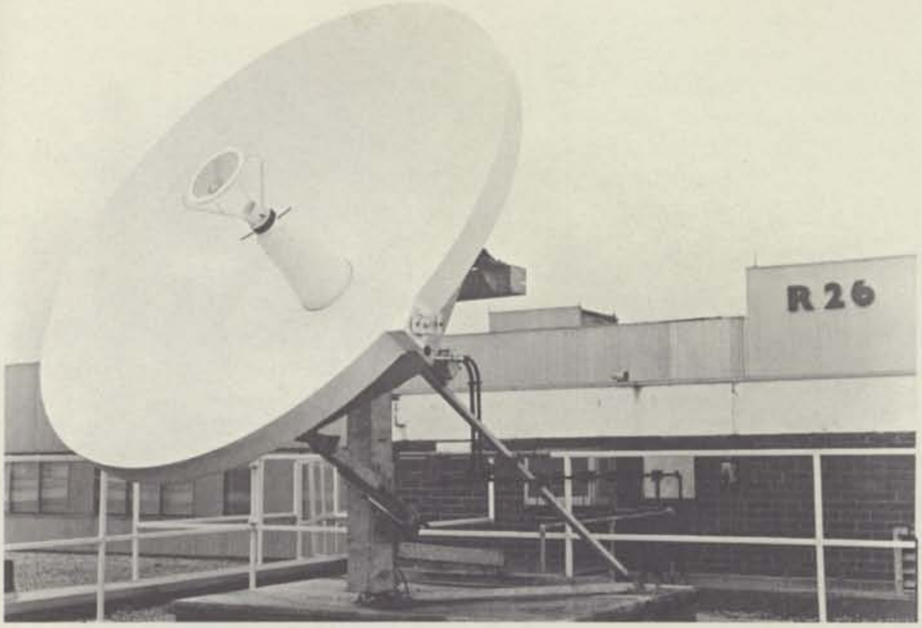
Au cours du dernier trimestre de 1979, le programme du modèle d'identification a progressé dans l'ensemble conformément aux plans du niveau système, avec l'exécution de contrôles destinés à vérifier les interfaces mécaniques, électriques et de transmission de signaux, ainsi que d'essais fonctionnels effectués à l'aide du logiciel de vérification et du logiciel des opérations orbitales (OBC). L'élaboration et la mise en service du logiciel ont progressé de façon notable et les essais intégrés des sous-systèmes ont été exécutés dans leur presque totalité sur tous les éléments du système, sauf en ce qui concerne le sous-système de commande d'orientation et de correction d'orbite (AOCS) et les interfaces connexes.

En dépit d'un effort accru sur l'AOCS, les unités restantes — l'électronique de commande d'orientation et de correction d'orbite et l'ensemble gyroscopique — ne sont toujours pas disponibles chez le contractant principal pour l'intégration au niveau système. L'absence de ces éléments a obligé à revoir le programme du modèle d'identification en décembre 1979, avec pour résultat l'approbation d'une séquence modifiée dont les points les plus marquants sont l'avancement de certains essais 'système' du modèle d'identification (mesures physiques, essais d'antenne, activités initiales d'alignement). Ces essais sont maintenant achevés, l'évaluation des données est en cours et une expérience précieuse a été acquise dont parti pourra être tiré pour le modèle de vol. La suite du déroulement de la séquence de référence des activités relatives au modèle d'identification est entièrement subordonnée à la disponibilité des unités AOCS pour l'intégration au niveau système.

Parallèlement aux activités du niveau système concernant le modèle d'identification, l'achèvement de la plupart des examens conceptuels des sous-systèmes a permis de donner le feu vert à la fabrication des unités correspondantes de réserve et de vol.

Charge utile

Exception faite pour les détecteurs de l'expérience moyenne énergie, les travaux relatifs au modèle d'identification sont



3m antenna of the terminal that will serve the SRC Rutherford and Appleton Laboratories (UK) during the OTS STELLA experiment.

L'antenne de 3 m du terminal qui desservira les laboratoires Rutherford et Appleton du Conseil de la Recherche scientifique (R-U) pendant le déroulement de l'expérience STELLA.

ground stations
- Images incorrectly processed due to this problem would be withdrawn from release until six months after correction of the data or publication of the algorithm to protect the rights of the original observers.

A team of British observers has already used their IUE data to demonstrate the the existence of a hot disc of gas being accreted on to the dwarf nova VW Hydri, finding excellent agreement with the theoretical prediction that the flux should vary with the cube root of the frequency. This demonstration of an 'accretion disc' is important because of the probable presence of similar phenomena in quasars and X-ray sources.

As noted elsewhere in this Bulletin (see page 74), observations of the bright comet Bradfield were made in January in collaboration with British and US observers, again demonstrating IUE's unique ability to respond quickly to unexpected astronomical events.

OTS

OTS continues to operate nominally, with all systems in good working order.

The satellite is being used intensively. The French PTT has applied for a one-year extension to the TV transmission experiments to Tunisia, until June 1981, and for the use of Channel-2 for experiments between Pleumeur-Bodou and Gometz to prepare for Telecom-I.

Also the Irish administration has applied for time for a transmission experiment between the Irish mainland and offshore oil platforms. The French PTT has also requested permission to transmit coverage of the Olympic games and to commence a data-transmission experiment between Russia and France. All these proposals are being discussed by the ECS Council.

Preparations are in hand for the data-transmission demonstration between Geneva and the United Kingdom following the opening of the STELLA terminal at CERN on 6 March (see page 73).

Exosat

Satellite

During the last quarter of 1979, the engineering-model programme progressed roughly in accordance with system-level plans, covering verification checks on mechanical, electrical and signal-line interfaces and functional tests utilising the checkout and orbital-operations (OBC) software. Significant progress has been achieved in the development and commissioning of software, and integrated subsystem tests have been performed and almost completed on all system elements except for the attitude and orbit control subsystem (AOCS) and associated interfaces.

In spite of increased efforts on the AOCS, the attitude and orbital control electronics and gyro package are not yet available at the prime contractor's premises for system integration. As a result, an assessment of the engineering-model programme made in December 1979 resulted in an agreed modified integration sequence, the salient feature of which is the advancement of some engineering-model system tests (physical measurements, antenna tests, initial alignment activities). These tests have now been completed, data evaluation is in progress, and some valuable experience has been obtained for application to the flight model. Further progress in the engineering-model baseline activity sequence is wholly dependent on the availability of AOCS units for system integration.

In parallel with engineering-model system-level activities, the completion of most subsystem design reviews has resulted in a go-ahead for the relevant spare/flight-model unit production.

Payload

With the exception of the medium-energy detectors, engineering-model activities at the various unit contractors have been concluded and engineering-model results reviews conducted, leading to full or partial go-ahead for flight-model production. Owing to the delays in the engineering-model system integration and test sequence, and the lack of system-level electromagnetic compatibility/interference results, certain risks have had to be taken in giving the go-ahead for flight-model electronics manufacture. The schedule for supply of the flight-model and flight-spare experiment units is tight, with a minimum of contingency, due to the problems experienced earlier during production/testing of the experiment detectors.

Launcher (Ariane + fourth stage)

Results from the first Ariane development flight have confirmed most performance/environmental parameters to be as expected, but problems relating to contamination caused by retro- and spin-up rockets and verification of the performance margin of the fourth-stage *terminés chez les contractants chargés des différentes unités et les résultats obtenus sur le modèle d'identification ont été examinés, après quoi les feux verts ont été donnés, intégralement ou partiellement, pour la réalisation du modèle de vol. Etant donné les retards intervenus dans la séquence d'intégration et d'essais du modèle d'identification au niveau système, avec les incidences correspondantes sur la chronologie et le volume des informations obtenues, et l'absence de résultats d'essais de compatibilité et d'interférence électromagnétiques au niveau système, certains risques ont dû être pris lorsque l'on a donné le feu vert pour le démarrage de la fabrication de l'électronique de vol. Le calendrier d'approvisionnement des unités du modèle de vol et de réserve est serré, et ne comporte qu'une marge minimale du fait de problèmes rencontrés au cours de la fabrication et des essais des détecteurs des expériences.*

Lanceur (Ariane + 4ème étage)

Les résultats du premier tir de développement d'Ariane ont confirmé la plupart des données relatives aux performances et à l'environnement, mais des problèmes de contamination par les rétrofusées et les fusées de mise en rotation, ainsi que la vérification de la marge de performance de l'amortisseur actif de nutation du 4ème étage, font l'objet d'une étude active.

Les moyens nécessaires aux opérations du satellite sur l'aire de lancement du Centre spatial guyanais (CSG) et le calendrier des opérations de lancement d'Exosat ont été récemment examinés à Kourou avec les autorités responsables du lanceur.

Activités ESOC

Les préparatifs concernant la documentation opérationnelle et le logiciel connexe avancent à l'ESOC de façon à peu conforme au calendrier.

L'adaptation des matériels du système sol progresse de façon satisfaisante, mais le calendrier d'approvisionnement de l'antenne reste serré.

Télescope spatial

Réseau solaire

La revue de conception préliminaire supplémentaire a été menée à bonne fin. Elle avait pour objet de vérifier certains sous-systèmes pour lesquels des conceptions d'interface avaient été définies tardivement, de telle sorte que leur examen avait dû être ajourné au moment de la revue principale. Le document de contrôle des interfaces, décrivant en détail les interfaces entre le réseau solaire et le Télescope, est parvenu à un degré d'avancement suffisant pour recevoir le feu vert de toutes les parties et être transmis au contrôle de configuration officiel de la NASA. Le contrat du réseau solaire a été signé.

Des essais ont été menés au Marshall Space Flight Center dans la piscine du simulateur d'apesanteur afin de s'assurer que la conception des interfaces équipage/système est correcte. Ces essais ont montré que la conception du réseau solaire permet son remplacement en orbite. Les essais de développement se sont poursuivis pendant toute cette période et ont abouti à l'adoption de quelques modifications de conception, notamment en ce qui concerne la lubrification des moteurs et mécanismes commandant le système à deux bras de déploiement et de rétractation.

Module de la chambre de prise de vues pour astres faibles

Le programme d'essais du modèle thermique de la structure a débuté avec les essais en vibration du banc optique. Au cours de l'étuvage, quelques mesures préliminaires avaient été effectuées pour déterminer également la stabilité du banc optique. La structure porteuse a été livrée afin de poursuivre l'intégration du modèle thermique de la structure complète de la chambre. On est en train de revoir le programme de livraison de la chambre à la NASA, suite à la reformulation par cette dernière des détails du programme d'assemblage et de vérification des instruments scientifiques au Goddard Space Flight Center. De même, les détails des interfaces de commande et de télémesure sont réétudiés dans le cadre du réexamen par la NASA des impératifs détaillés et des coûts associés au secteur sol du Télescope. Un élément optique supplémentaire a été introduit dans la chambre, permettant de tripler le grossissement de l'image sur une partie du champ de visée, afin de renforcer la résolution sur la bande UV du spectre.

Détecteur de photons

Un examen de conception intermédiaire s'est achevé en janvier. Dans l'ensemble positif, cet examen a fait ressortir la nécessité d'apporter certaines améliorations de conception dans une partie de l'électronique du détecteur de photons. Il en est également ressorti qu'un effort supplémentaire devrait être apporté à l'essai du détecteur de photons en raison de décharges corona. Plusieurs détaillances se sont produites au cours du programme d'essai sous vide des éléments du modèle d'identification, des décharges corona étant observées dans la partie intensificateur, la section chambre et les connecteurs haute tension.

Les modèles thermiques et de structure ont été livrés au contractant de la FOC, mais il faudra encore apporter des modifications de conception aux pieds qui raccordent la tête de détection au banc optique.

Activités NASA

Le programme de la NASA se poursuit conformément au calendrier. Le Télescope spatial vient d'être affecté au lancement No. 25 de la Navette, fixé au 14 décembre 1983. La NASA a nommé le Dr P. Speer nouveau Chef de projet du Télescope spatial pour la NASA à la suite de l'affectation de M. W. Keathley à la direction de la Gestion des projets du Goddard Space Flight Center.

Traîneau spatial

Les examens des matériels au niveau sous-système ont tous été menés à bonne fin en janvier. Seuls quelques points mineurs ont été relevés et les mesures correctrices appropriées, sans incidence sur le programme, ont été convenues. La fabrication des pièces des sous-systèmes est bien avancée et le montage des sous-ensembles a commencé.

Le calendrier de l'ensemble du programme a été examiné avec les contractants chargés des sous-systèmes de façon à réduire au minimum les retards qui proviennent pour l'essentiel d'anciens problèmes d'approvisionnement et de difficultés rencontrées pour régler certains détails de la conception définitive. On a pu limiter les retards des sous-systèmes à quelques semaines sans pour autant prolonger la durée totale du programme, et ceci grâce d'une part à un remaniement du planning et d'autre part au fait que les active nutation damper are being actively assessed.

Resources needed for satellite operations at the Guiana Space Centre (CSG) and the Exosat launch operations schedule have recently been reviewed at Kourou with the launcher authorities.

ESOC activities

Preparations at ESOC in terms of operational documentation and associated software are reasonably on schedule. Adaptation of ground-system hardware is progressing well, though the antenna procurement schedule remains tight.

Space Telescope

Solar array

The secondary Preliminary Design Review – held to review some subsystems on which late interface designs were introduced, and which could not therefore be reviewed at the main PAR – was completed successfully. The Interface Control Document which describes all details of the interfaces between the solar array and Space Telescope has been completed to the extent that it could be signed-off by all parties and put under formal configuration control by NASA. The solar-array contract was also signed.

Verification tests have been carried out at Marshall Space Flight Centre in a neutral-buoyancy water tank, to ascertain the correct design for the solar-array crew systems. The tests confirmed that the solar array's design allows its in-orbit replacement. Development tests have continued throughout the period, leading to some design modifications being introduced, for example in the lubrication of the motors and gear for the bi-stem deployment/retraction operation.

Faint Object-Camera (FOC) module

The structural thermal model test programme has started with vibration tests on the optical bench. During bake-out, some preliminary measurements were also made of optical-bench stability. The load-carrying structure has been delivered, allowing integration of the overall FOC structural thermal model to be continued.

The delivery programme for the FOC to NASA is under review, in connection with NASA's re-statement on the details of the verification and assembly programme for the scientific instruments at Goddard Space Flight Centre. Similarly, the details of the telemetry and control interfaces are being re-analysed in the light of NASA's restatement of the details of the requirements and associated costs for the Space Telescope ground segment. An additional optical element has been introduced into the FOC, allowing an additional factor three of image magnification over part of the field of view, to enhance resolution in the ultraviolet part of the spectrum.

Photon Detector Assembly (PDA)

An intermediate design review was completed by January. In general successful, the review demonstrated the need for some design improvements in some of the PDA electronics. Also, it became clear that additional efforts will have to be made in testing the PDA for corona discharge performance. Several failures have occurred during the engineering-model-unit test programme in vacuum, where corona discharges were observed in the intensifier section, the camera section and at high-voltage connectors.

The structural thermal models have been delivered to the FOC contractor, but some redesign of the feet that mount the detector head unit to the optical bench will still have to be carried out.

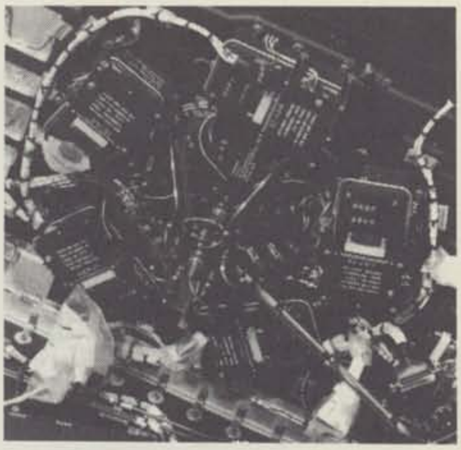
NASA

The NASA programme is continuing on schedule. The Space Telescope has now been assigned Shuttle launch no. 25 on 14 December 1983. NASA has nominated Dr. F. Speer as the new NASA Space Telescope Project Manager, after Mr. W. Keathley's nomination as Director for Project Management at Goddard Space Flight Centre.

Sled

Project Hardware Reviews for all subsystems were successfully completed during January. Only a few minor discrepancies were found and appropriate corrective actions were agreed without impact on the programme. Subsystem component manufacture is well advanced, and subassembly build-up has begun.

The overall programme schedule has been reviewed with subsystem contractors with a view to minimising delays resulting mainly from past procurement problems and difficulties in clearing some final design details. It has been possible to limit subsystem delays to several weeks and to avoid extending the total length of the programme. That this could be done has been due mainly to re-planning, and to contractor agreement to allocate additional manpower to identified schedule drivers.



Marecs spacecraft transistor power amplifier for L- band transmissions to maritime traffic.

Amplificateur de puissance à transistors destiné aux transmissions en bande L du satellite Marecs aux navires.

The Spacelab Programme Board recently decided to transfer the Sled from the First Spacelab Payload (FSLP) to a later flight in order to bring the total FSLP mass within the earlier agreed limit. The Sled experiments will remain part of FSLP to perform static and dynamic experiments, albeit with reduced scientific yield. Development of the Sled Facility continues in anticipation of the later flight which is currently being identified by the Agency.

ECS

The Critical Review activity came to a close in February, with the completion of system and subsystem reviews.

A study of possibilities for extending the eclipse capability of the ECS series of satellites, in combination with enhanced orbit inclination control, has been completed at the request of EUTELSAT. The proposed options are presently being reviewed by EUTELSAT. Steps are also being taken to explore the applicability of ECS for specialised small-terminal services.

contractants ont accepté d'affecter des effectifs supplémentaires aux secteurs identifiés comme pouvant peser sur le calendrier.

Le Conseil directeur du programme Spacelab a récemment décidé de reporter l'embarquement du Traîneau sur un vol ultérieur du Laboratoire spatial afin de conserver la capacité d'emport totale de la Première charge utile (FSLP) dans les limites approuvées. Toutefois les expériences du Traîneau demeurent partie intégrante de la FSLP en vue des mesures statiques et dynamiques, quoiqu' avec une portée scientifique réduite. Le développement du corps du Traîneau lui-même se poursuit en prévision d'un vol ultérieur que l'Agence est en train d'étudier.

ECS

L'examen critique de la conception est arrivé à son terme en février, après achèvement des examens relatifs aux sous-systèmes et systèmes intéressés.

Une étude a été faite, à la demande d'EUTELSAT, sur la possibilité d'accroître les capacités de fonctionnement des satellites ECS en période d'éclipse, en liaison avec un contrôle renforcé de l'inclinaison de l'orbite. Les options proposées sont actuellement examinées par EUTELSAT. On s'emploie également à déterminer les possibilités d'utilisation d'ECS pour des services spécialisés mettant en oeuvre de petits terminaux.

Un contractant a été choisi pour la station d'essais et de surveillance de la charge utile, et la réalisation de cet élément majeur du secteur sol d'ECS doit commencer vers la fin mars de cette année pour s'achever fin 1981.

Marecs

L'intégration de Marecs-A se poursuit simultanément chez BAe à Stevenage, en ce qui concerne le module 'plate-forme', et chez MSDS à Portsmouth, en ce qui concerne le module 'charge utile'.

Les deux modules seront assemblés fin avril et le véhicule spatial complet sera prêt à subir les essais fonctionnels et de performances électriques en mai. Les essais d'ambiance suivront ensuite, en

vue d'un lancement par Ariane L04 en décembre.

L'intégration du véhicule spatial Marecs-B commencera à l'automne. La fabrication des éléments de Marecs-C avance de façon satisfaisante.

A la suite de l'appel d'offres lancé en mars par l'organisation INMARSAT, l'ESA prépare une offre de 'leasing' de satellites Marecs pour assurer les services de communications maritimes demandés, ainsi que d'exploitation TTC de ces satellites à partir de stations sol situées à Villafranca (Espagne) et en un point de l'Océan Pacifique.

L-Sat

L'exécution du contrat relatif à la phase B1 de définition du projet a commencé le 17 décembre 1979, par la première partie de cette phase consacrée aux études de compromis du niveau système. Ces études, exécutées par British Aerospace et une équipe industrielle intégrée composée de représentants des pays participants, seront en principe achevées fin mars 1980 et seront suivies par les études de compromis du niveau sous-système et les activités relatives à la configuration 'système'.

La définition de quatre éléments de charge utile candidats et de leur utilisation potentielle se poursuit en parallèle, les travaux étant principalement axés dans chaque cas sur les options d'antennes et de répéteurs. Vers les mois d'avril-mai, des décisions seront prises sur la charge utile composite à élaborer au cours de la phase B2.

La demande de prix relative à la phase B2 de définition du projet, qui doit commencer dès l'achèvement de la phase B1 en juin, a été lancée le 7 mars pour une soumission début mai.

L'Autriche s'est récemment jointe au Canada pour demander à adhérer au programme, et des décisions seront arrêtées très prochainement pour l'un et l'autre cas. Les sept pays participant déjà au programme sont la Belgique, le Danemark, l'Italie, les Pays-Bas, l'Espagne, la Suisse et le Royaume-Uni.

Parallèlement aux activités relatives à la définition du premier modèle de vol, à sa mission et à son utilisation, les travaux se poursuivent sur l'étude du marché, la définition générale et la promotion des dérivés de L-Sat.

Météosat

Secteur spatial

A part sa mission de collecte des données qu'il continue d'accomplir, Météosat-1 est toujours hors d'état de fonctionner malgré les nombreuses tentatives faites pour le remettre en service. On essaie de tirer parti de la période d'éclipses du printemps pour provoquer des stimulations énergétiques et thermiques, mais ces tentatives n'ont jusqu'à présent (7 mars) donné aucun résultat.

Météosat-2 a terminé ses essais de recette et va maintenant être légèrement modifié à la suite de la défaillance de Météosat-1.

Le contrat relatif à l'amortisseur de vibrations a été annulé étant donné les bons résultats obtenus sur le premier vol d'Ariane.

Exploitation

Depuis la défaillance de Météosat-1, les opérations accomplies pour le compte des utilisateurs se sont limitées au soutien du système de collecte des données. Les travaux se poursuivent en vue d'affiner l'ensemble du système (y compris l'archivage) et de préparer Météosat-2. Bien qu'aucune nouvelle image n'ait été prise, le service de données continue d'alimenter les utilisateurs en images et autres informations.

A contractor for the Payload Test and Monitoring Stations has been selected and the development of this major part of the ECS ground segment was due to begin towards the end of March, for completion by the end of 1981.

Marecs

Marecs-A integration is proceeding in parallel at British Aerospace (BAe) Stevenage for the platform module and at Marconi Space and Defence Systems (MSDS) Portsmouth for the payload module.

The two modules were to be mated at the end of April and the complete spacecraft will be ready for electrical performance and functional testing in May. Environmental tests will then follow and these are geared to a launch in December 1980 on the fourth Ariane development flight (L04).

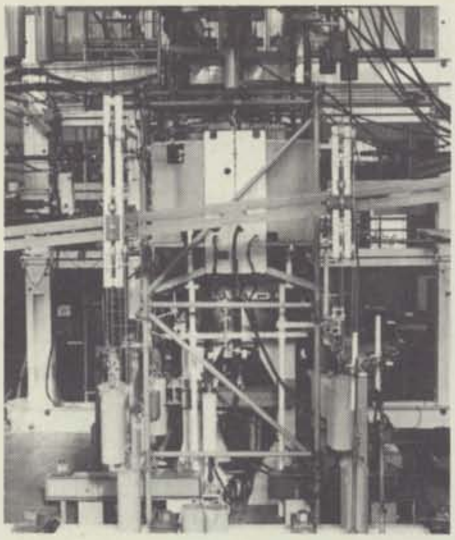
Marecs-B spacecraft integration will start this autumn and Marecs-C unit manufacture is progressing satisfactorily.

Following a Request for Quotation (RFQ) issued by the INMARSAT organisation in March, ESA is preparing an offer for the lease of Marecs satellites to provide maritime communications services, together with the provision of telemetry and telecommand operations (TTC) for these satellites from ground stations at Villafranca (Spain) and another site in the Pacific Ocean area.

L-Sat

The contract for Phase B1 of L-Sat project definition started on 17 December 1979, the first part of this phase being devoted to system-trade-off studies. These studies, being performed by British Aerospace (BAe) and an industrial team drawn from the countries participating in the project, are expected to be completed by the end of March 1980 and will be followed by the subsystem trade-off studies and system-configuration activities.

Definition of four candidate payload elements and their potential utilisation is proceeding in parallel, with work concentrated on the antenna and repeater options in each case. In April/May 1980, decisions will be reached on the composite payload to be elaborated during Phase-B2.



ECS spacecraft undergoing structural testing at Aeritalia (Turin).

Le véhicule spatial ECS au cours des essais de structure chez Aeritalia (Turin).

The Request for Quotation (RFQ) for Phase-B2 of the project definition, which is planned to follow completion of Phase-B1 in June 1980, was issued on 7 March, with a proposal due in early May.

Austria has recently joined Canada in requesting to join the programme, and decisions on both cases will be taken very shortly. The seven countries already participating in the L-Sat programme are Belgium, Denmark, Italy, Netherlands, Spain, Switzerland and the United Kingdom.

In parallel with the activities related to the definition of the L-Sat first flight model and its mission and utilisation work is proceeding on the outline definition of, investigation of the market for, and promotion of L-Sat derivatives.

Meteosat

Space segment

Meteosat-1 is still out of commission, except for the data collection mission, in spite of many attempts to recover it. Advantage is being taken of the spring eclipse season to provoke power and thermal variations but these have so far (7 March) had no effect.

Meteosat-2 has completed its acceptance tests and it will now be slightly modified as a result of the Meteosat-1 failure.

The contract for the vibration isolator device has been cancelled because of the good vibration results observed on the first Ariane flight.

Exploitation

Since the Meteosat-1 problem manifested itself, the operations for the users have been reduced to supporting the data-collection system. Work continues on the refinement of the total system (including archiving) as well as on preparations for the Meteosat-2 mission. Although there have been no new images, the data service continues to provide users with images and other information.

Operational Meteosat programme

An outline proposal for a five-satellite operational Meteosat programme to cover the period 1984–1994 has been submitted to the European Meteorological Agencies. The Cosmos offer for the space-segment part of this programme is presently under review. An outside company has recently finished an independent review of the present and proposed ground segment. A complete offer for the overall Meteosat space/ground system will be sent to potential users later this year.

Sirio

In February the mechanical model of the satellite passed its vibration tests at qualification levels. The Intermediate Design Review which is scheduled for April 1980 is expected to provide the go-ahead for the assembly of the integration model.

The preparations for the exploitation phase have made significant progress by virtue of:

- the positive vote by the Meteorological Satellite Programme Board on a resolution enabling procurement of the critical elements for this phase
- the offer by the Italian Delegation to pre-finance these preparatory activities, the major part of which will be contracted to Telespazio
- the setting up of the LASSO Working Group (LWG) to advise the Executive on all aspects of the LASSO experiment, and
- the successful Intermediate Design Review of the prototype users' station for the meteorological data dissemination (MDD) mission.

Programme Météosat opérationnel

Les grandes lignes d'une proposition portant sur un programme Météosat opérationnel à cinq satellites pour la période 1984-1994 ont été soumises aux organes météorologiques européens. L'offre COSMOS concernant le secteur spatial de ce programme est actuellement à l'examen. Une firme extérieure a été chargée de procéder à une étude indépendante du secteur sol actuel et de celui qui est proposé; ce travail vient de s'achever. Une offre complète pour l'ensemble des secteurs spatial et sol composant le système Météosat sera envoyée plus tard dans l'année aux utilisateurs potentiels.

Sirio

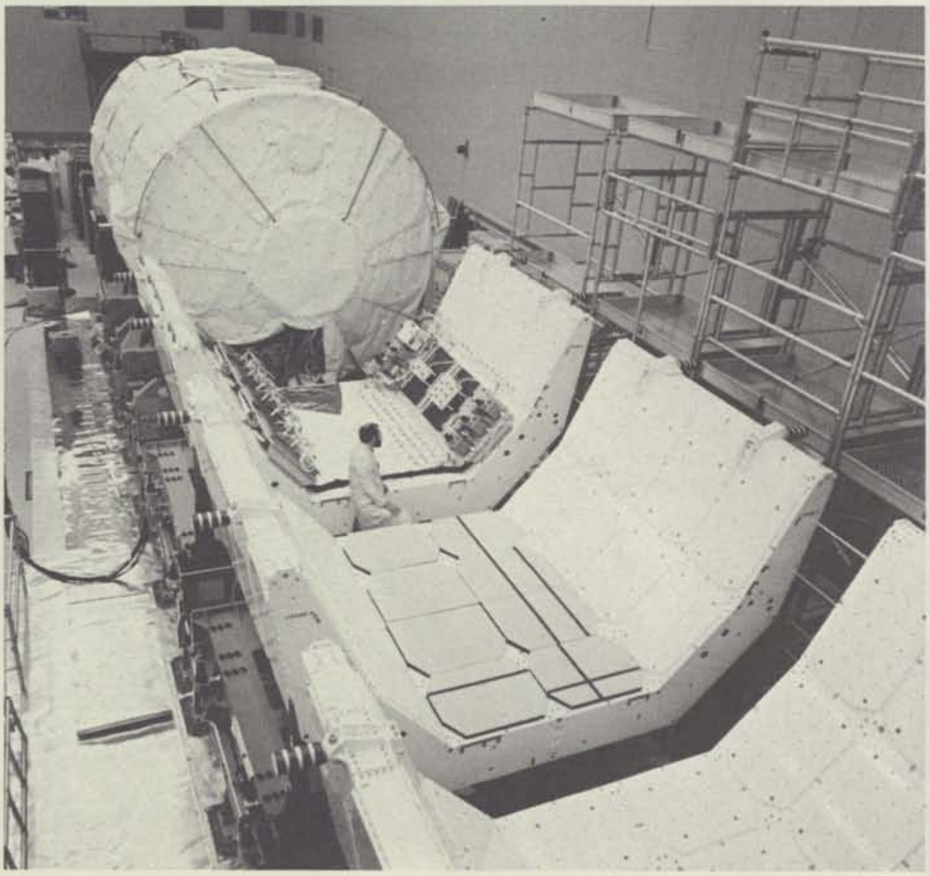
En février, le modèle mécanique du satellite a passé les essais de vibration au niveau de la qualification. La revue intermédiaire de la conception est prévue pour avril et l'on espère qu'elle permettra de donner le 'feu vert' pour l'assemblage du modèle d'intégration.

Les préparatifs en vue de la phase d'exploitation ont considérablement progressé à la suite:

- *du vote positif par le Conseil directeur du programme météorologique d'une résolution autorisant l'approvisionnement des éléments critiques pour cette phase d'exploitation;*
- *de l'offre faite par la Délégation de l'Italie de préfinancer ces activités préparatoires dont la majeure partie sera confiés par contrat à Telespazio;*
- *de la constitution du Groupe de travail LASSO chargé de conseiller l'Exécutif sur tous les aspects de l'expérience LASSO;*
- *des conclusions satisfaisantes de la Revue intermédiaire de la conception concernant les prototypes de stations d'utilisateurs pour la mission de diffusion des données météorologiques (MDD).*

L'armoire à rangement double destinée aux expériences en science des matériaux à bord de Spacelab.

Double rack for material-sciences experiments on Spacelab



Spacelab en configuration module long + 3 porte-instruments. Le premier laboratoire spatial comprendra un module long + un porte-instruments.

Spacelab long-module and three pallets. The first Spacelab flown will consist of the long module plus one pallet.

Télédétection

Dans le cadre du programme préparatoire de télédétection, plus de la moitié des activités identifiées début 1979 a été maintenant confiée à l'industrie et 75% des appels d'offres ont été émis.

Le Canada a demandé officiellement de participer au Programme préparatoire. Cette demande, acceptée par les délégations au Conseil directeur du programme, sera soumise pour approbation au Conseil de l'Agence. La participation financière du Canada est de l'ordre de 1,7 million de dollars canadiens.

Les études sur le système et les charges utiles de télédétection progressent conformément au calendrier établi: en particulier, les études de définition

- *de l'instrument de prises de vues optiques pour le système d'applications terrestres (LASS) et*
- *du radiomètre hyperfréquence (IMR) du système de surveillance des océans dans les zones côtières (COMSS)*

Remote Sensing

In connection with the Preparatory Remote-Sensing Programme (PRSP), more than half of the activities identified in early 1979 have now been placed with industry and 75% of the calls for tender have been put out.

Canada has officially asked to participate in the Preparatory Programme. This request has been accepted by the delegates to the Remote-Sensing Programme Board and will be submitted for approval to the ESA Council. Canada's financial participation will be about 1.7 million Canadian dollars.

The system and remote-sensing-payload studies are going ahead on schedule, notably the definition studies for the:
- optical image-taking instrument for LASS (Land Applications Satellite System)
- microwave radiometer (IMR) for the COMSS (Coastal Ocean Monitoring Satellite System),

have been placed with industrial groups led by Matra and British Aerospace, respectively.

Following discussions within the Agency and after consulting the German authorities, a new orientation to the programme has been proposed to the Board, in the light of the very limited possibility of carrying a synthetic-aperture radar on the first satellite in late 1985. Delegates' reactions are currently being considered in preparing a programme proposal to achieve the best possible compromise between the various factors involved, i.e. mission, costs, planning, availability of instruments.

Spacelab

First Spacelab Payload (FSLP)

A further delay in the launch of the first Spacelab mission is now expected. At the meeting in February between the NASA Administrator and the ESA Director General, it transpired that the most likely date is now December 1982.

For FSLP, the principle remains that the most cost-effective way forward is to still complete the European integration at the earliest possible moment. The requested delivery dates for the scientific instruments will therefore not be changed (November 1980 to February 1981).

Phase I of the integration and test contract commenced at ERNO in mid-November. This phase covers preparations for the physical integration, and provides for a full definition of the integration and test methods, plus the provision of facilities at Bremen for the development of the flight applications software. The contract runs until May 1980, with a review of the implementation plans in April.

A Programme Review was held in conjunction with NASA in November at ESA/SPICE. It was observed that progress has been good, except for the weight situation, where NASA formally requested that the European portion of the payload be reduced to the original allocation of 1392 kg. Together with the formal request NASA indicated that it would guarantee to ESA, at terms equivalent to those in effect for FSLP, a later flight of those experiments that could be selected for descoping before 31 March 1980.

Spacelab acceptance

Approximately 95% of the flight-unit hardware has been accepted by ERNO from the co-contractors.

Formal acceptance of the Spacelab system by ESA and NASA is in preparation, starting with part I of engineering model acceptance in the second half of April 1980, to be finalised with part II in September/October 1980.

Flight-unit acceptance is planned for the end of this year (FAR I) for the module configuration and in April 1981 (FAR II) for the igloo configuration.

Follow-on production (FOP)

Negotiations between ESA and NASA for the production of a second Spacelab for NASA were successfully concluded in January. The contract provides for the payment to ESA of the equivalent of:
- 117.1 MAU (1979 economic conditions and exchange rates) for the industrial element – about 95% of which is fixed-price with an escalation clause
- an estimated 12.2 MAU, to cover the Agency's internal costs – in a cost-reimbursement with no fee mode – to which the financial charges for the loan will be added.

ERNO was involved in some of the ESA/NASA negotiations in early November, to ensure agreement on common issues, and the ESA/ERNO contract was then signed on 30 January. The latter provides for the supply to NASA of a fully-equipped pressurised module, five instrumentation pallets, and various associated equipment and spares. These items will be supplied to the United States in deliveries phased over the period October 1981 to April 1984.

Ariane

L02 launch campaign

A detailed evaluation of the parameters recorded during the L01 launch has confirmed the total success of the first flight.

The experience acquired during this first launch has made it possible to reduce the length of the L02 launch campaign from 55 to 35 days, chiefly by reorganising the launch teams so that the L02 launch can be carried out between 20 and 30 May.

The L02 flight stages left France on 18 March for French Guiana and the launch campaign began on 3 April.

Concurrently with the launch activities in Guiana, the final ground qualification tests for the third-stage, qualification of which is required before the L02 launch, are being carried out in Europe.

Only a very limited number of modifications have been made to the L02 vehicle compared with L01, namely:
- activation of the second-stage Pogo correction systems (fitted on L01 but not activated);
- modifications to the measurements made on the engines of the first stage during the release sequence of the launcher retaining jaws;
- repositioning of certain measurement sensors.

In addition to the Technological Capsule (CAT), the L02 launcher will carry two passengers, namely Firewheel, a scientific satellite for studying the upper atmosphere, and Oscar-9, a radio-amateur communications satellite *ont été confiées respectivement à des groupements industriels conduits par Matra et British Aerospace.*

Comme suite aux réflexions menées au sein de l'Agence après consultation des autorités allemandes, une orientation nouvelle du programme a été proposée au Conseil directeur du programme, tenant compte de la possibilité très réduite de pouvoir embarquer un radar à ouverture synthétique sur le premier satellite fin 1985. Les réactions des délégations sont actuellement prises en compte pour l'élaboration d'une proposition de programme réalisant le meilleur compromis possible entre les aspects mission, coûts, planning et disponibilité des instruments.

Spacelab

Première charge utile (FSLP)
On prévoit maintenant un nouveau report du lancement de la première mission Spacelab. A la réunion que l'Administrateur de la NASA et le Directeur général de l'ESA ont tenue en février, il a été indiqué que la date de lancement la plus vraisemblable serait décembre 1982.

Pour la FSLP, on s'en tient toujours au même principe à savoir que la meilleure formule sur le plan de l'efficacité des coûts est d'en terminer dès que possible avec l'intégration en Europe. Les dates de livraison requises pour les instruments scientifiques (de novembre 1980 à février 1981) ne seront donc pas modifiées.

La Phase I du contrat d'intégration et d'essais a démarré chez ERNO à la mi-novembre 1979. Cette phase couvre la préparation de l'intégration matérielle et prévoit une définition complète des méthodes d'intégration et d'essais ainsi que la fourniture d'installations à Brême pour la mise au point du logiciel d'application de vol. Le contrat couvre la période comprise jusqu'au mois de mai 1980, avec un examen des plans d'exécution en avril.

Un examen du programme s'est tenu avec la NASA en novembre au SPICE. On a noté à cette occasion que les progrès étaient satisfaisants, à l'exception de la situation en ce qui concerne la masse. La NASA a officiellement demandé de ramener à l'attribution de masse originale de 1392 kg la partie européenne de la charge utile de SL-1. Dans sa demande, la NASA a indiqué qu'elle garantirait à l'ESA, aux mêmes conditions que pour la FSLP, un vol ultérieur des expériences qui seraient choisies pour l'opération de réduction avant le 31 mars.

Recette du Spacelab
Environ 95% du matériel de l'unité de vol fourni par les sous-traitants ont été réceptionnés par ERNO.

La recette officielle par l'ESA et la NASA du système Spacelab est en préparation et démarrera avec la première partie de la recette du modèle d'identification au cours de la deuxième quinzaine d'avril pour prendre fin avec la deuxième partie en septembre-octobre.

La recette de l'unité de vol devrait avoir lieu à la fin de l'année (FAR 1) pour la configuration module et en avril 1981 (FAR 2) pour la configuration igloo.

Production ultérieure (FOP)
Les négociations entre les deux Agences en vue de la production d'un deuxième Spacelab pour le compte de la NASA se sont achevées avec succès en janvier. Le montant total du contrat se compose de l'équivalent:

- *de 117,1 MUC (aux conditions économiques et aux taux de conversion de 1979) pour la partie industrielle — dont 95% constitue un prix forfaitaire avec clause de variation pour hausse de prix;*
- *d'un montant estimatif de 12,2 MUC, pour couvrir les frais internes de l'Agence — calculés sur la base du remboursement des frais sans profit — auquel s'ajouteront les charges financières de l'emprunt.*

ERNO a été associé à une partie des négociations, début novembre, pour s'assurer qu'un accord existe sur toutes les questions d'intérêt commun. Le contrat a ensuite été signé entre l'ESA et ERNO le 30 janvier 1980. Il prévoit la fourniture à la NASA d'un module pressurisé complètement équipé, de cinq porte-instruments et de divers équipements et pièces de rechange connexes. Ces articles seront fournis aux Etats-Unis et les livraisons s'échelonneront entre octobre 1981 et avril 1984.

Ariane

Campagne de lancement L02
L'évaluation détaillée des paramètres enregistrés lors du lancement L01 a confirmé le succès total du lancement.

L'expérience acquise durant ce premier lancement a permis de réduire sensiblement la durée de la campagne de lancement L02 de 55 à 35 jours, grâce en particulier à une réorganisation des équipes de lancement, ce qui permettra d'assurer le lancement de L02 entre les 20 et 30 mai.

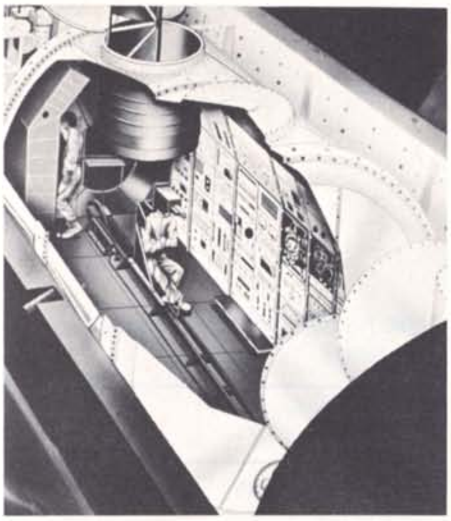
Les étages de vol L02 ont quitté la France le 18 mars pour la Guyane et la campagne de lancement a commencé le 3 avril.

En parallèle aux activités de lancement en Guyane, se déroulent en Europe les derniers essais de qualification au sol du 3ème étage, dont la qualification est un préalable pour le tir L02.

Par rapport à L01, le lanceur L02 n'a subi qu'un nombre très limité de modifications, à savoir

- *activation du système correcteur Pogo du 2ème étage (système en place mais non activé sur L01);*
- *modification des mesures prises sur les moteurs du 1er étage pendant la séquence de largage des crochets retenant le lanceur;*
- *déplacement de certains capteurs de mesure.*

Le lanceur L02 emportera, outre la capsule Ariane technologique (CAT), deux passagers: Firewheel, un satellite scientifique destiné à l'étude de la haute atmosphère et Oscar-9, un satellite de télécommunication pour radio-amateurs.



The Sled Programme

J.A. Steinz, Sled Project Division, Technical Directorate, ESTEC, Noordwijk, Netherlands

The Sled programme schedule is extremely short, with a span of less than two years from original conception to final delivery of the flight unit for Spacelab. This rigid time constraint has not permitted the usual selection of an industrial prime contractor, with the result that responsibility for the execution of all system-level work has been assigned to the Sled Project Division itself, with major subsystems being contracted to industry. This article outlines the Sled programme, the design features of the Sled itself, and the working arrangement that has been established to produce it*.

The Sled is being developed to study the effects of the weightlessness upon man during a Spacelab mission, and hardware produced by several organisations in Europe and North America will be carried. The experimental data produced are to be studied by an international collaboration of life scientists drawn from ten scientific institutes and universities, in Canada, France, Germany and the United States.

The Sled programme as it now stands is the result of a proposal by a special team set up in ESTEC in late 1978 with the task of defining a new Sled concept that could be produced in-house at low cost within the very much reduced schedule of eighteen months, since the Sled programme originally foreseen in industry could not be completed within the prevailing cost, schedule and mass (<165 kg) constraints. The revised concept avoids complicated design features, uses well established technologies, and moreover does not compromise the scientific significance of planned experiments. A novel and essential feature of the revised programme is that all system-level work and especially critical development work is being performed by the Agency itself, with the detailed design of subsystem and associated hardware production being undertaken by contractors chosen for each particular expertise. This solution was the only one that offered the mix of flexibility and efficiency needed to produce a new system for experimentation in space within the prevailing monetary and time constraints.

Scientific objectives

Scientific interest in the behaviour of the human body under weightless conditions stems from the fact that many astronauts have suffered for several days on previous flights from a form of space motion sickness that besides inducing discomfort also severely impairs work efficiency. The importance of this factor's influence upon crew effectiveness is obvious for short-duration space missions of the type to be undertaken initially by Spacelab (± seven days per sortie).

Of equal importance to life scientists is the fundamental interest in unravelling the processes by which the human senses his orientation and how his automatic responses to these senses work. The absence of gravity, an ever present factor in earth-bound researches into these topics, should help produce a better understanding of the basic phenomena involved.

Man senses his orientation and direction of motion from several independent sources. The primary sensors are the balance (vestibular) organs, located in the inner ear and consisting of two main parts: one, the otolith, senses linear accelerations and the other, the semi-circular canal system, senses angular accelerations. Other orientational and directional senses are those of sight, hearing and physical feel. The brain interprets all of these sensory signals in order to establish orientation and direction of motion.

Biliousness (motion sickness) is often induced as an automatic response when

* For latest flight status, see page 53.

Figure 1 – Accommodation of the Sled aboard Spacelab

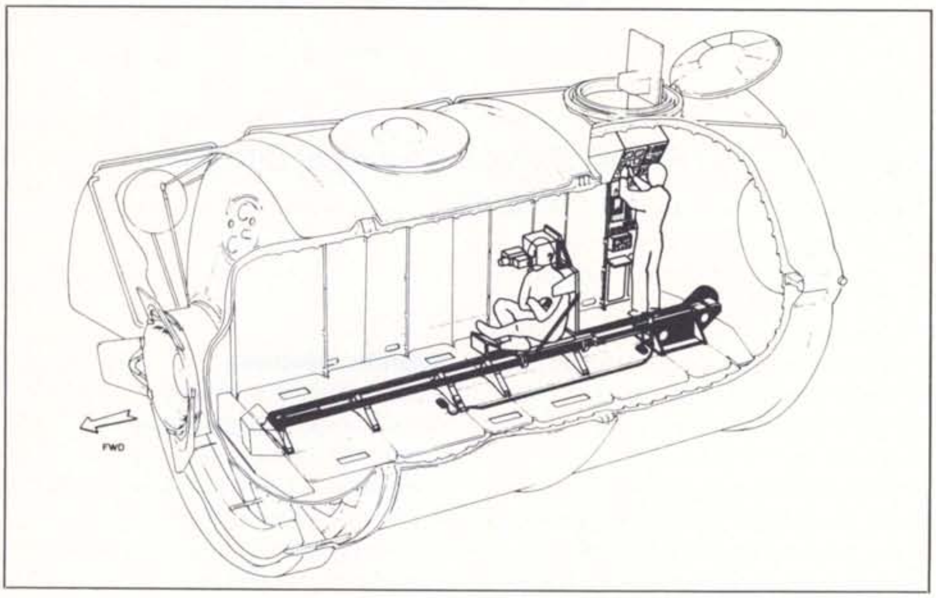


Table 1 – Run-mode performance parameters

Mode
Peak acceleration (m/s²)
Frequency (Hz)
Period (s)
Oscillation amplitude (m)
Number of oscillations (full or half)
Maximum peak velocity (m/s)
Accuracy of velocity
Transients:
Overshoot amplitude
Transition time

* 1.60 m maximum amplitude preferred. Other parameter ranges will be modified if this cannot be achieved.

these signals do not correlate. Movements in a zero-gravity environment cause similar sickness symptoms, the severity of which is not the same for all astronauts, and which can be reduced by temporarily keeping the head still or through the taking of drugs. The effect can also be reduced through a conditioning period of several days, during which the brain assimilates new correlation standards for its new environment. Similar effects are observed during the first few days after an astronaut's return to earth.

In the Sled experiments, emphasis will be placed on the study of linear acceleration effects, because the earlier, extensive studies with the Skylab Rotating Chair Experiment have shown no correlation between motion-sickness symptoms and angular accelerations. The specific objectives of the Spacelab experiments are:

- to study the response mechanism of the human sensory balance system to inertial (acceleration) forces that are not adversely affected by earth-bound gravity forces
- to investigate the relative interactions between balance (inertial), visual, audio and other physical sensations processed by the human brain to elicit automatic and conscious responses to motion perception
- to understand and find ways of alleviating the problems of space sickness, for example by defining methods for identifying crew members with a low susceptibility and for conditioning the sensory balance system.

Sled system

The physical configuration of the Sled inside the Spacelab module is shown in Figure 1. The seat, which is mounted on an integral rail structure that bolts to the Spacelab floor, can be oriented in any one of three mutually orthogonal directions: facing the direction of motion of the carriage, facing sideways, and facing upwards away from the Spacelab floor. Carriage movements back and forth along the length of the Spacelab module are controlled by a DC electric motor, which is activated by an electronics control unit situated in a standard Spacelab equipment rack at the aft end of the module.

All Sled experiments are to be controlled by the test operator in the aft end of Spacelab. Monitoring from the ground or from the Orbiter aft flight deck can only be by way of voice communication with the test operator. The test operator and the test subject can interrupt experiments at any time.

Dynamic performance

Two types of oscillatory motion, a sinusoidal oscillation (SO) mode and the constant-gravity oscillation (OGO) mode, are required for scientific experiments. In the former, the accelerations describe a sinusoid, whereas in the latter they follow a square wave. The performance parameters and accuracies for these two run modes are summarised in Table 1.

Some typical measured motion profiles are shown in Figure 2. These measurements were taken with a breadboard model of the Sled electronics unit (SEU), with a one-third scale drive amplifier operating in closed loop with a mechanical test rig that simulates one third of the inertia of Sled moving parts (Fig. 3). The asymmetries in Figure 2 are due mainly to the wide tolerances of the electronic components used in the breadboard model.

Control and electrical systems

The functional interrelationships in the Sled system are shown in Figure 4.

Sinusoidal oscillation	Constant gravity oscillation
0.03 – 1.96	0.01 – 1.96
0.023 – 1.0	0.015 – 0.21
1.0 – 44	4.9 – 68
0.019 – 1.45*	0.087 – 1.45*
0 – 999	0 – 6 (at least)
1.7	2.4
0.04 m/s or 5% (whichever is greater)	
<15% <0.5 s for accel. >1.0 m/s² <2.0 s for accel. = 0.01 m/s²	

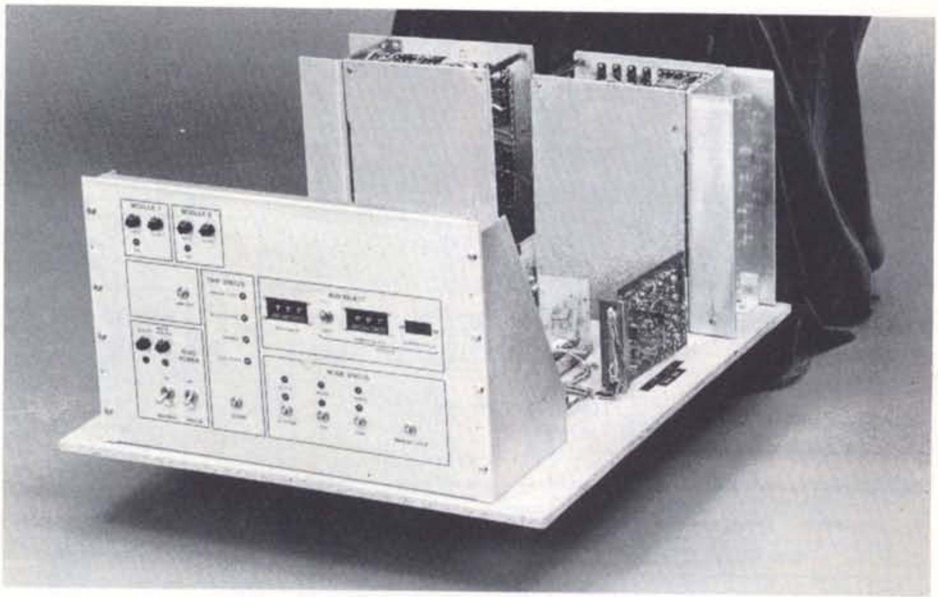


Figure 3 – Breadboard model of Sled electronics unit (SEU) (built by Bell Telephone Manufacturing Co.)

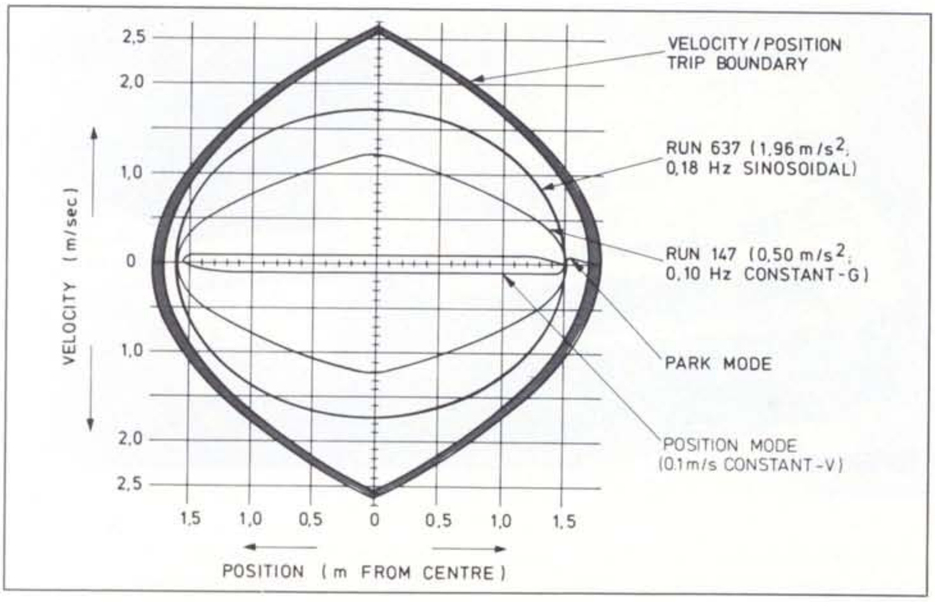


Figure 2 – Sled velocity/position trajectories

Carriage movements are controlled by a velocity control loop using the signal of a tachometer on the drive motor as input. A second slow control loop, the position loop, relies on a potentiometer arrangement to correct the reference mid-point of carriage oscillations.

The SEU situated in the Spacelab rack at the aft end of the module controls all the electronic functions. The *profile generator* has all the necessary motion trajectories permanently stored in its electronic memory (PROM). They include nearly 200 different profiles for scientific experiments, several profiles for positioning the Sled, and about ten calibration and checkout profiles. Each of them uniquely defines the velocity and positional parameters of the various motions and has its own run code number. The test operator can select the number of full or half oscillations to be performed from the SEU control and monitoring panel. The *sequencer* ensures that commands are carried out only in the correct sequence. The *control unit* of the SEU controls the dynamics of the Sled's movements via velocity and position feedback loops, with independent safety circuits that cut power or activate the brake mode in the event of an anomaly. The *drive amplifier* powers the motor and consists of six parallel modules which convert the 28 V Spacelab power supply to the varying output voltage commanded by the control laws. These modules also have dissipative braking stages for decelerating the Sled.

System safety

The Sled system has a number of major safety features designed into it:

- A crushable end stop that ensures smooth retardation within 45 cm from the 3 m/s maximum velocity (<2 g deceleration; ≤100 g/s jerk), should the SEU become inoperable as a result of a malfunction. The buffer cartridges are not re-usable, but several spares are to be carried in a Spacelab rack.
- Independent safety circuitry that cuts off power to the drive motor

Figure 4 – Sled system functional block diagram

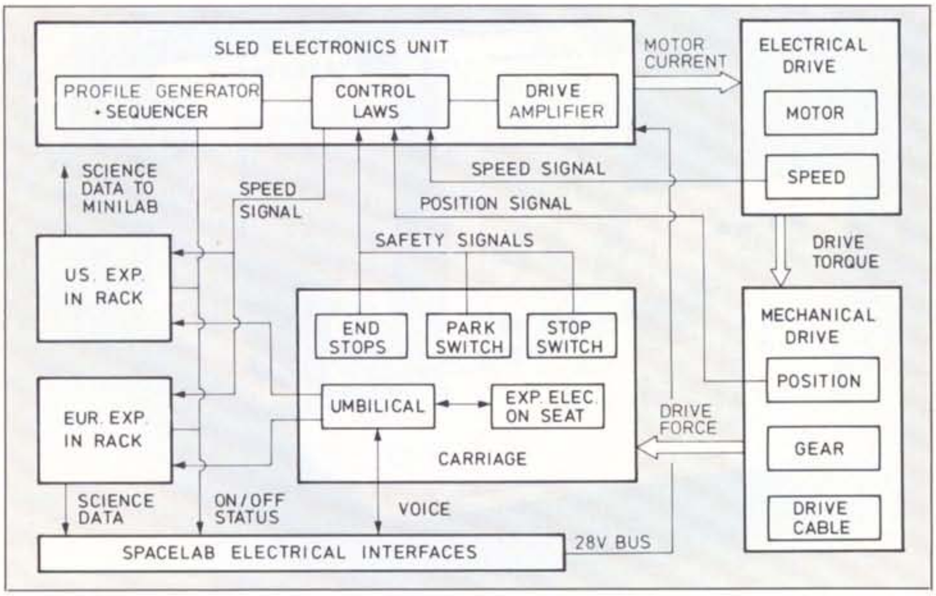
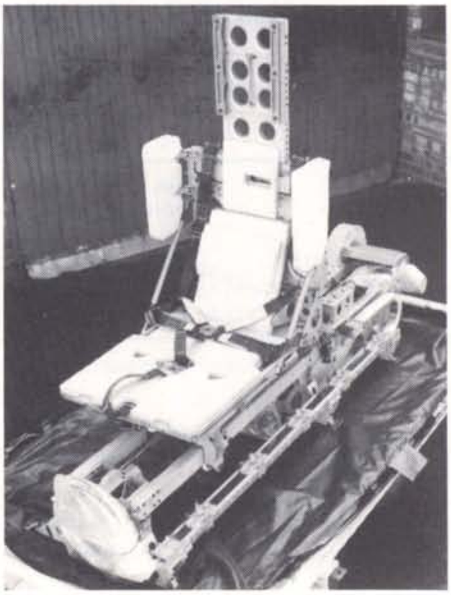
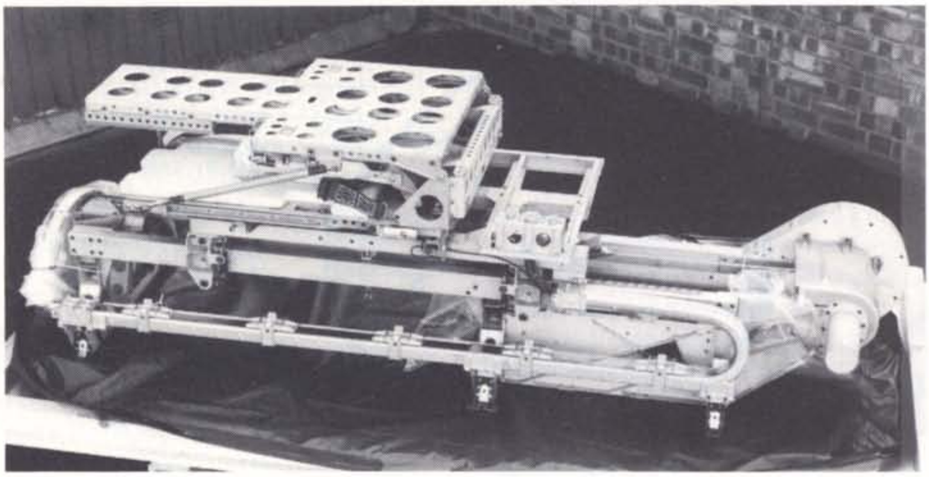


Figure 5 – Sled protoflight model, built by Marshall of Cambridge (Eng.) Ltd.
(a) Operational configuration
(b) Launch configuration


(a)


(b)

whenever the carriage velocity exceeds the maximum safe design speed (3 m/s in run mode or 0.2 m/s in positioning or park mode) or when the end stop is partially crushed by the carriage.
- A further independent system that commands the system into the brake mode (deceleration of at least 1.96 m/s^2) whenever the combination of instantaneously measured velocity and position are at the limit where the carriage could still be stopped electrically before reaching the end stops (i.e. brake switches at the velocity/position trip boundary of Figure 2).

The incorporation of these last two safety features means that several electronic malfunctions would have to occur in combination before the crushable end stop would be called into use.

Design details

Seat and carriage

The test subject sits cross-legged on the seat, which is latched to the carriage, and is held in place with a five-strap harness. A mock-up of the flight seat is shown in Figure 5 in the operational (unfolded) and launch (folded) configurations. The carriage's motion along the two parallel rails is controlled by twelve separate wheels that are pressed up against the rails by spring-loaded arms.

Drive assembly

The carriage is propelled backwards and forwards along the rails by cables wrapped over a spiral-grooved cable drum driven by the DC electric motor through a toothed-belt/pulley arrangement. The whole drive assembly is designed so that there can be no slipping in the relative movements of carriage and drive motor.

Electrical harness and umbilical

Electrical harnesses are provided for the Sled itself and electrical signals and power are transmitted from the experimenter electronics on the moving carriage to the stationary Spacelab racks via an umbilical (Fig. 5). This Sled umbilical is an aluminium spiral conduit of square cross-section, made in such a way that it can bend in only one plane. The umbilical rolls out of and into a tray attached to the rail supports as the carriage moves along the rails.

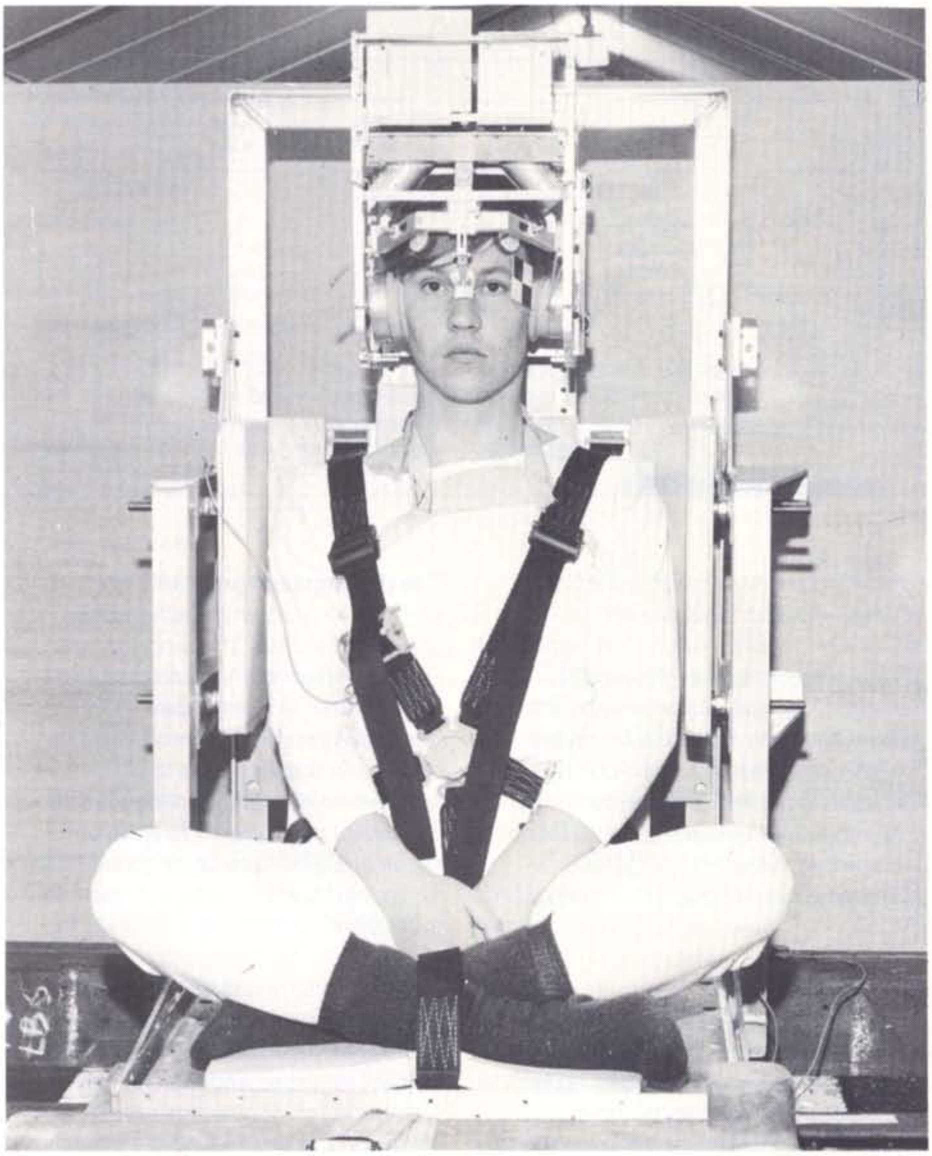


Figure 6 — Safety tests with an early seat mock-up; photograph courtesy of Royal Air Force Institute of Aviation Medicine, Farnborough.

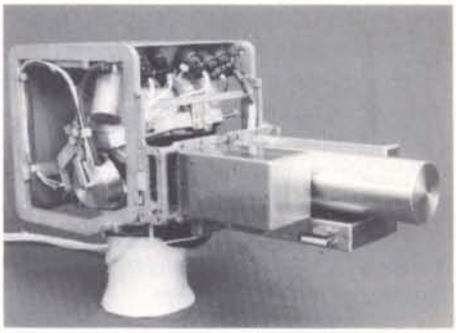


Figure 7 — Prototype of the European experiment helmet; photograph courtesy of DFVLR and Kayser-Threde GmbH.

Sled experiments

Several experiments are to be performed independently with the Sled and they rely on different hardware configurations to satisfy different scientific objectives. All experiments have control and monitoring panels in equipment racks in the aft end of Spacelab so that they can be controlled by the Sled test operator.

European experiment

This experiment is a collaborative German (DFVLR) and French (CNES) undertaking. A helmet-like structure that will restrain the head of the test subject is to be attached to the Sled seat (Fig. 6). It contains a TV monitor and an infrared TV camera (mounted in front of the test subject's eyes, Fig. 7), heating and cooling devices for the balance organs, electronic conditioning equipment for accelerometers and various physiological sensors. One of the roles of the TV monitor will be to stimulate one eye with changing patterns, while the infrared camera will record the movements of the other in response to accelerations and other physical stimuli.

An electronic package mounted permanently on the Sled carriage digitises all scientific data from the helmet and from other body sensors. It transmits its data and receives commands and power via the Sled umbilical.

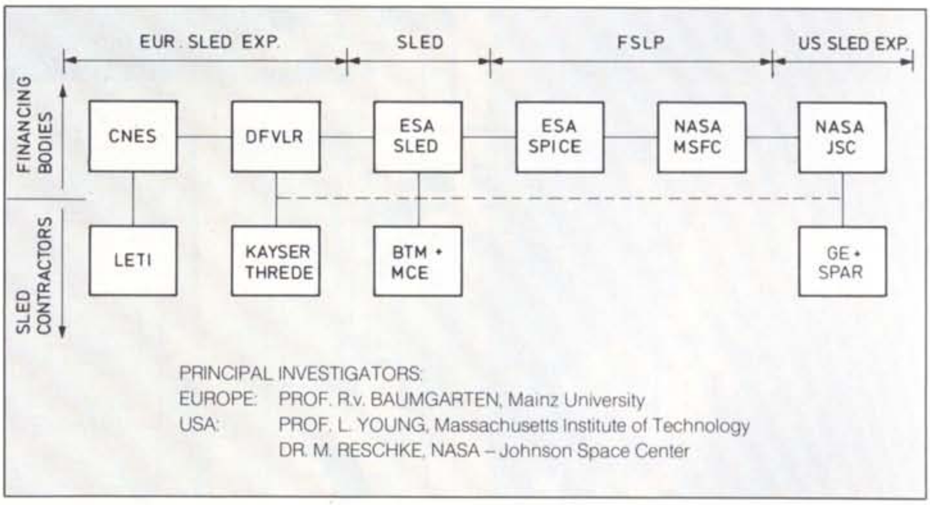
A joystick control box which will be held and operated by the test subject will give quantitative indications of perceived motions. The manual override for stopping the Sled is attached to this box. Both units are stored for launch and landing. There will be a video-recorder and experiment control unit in the aft Spacelab racks, opposite that housing the SEU.

US experiments

One of the American experiments, produced by Massachusetts Institute of Technology (MIT), also uses a 'helmet' assembly, but theirs will completely enclose the head. It houses a motorised 35 mm camera and lights for recording eye movements, eye-movement electrode sensors, loud-speakers to obscure audible noise cues during acceleration tests, accelerometers and other electronic gear. This experiment also uses the joystick box developed for the European experiment.

The second US experiment, produced primarily by NASA's Johnson Space Center (JSC), is quite different in that it measures the Hoffman reflex (leg muscle responses to perceived g-level changes). A special structure attached to the Sled

Figure 8 – Sled project organisation



seat will support both of the subject's legs in an outstretched (horizontal) position (not folded as in other experiments) and calf-muscle responses to an electrical stimulus applied to the tibial nerve in the hollow behind the knee will be measured. The necessary electronics are mounted on the leg-support structure. This experiment uses the helmet developed by MIT, but without the camera.

Both US experiments are to be controlled by the test operator through control units housed in the aft equipment racks and they will also rely on the Sled umbilical for power and signal transmission.

Organisation

A large number of organisations are involved in the realisation of Sled and its experiments:

Organisation	Responsibility
NASA/MSFC	Overall mission
ESA/SPICE	European payload
ESA/SLED	Sled development
DFVLR	European Sled experiment
CNES	Infrared camera for European experiment
NASA/JSC	US Sled experiments

The organisational relationship between these bodies is shown in Figure 8, together with contractors involved in the development of Sled and its experiments. The solid lines represent formal coordination links for engineering and operational matters, while the dotted line represents an informal link where agreements made remain preliminary until confirmed by ESA/SPICE and NASA/MSFC at overall payload system level.

Each financing body maintains its own communications with the scientific user community. In the case of the ESA Sled project, the formal link is via the Sled Science Team, an ESA-appointed body representing the user community.

The work breakdown within the Sled programme is as follows: systems engineering and management – ESA Sled project team; umbilical/electrical harnesses, critical parts development and system assembly, integration and test – ESTEC Test Services Division; Sled electronics unit and EGSE – Bell Telephone Manufacturing Co. (BTM); mechanical subsystem and MGSE – Marshall of Cambridge (Engineering) Ltd. (MCE).

Sled deliverables

Two Sleds are to be built, one for flight (protoflight model – PFM) and one for crew training (TM). Both are being built to the same standard, the difference being that only the PFM will be vibration tested for the expected flight environment. Both models will be delivered to SPICE with a complete set of ground support equipment and with sufficient spares to satisfy the following usage requirements over a period of eighteen months:

	PFM	TM
In-flight operations:		
Total usage	30 h	–
Dynamic usage	16 h	–
On-ground operations:		
Total usage	150 h	700 h
Dynamic usage	50 h	250 h

The development programme

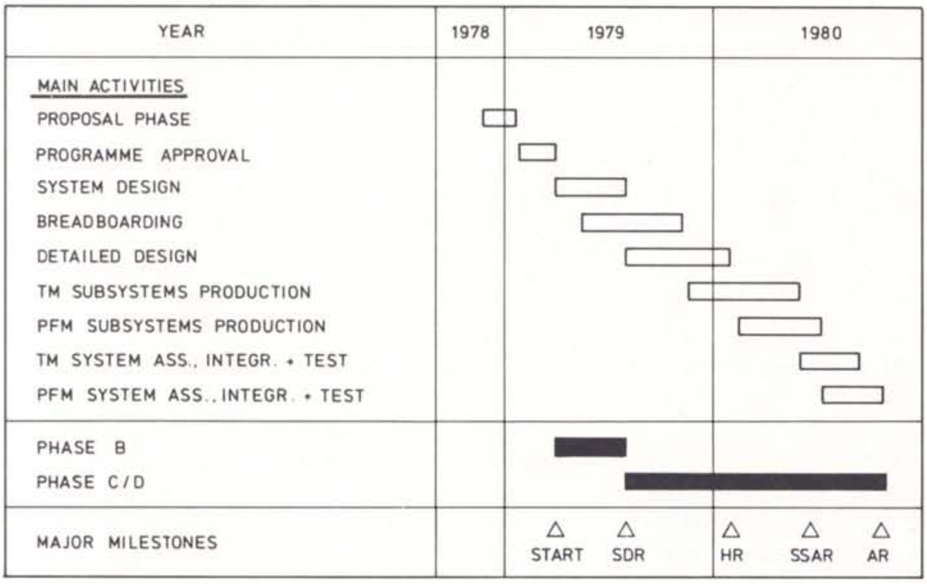
The overall programme schedule is shown in Figure 9. The programme started with an intensive proposal phase at the end of 1978 to re-define the concept down to the level where subsystem specifications could be established with high confidence that no significant changes would have to be made at a later date. During this phase, first contacts were made with candidate subsystem contractors.

The programme was approved by the Science Programme Committee towards the end of March 1979 and the selection of Bell Telephone and Marshall of Cambridge as contractors for the electrical and mechanical subsystems, respectively, was approved the following month.

Phase-B system and subsystem design began in early April 1979 and breadboard testing of critical design elements was started within six weeks (some of the photographs accompanying the article stem from those breadboard activities). The main tests conducted during Phase-B included:

- deceleration tests with a seat mock-up to verify test-subject safety and to define ergonomic interfaces (performed by the Royal Air Force Institute of Aviation Medicine)

Figure 9 – Sled programme schedule



- performance testing of parts critical to control-loop simulations (frictions and stiffnesses of mechanical parts, dynamics of drive motor and sensors) and offgassing/flammability/odour tests of as yet unapproved parts and materials (ESTEC)
- breadboard testing of all electrical circuits and a power module (BTM), of critical mechanisms (MCE), and of the umbilical (ESTEC).

These activities were continued after the completion of Phase-B to a higher level of assembly, including:
- tests on a one-third-scale breadboard model of the SEU (BTM)
- closed-loop testing of an SEU breadboard model with a test rig simulating the inertias of Sled moving parts (ESTEC)
- crushable-end-stop development tests and ergonomic and functional checks on the flight-seat mock-up (MCE)
- development testing of umbilical, of mechanical drive parts to reduce audible noise, and improvements to the commercial drive motor to comply with minimum flight quality and performance requirements (ESTEC).

The breadboarding and development activities provided the necessary inputs for the design work which was performed in parallel. They also identified a need for extra development work in some areas which was not originally anticipated.

The major milestones of the programme and their main objectives are:
- System Design Reviews (SDR) to demonstrate the compatibility of system and subsystem requirements prior to freezing of the detailed design and commencement of long-lead-item manufacture
- Hardware Reviews (HR) to verify compatibility of manufacturing plans and procedures with requirements and design of all subsystems
- Subsystem Acceptance Reviews (SSAR) to demonstrate satisfactory performance by test for ESA acceptance of subsystems
- Acceptance Reviews (AR) to demonstrate satisfactory performance by test of the Sled training and protoflight models (TM and PFM) before delivery to SPICE.

Concluding remarks

The programme has reached the stage where parts manufacture is well under way and the building-up of sub-assemblies has begun. All subsystem Hardware Reviews have been completed successfully.

Experience gained in this tightly time-constrained programme has demonstrated the importance of deploying a relatively large amount of effort in the early conceptual and system design phases. It has also been shown to be important that breadboard activities be started early and be carried out with sufficient intensity for feedback to the design to be available before it has proceeded too far. The usual problem of parts procurement has required constant attention, to ensure that all the items called for in the design can be made available on time.

With this approach it has been possible to date to avoid major problems, and thus to maintain the overall schedule and the original cost estimates. The aim is to maintain this healthy state throughout the coming assembly and test phases, which will be the real measure of programme success!

Acknowledgement

This article is the result of keen collaborative effort by all parties directly or indirectly involved in the project. The cooperation of and inputs given by Bell Telephone Manufacturing Co., Marshall of Cambridge (Engineering) Ltd., the Sled experimenter groups and ESA staff are gratefully acknowledged.

The First Clients for the Ariane Operational Phase

B. Stockwell, Ariane Department, ESA, Paris

The past several years have seen many contacts between the Agency and potential users of Ariane, and at the time of the first launch of the vehicle in December last year a number of firm commitments had been made by both European and non-European users. Over the months preceding that first and entirely successful launch*, and particularly since, the number of contacts has increased considerably and the Ariane launch manifest is filling rapidly.

* See ESA Bulletin No. 21, pages 2–7.

The user programme

The first user of Ariane beyond the vehicle's development programme, during which a number of payloads will be flown, will be the ESA Marecs programme. This programme's first maritime communications spacecraft will be launched on the last Ariane development flight in late 1980, and then a second model will be launched in April/May 1981 on the first Ariane production vehicle (L5). This same flight will also carry the Agency's Sirio-2 experimental telecommunications spacecraft, and this will be the dual launch that will demonstrate the Ariane dual- payload capability.

The two Marecs spacecraft represent the first part of the Agency's contribution to the proposed L/C-band INMARSAT maritime communications system and they will establish a high-quality ship-to-shore and shore-to-ship operational service. A third spacecraft will be launched later in order to maintain that system. The first two Marecs launches were committed to Ariane in 1979.

The July 1981 launch slot is currently free, having been vacated by the first committed non-European user, INTELSAT, which provides international fixed communications services on a world-wide basis (initially C-band, and now C and Ku-band). INTELSAT has incurred a number of spacecraft delays in preparing its Intelsat-V series, and has now requested that this first Ariane launch be rescheduled for the end of 1981. INTELSAT has also contracted for two optional launches in April and July 1982, has provisionally reserved the launch slot of December 1982, and in addition proposes to reserve the launch slots of December 1983 and of February and July 1984, the last three being either for the launch of Intelsat-V/VA re-orders, or for new hybrid spacecraft of a smaller class. The custom of the INTELSAT programme (Fig. 2) is important to the future of Ariane, and the contractual negotiations currently in hand carry great weight.

The October/November 1981 launch slot, currently the second operational launch, is assigned to ESA's Exosat scientific satellite. This mission calls for a highly elliptical near-polar orbit, and in addition requires a fourth stage to be added to the basic three-stage Ariane launcher. This fourth stage, a derivative of the French Diamant third-stage motor, is being developed under the Ariane development programme specifically for Exosat. The Exosat mission is therefore of great interest, in that it will demonstrate the launch vehicle's near-polar high-energy launch capabilities. The whole programme, including the fourth-stage development, is a fixed-price undertaking.

The fourth operational launch will fly the ECS-1 communications spacecraft, the first of a series of such satellites to be launched in fulfilment of the Agency's obligations to EUTELSAT to provide an operational fixed-services Ku-band telecommunications system for Europe, for the use of the European postal and telecommunications services. Ariane has accepted the commitment to provide a minimum of four launches for the ECS satellite series at ceiling prices, through

Figure 1 — Ariane lifting-off on 24 December 1979 at the start of its highly successful first test flight

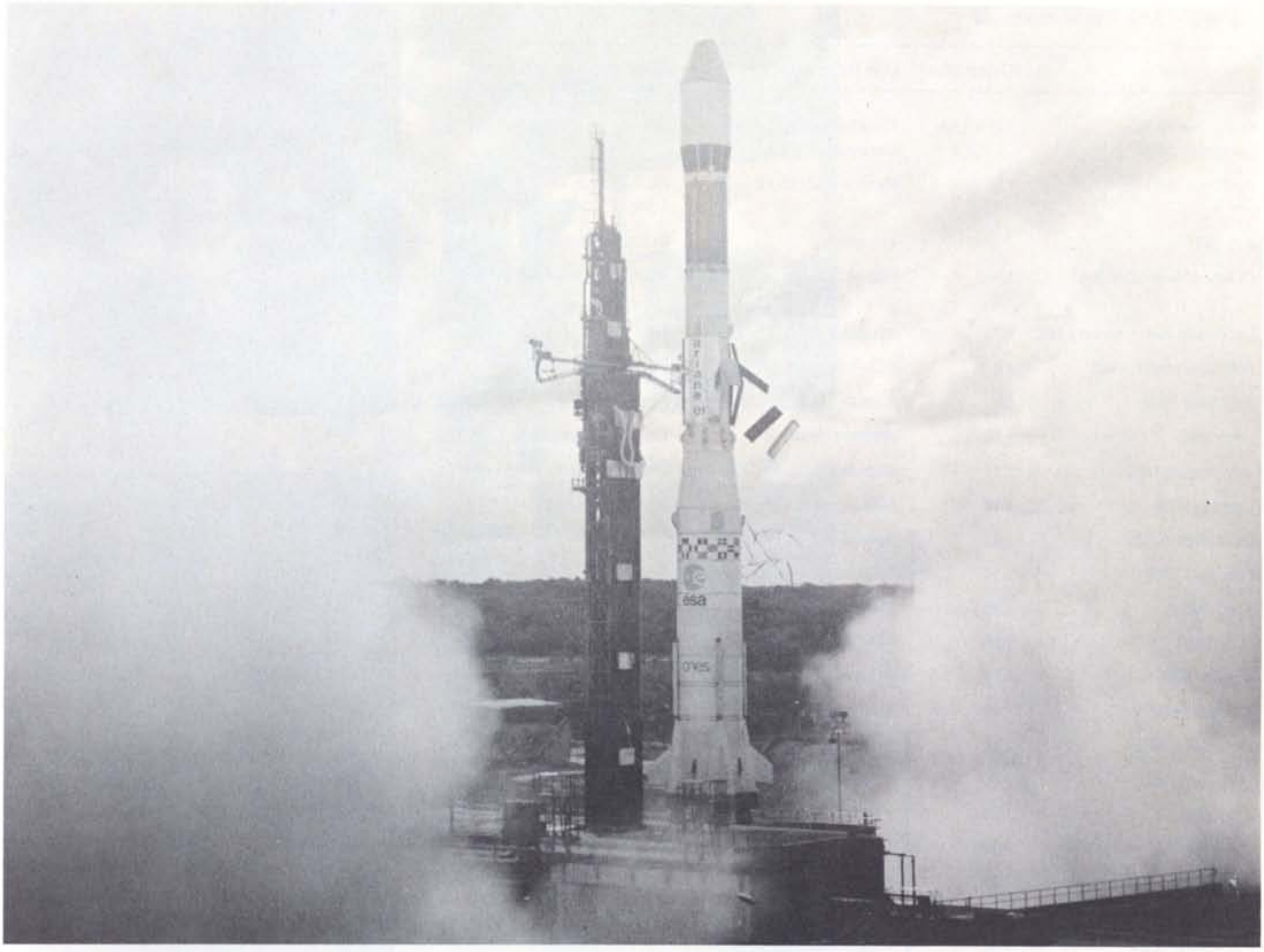


Figure 2 — Intelsat-V, presently scheduled for a December 1981 launch on Ariane's seventh flight

1986. Generally these will be dual launches with companion operational payloads, although in the case of ECS-1 the proposed partner is a Solar Sail experimental package.

As already mentioned, the fifth operational launch in April 1982 is currently reserved for INTELSAT, while the sixth in June 1982 is reserved for satellites belonging to the Western Union Telegraph Company – fixed communications services missions for non-European domestic use at C-band. This latter reservation has been made against a firm price quotation for the launch service, and is under negotiation.

The seventh launch, in July/August 1982, is also provisionally reserved for INTELSAT, and there is every probability that the two INTELSAT options for 1982 will be converted to firm launches next month.

It is planned that October 1982 will see the first launch of the uprated Ariane, Ariane 3A, which will initially be able to inject some 2330 kg of payload into transfer orbit, compared with the conservative claim of 1700 kg for Ariane-1. The Ariane dual-launch (Sylda) system occupies 140 kg of this gross payload, leaving 2190 kg for the two passengers; by mid-1983 this figure will be 2280 kg.

photo aerospatiale

Figure 3 – The second of the Agency's meteorological applications satellites Meteosat-2, due for launch on the third Ariane development flight (L03)

Figure 4 – Artist's impression of the Agency's Marecs maritime communications spacecraft, the first of which is to be launched before the end of this year (Ariane L04)

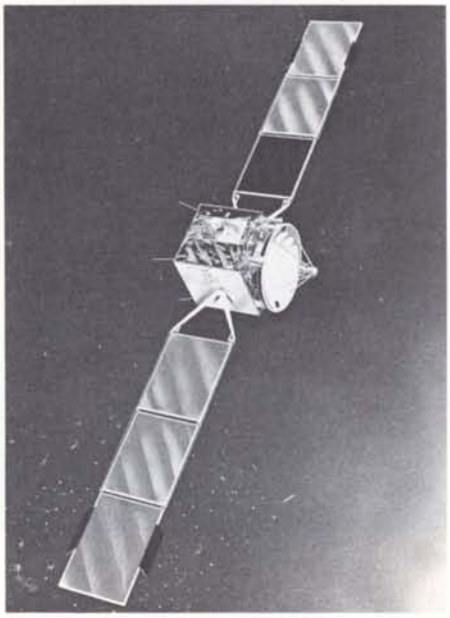


Table 1 – The Ariane manifest

Launch date	Designation	User payload	Comment
December 1979 – December 1980	L01 – L04	Firewheel, Amsat, Apple, Meteosat, Marecs	Development flights
April/May 1981	L5	Marecs and Sirio-2	Dual-launch – first production flight
July 1981		Vacant	Could be allocated
October/November 1981	L6	Exosat	Fourth stage added to basic launcher
December 1981/January 1982	L7	Intelsat-V	Firm launch
February/March 1982	L8	ECS-1 plus companion	Possible second passenger
April/May 1982	L9	Intelsat-V	First option
June 1982	L10	Western Union	US domestic satellite
July/August 1982	L11	Intelsat-V	Second option
October 1982	L12	ECS-2 plus companion	Ariane-3A available
December 1982	L13	Intelsat-V	
February 1983	L14	Telecom-1 A + companion	
April 1983	L15	Two companions (tdb)	
June 1983	L16	ATT Telstar-3	Ariane-3 available
August 1983	L17	Reserve slot	
October 1983	L18	Telecom-1B + companion	
December 1983	L19	3 Intelsat-V/hybrid	
February 1984	L20	1 TV Sat	
April 1984	L21	1 TDF	
June 1984	L22	1 L Sat	Second pad available
July 1984	L23	Spot	
August 1984	L24	Operational Meteosat	
September 1984	L25	1 reserve slot	
October 1984	L26		

One of the two passengers on the uprated vehicle in October 1982 will be ECS-2; the other will be one of two regional C-band missions that have scheduled reservations in this time frame and which are under negotiation, the exact flight allocations depending upon passenger demands and readiness. There are several such non-European Ariane half-payloads proposed for the period between October 1982 and the end of 1983, including the Arabsat regional C-band mission, various RCA US domestic missions, and the Indonesian Palapa-B system.

The ninth and tenth operational launches, in December 1982 and February 1983, will be assigned to INTELSAT and to the French national specialised fixed-service Telecom-1A mission. The latter will be a dual launch, as will that of April 1983, the exact mix of committed users again depending upon user programme readiness.

The twelfth launch, in June 1983, is committed to the US domestic American Telephone and Telegraph (ATT) Telstar-3 mission, for which contract negotiations are quite advanced (as always, on the basis of fixed prices).

Still later launches, through operational flight 22 in October 1984, will carry payloads for such missions as the Franco-German TV broadcasting projects, the ESA L-Sat large-platform experimental TV broadcast and specialised services project, the operational Meteosat programme, the French national earth-observation project, for INTELSAT, and for a number of third-party users around the world who are already approaching Ariane.

Figure 5 – An Ariane first stage in the process of integration at Aerospatiale's Launcher Integration Site at Les Mureaux (France)

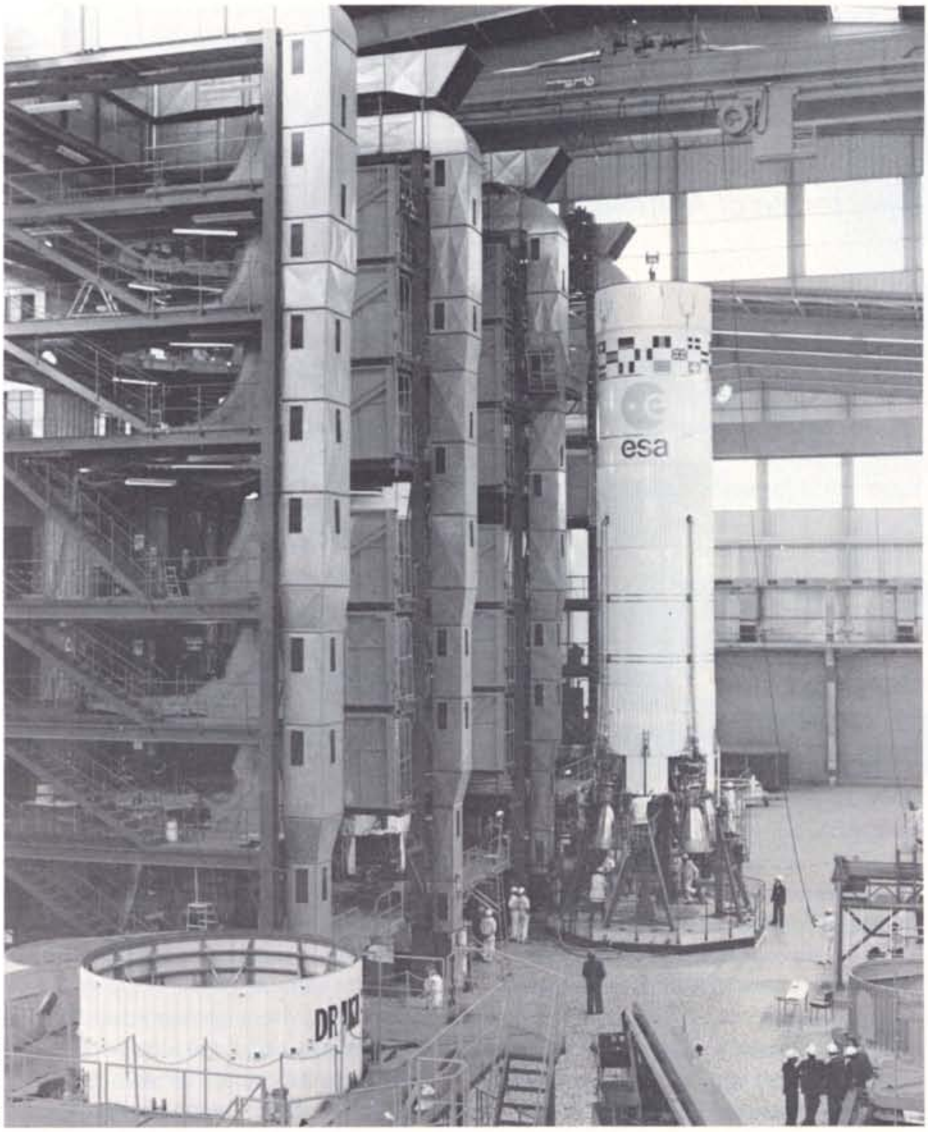


photo aerospatiale

Conclusion
The trickle of launch-service requests received in 1978/79 threatens to become a flood. Given a successful launch in May (L02), it can be anticipated that many options and early requests will be confirmed. There is already pressure to utilise the small number of reserve slots that have been set aside, and the completion and commissioning of a second launch pad at the Guiana Space Centre (Kourou) by mid-1984 is now a matter of urgency.

Meanwhile, the American Delta launch vehicle programme has been extended through 1984; there are indications that Atlas-Centaur production may also be extended. Competition is therefore extremely keen, but Ariane can certainly match the prices of the US expendable launch vehicles and is rapidly gaining the confidence of potential users. When the Shuttle eventually becomes operational it will provide further stiff competition for Ariane launch services, and so Ariane cannot afford to be complacent. Ariane pricing is keen and getting keener, with a follow-on development programme under way that promises to almost halve the unit launch cost. With the Ariane production phase now being reshaped as an industrial undertaking, there are clearly interesting years to come.

ESA's New Contract Regulations – An Instrument for Industrial Policy

W. Thoma & H. Greiffenhagen, Contracts Department, Directorate of Administration, ESA, Paris

At the beginning of this year, new contract regulations entered into force within the Agency which will be an important instrument for shaping industrial policy.

Reasons for change

The original rules and procedures for the award of contracts were formerly laid down in the ESRO Financial Rules. These rules reflected principles as they are generally applied by Government agencies for the provision of goods and services. They ascertained fair and equitable procedures for the award of contracts with a built-in mechanism for control by the Member States. This control mechanism was exercised via the Administrative and Finance Committee, which fulfilled an auditing function on the correct application of the rules in the award of contracts.

On the other hand, the possibilities for playing an active role in the selection of contractors, which forms an important part of an overall industrial policy, were rather limited. In fact there was a continual possibility of a conflict situation arising in cases where the Committee wanted to reverse, for reasons of industrial policy, recommendations that had been based on the principle of 'best value for money'.

ESRO could live with this during its first years of existence, because its contracts were then a much less important feature of its running. In 1964, for example, ESRO placed 67 contracts with a total value of 7.30 MAU. The growth of the Agency in the last fifteen years has been such that in 1979 ESA placed 562 contracts with a total value of 358.88 MAU*.

Another reason for the growing concern about the contractor-selection process has been that certain ESA projects can lead to whole groups of undertakings not solely within the Agency's own domain. A good example is the European Communications Satellite (ECS) system, which is a follow-on contract to the Orbital Telecommunications Satellite (OTS) project, and which involves a total of five spacecraft. It has been followed by the Marecs A and B spacecraft and might lead to a contract with INMARSAT for a Marecs C and D. It also prompted the French authorities to choose the same platform as a basis for their national Telecom-1 satellite. Similarly, the original Spacelab development contract has provided the basis for the placing by NASA of an order for a further Spacelab from Europe.

It is therefore understandable that the interest of Member States in the award of contracts has been growing over the years. As a first step, the Member States created the Industrial Policy Committee (IPC), which is now responsible for all aspects of the Agency's industrial policy. As a second step they wished to have contract regulations that would allow them to participate actively in industrial-policy decisions.

Main features of the new regulations

The particular features of the new regulations that have an impact on industrial policy are the following.

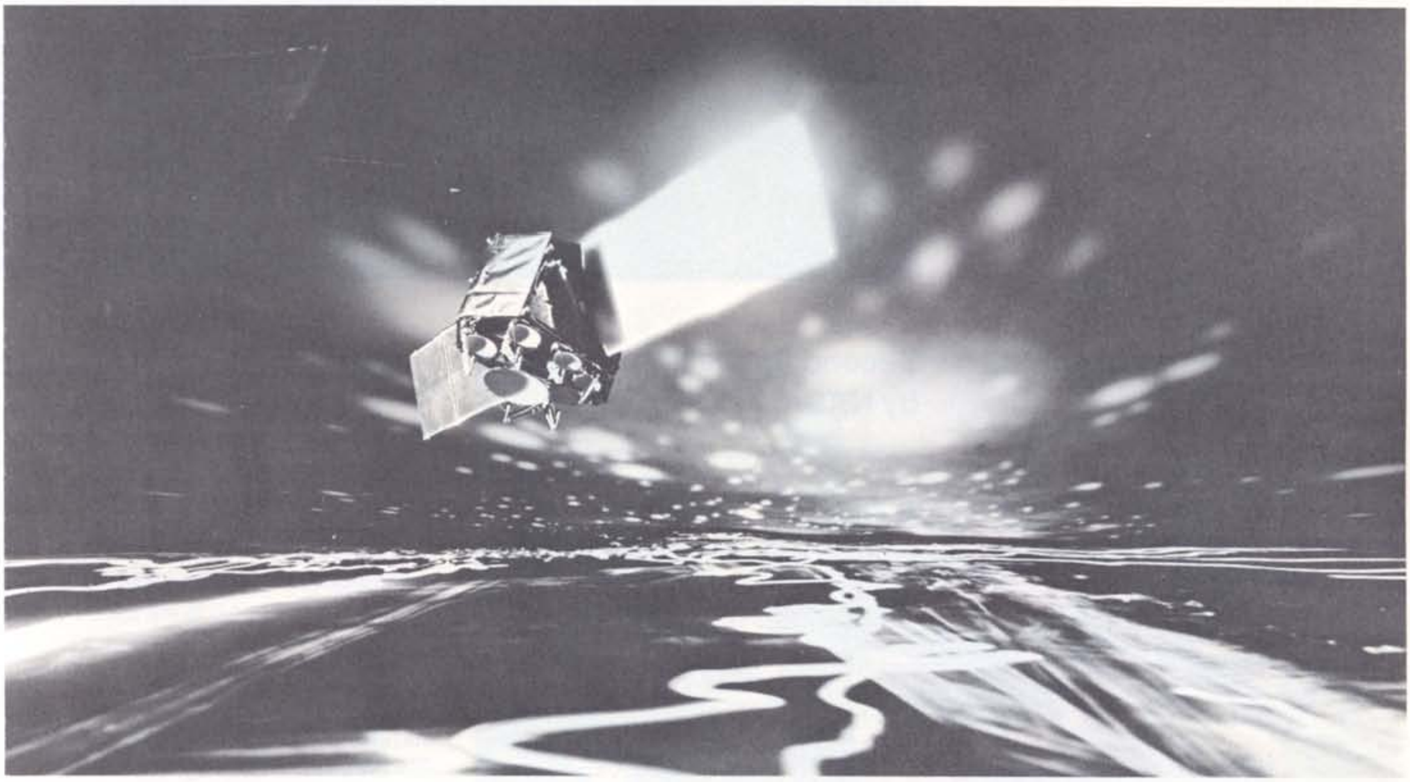
Visibility of contract situation

According to Article 23, the Director General will be obliged to report quarterly to the Industrial Policy Committee on

– all intended contract actions involving more than 50 000 AU

* 1 AU = ± 1.2 $US (1979 rate)

Figure 1 — OTS, the Agency's Orbital Test Satellite, which is paving the way for the ECS and Marecs operational telecommunications spacecraft of the 1980's.



- the contracts placed during the preceding quarter
- the state of the geographical distribution of contracts.

The list of contracts is particularly important as it will provide Member States with good visibility of forthcoming contract decisions.

Approval of contracting method
Before any contract action is taken – be it an open, a restricted, or a noncompetitive tender – approval will have to be obtained in certain cases from the IPC after submission of a procurement proposal. This is a substantial change in procedure and one that will allow the IPC to broaden or to limit the number of potential tenderers and to redirect the choice of a recommended contractor. Intelligent application of this procedure should help to avoid situations in future where the outcome of invitations to tender is in conflict with the requirements of the Agency's industrial policy.

Procurement proposals will have to be submitted in accordance with Article 9 for:
- general studies exceeding 100 000 AU
- technological programmes exceeding 200 000 AU per activity committed
- procurements for the space segment exceeding 500 000 AU
- ground and facility investments (hardware and software) exceeding 500 000 AU
- such other cases that the IPC asks to be submitted for approval.

Decisions on restricted competitive and noncompetitive tenders
As in the past, open competitive tender will be the normal procedure for the placing of contracts. However, the contract regulations now foresee, under Articles 5 and 6, the possibility that the IPC may give a guideline or directive to restrict competitive and noncompetitive tender. It should perhaps be added here that in the past direct negotiations were only permitted in cases of a single source, in connection with earlier contracts, and in cases of extreme urgency, leaving aside contracts of low value, for which a simpler procedure was applied.

The new procedure will allow competition to be limited to the firms of one or more selected countries or negotiation with one firm only if the IPC deems that justified.

Outlook
The new regulations should allow the IPC to play a more active role in industrial-policy matters than in the past. The success of the new regulations will, of course, largely depend on the attitudes of the Member States in applying them and in particular on their willingness to come to a consensus. The new regulations will be reviewed after one year of application and their practicality assessed. Only then will it be possible to judge whether the new concept is really realistic or perhaps too ambitious.

In Brief

photo ch. laurentin

Second Spacelab purchased by NASA

Signature on 30 January 1980 of the ESA contract with European industry for the manufacture of a second Spacelab for delivery by 1984. Seated from left to right are Mr. B. Kosegarten, ERNO Commercial Managing Director, Mr. R. Gibson, Director General of ESA, and Mr. H. Hoffmann, ERNO Technical Managing Director

NASA has recently signed a contract valued at US$ 183 960 000 with ESA for the manufacture and delivery, by 1984, of a second Spacelab, as was foreseen in the Memorandum of Understanding concluded in 1973 between NASA and ESA. This contract was converted by ESA on 30 January into a contract with European industry.

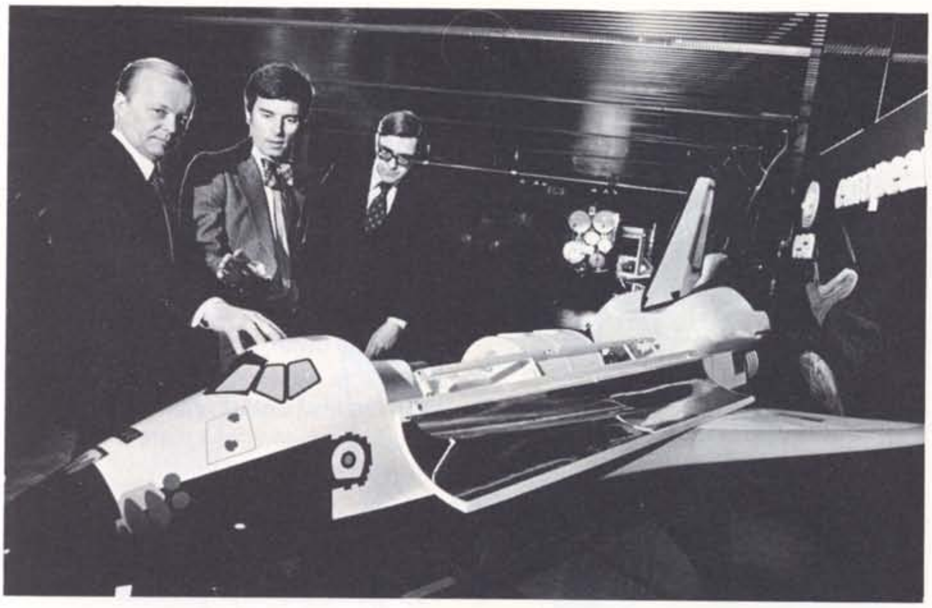
Under the terms of the NASA/ESA contract, NASA will be supplied with a fully-equipped Spacelab module, five instrumentation pallets, and various associated equipment and spares, with delivery dates phased over the period October 1981 to April 1984.

The second Spacelab, like the first which is expected to make its first flight in 1982, will have ERNO (Bremen, Germany) as ESA prime contractor. At least 26 subcontractors, in ten of the Agency's Member States – Germany, France, Italy, United Kingdom, Spain, Belgium, Netherlands, Switzerland, Austria and Denmark – as well as in the United States, are expected to be involved in producing components and subassemblies for the second Spacelab.

photo ch. laurentin

NASA Gift

The Administrator of NASA and the Director General of ESA meet at regular intervals to review progress on collaborative programmes and to discuss future possibilities of cooperation between the two organisations. At the meeting in Paris on 14 February 1980, Dr. Robert Frosch, Administrator of NASA, presented Mr. Roy Gibson, whose mandate as ESA's Director General ends on 14 May 1980, with a plaque in recognition of the latter's contribution to NASA/ESA cooperation. The plaque includes a small Union Jack which was taken to the Moon aboard Apollo XVII in December 1972.



A model of the Shuttle/Spacelab combination on display at an international exhibition 'Europäisches satelliten im Weltraum', at Daimler-Benz AG in Kiel (Germany) from 25 January to 10 February 1980. From left to right Horst Moebius, Director of Daimler-Benz (Kiel), Dr. Ulf Merbold, ESA Spacelab astronaut, and Dr. Reinhold Steiner, Director of ESA's European Space Operations Centre (ESOC), in Darmstadt (Germany)

Space-Transportation Press Conference

At a press conference held at the Agency's Paris Headquarters on 21 January, Mr. Roy Gibson, Director of ESA, Mr. Michel Bignier, Director of the Spacelab Programme, and Mr. Raymond Orye, Head of the Ariane Programme, made a joint presentation on the coming developments in space transportation in the context of Spacelab and Ariane. The presentation also included a showing of the video recordings and films of the highly successful first flight of Ariane on 24 December last.

Inauguration of 'Stella'

With the official opening of the CERN earth station on 6 March, the Commission of the European Communities (CEC), the European Organisation for Nuclear Research (CERN) and the European Space Agency (ESA) jointly inaugurated the European 'Stella' experiment, devoted to the experimental transmission of scientific data between CERN and six other high-energy physics laboratories in Europe via ESA's experimental communications satellite OTS.

In the course of the Stella experiment large amounts of electronic data will be transmitted with very high accuracy and at rates comparable with the working speeds of the computers, from CERN to:

- Desy Laboratory, Hamburg (Germany)
- CEA, Saclay (France)
- Rutherford Laboratory, Didcot (UK)
- Istituto Nazionale Fisica Nucleare, Pisa (Italy)
- National Board for Science and Technology, Dublin (Ireland)
- Institut für Nachrichtentechnik und Wellenausbreitung, Graz (Austria).

By exploring techniques for the high-quality transmission of large quantities of data at speeds of up to 1 Mbit/s (i.e. one million bits of information per second), Stella will help to strengthen European cooperation in the field of physics and at the same time provide the other bodies taking part with assistance in their planning of future European communications projects.

The Stella experiment is financed by ESA, the European Communities, the national telecommunications administrations of the countries concerned, and CERN.

photo cern

From left to right, R. Gibson, Director General ESA, L. van Hove, Research Director General CERN, F. Locher, Director Swiss PTT, F. Job, Secretary General Interim Eutelsat, and seated at the terminal M. Hine of CERN

Two Years of IUE Operations Completed

On 26 January the International Ultraviolet Explorer (IUE) satellite completed two years of outstandingly successful operations as an orbiting astronomical observatory. A joint venture by the UK Science Research Council (SRC), ESA and NASA, IUE has already been used by more than 500 scientists from 20 countries to study 12 000 ultraviolet spectra of planets, stars, the interstellar medium and other galaxies.

The satellite, in geosynchronous orbit some 30 000 km above the mid-Atlantic, was originally designed to have a minimum lifetime of three years, but this is now expected to be considerably exceeded (fortunately, because the observing time requested by astronomers is more than double that available in the three years).

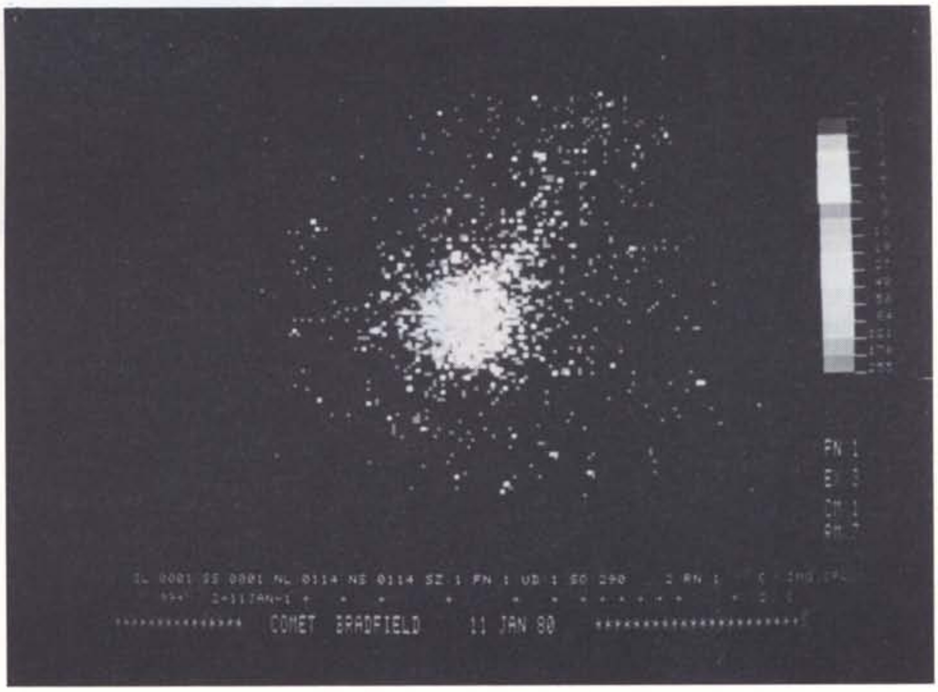
The satellite has pioneered a new method of operating a space telescope, in that astronomers visit a ground station to examine images relayed from IUE and they can direct the telescope in the same way as they would at a ground-based optical observatory. Although the space-based telescope is small (45 cm diameter) compared with modern ground-based optical telescopes, observing efficiency is high because there are no cloud problems, and long exposures can be made with minimal interference from background light.

Galaxy M100, about 60 million light years from earth (photograph courtesy of Asiago Observatory, Padua, Italy).

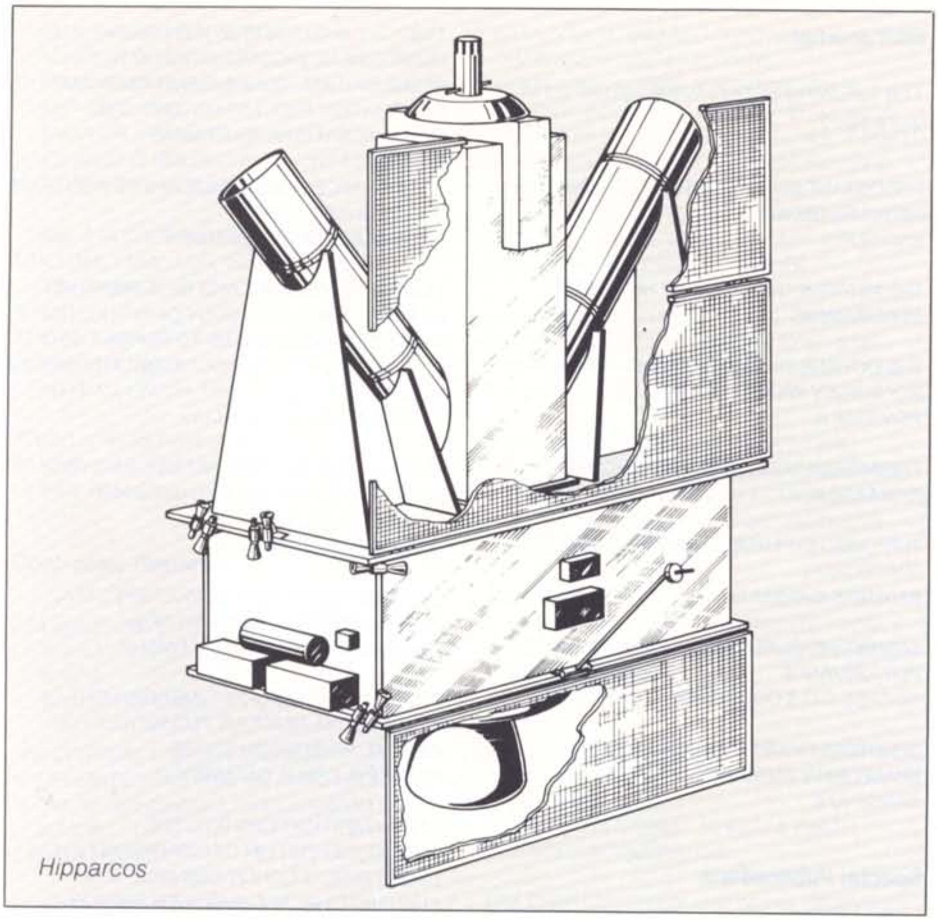
Using IUE, astronomers have already discovered that stellar winds – the process by which material is driven away from a star mainly by radiation pressure – exist in types of hot star not previously known to exhibit this phenomenon. Detailed data have been obtained on the material in the chromosphere and coronae of cool stars. New results show how the shock wave from an old supernova interacts with the interstellar material. Gas forming a hot coronal halo around the galaxy has been discovered, and it is believed that other galaxies also have such a halo. Ultraviolet studies have been made of X-ray binaries which are thought to comprise a normal star orbiting with an exotic object, which could be a white dwarf, a neutron star or a black hole. IUE observations have also been made of distant active galaxies, including quasars, which are known to emit vast amounts of energy.

The flexibility in operating with IUE has also allowed unexpected phenomena, such as the explosion of novae and supernovae or the approach of a bright comet, to be observed and followed at short notice. On 11 January, for example, IUE observed Comet Bradfield 1979–L, named after its discoverer, an Australian amateur astronomer. After crossing perihelion on 21 December 1979, and approaching the earth, it became visible via IUE at ESA's Villafranca ground station (near Madrid) on 11 January. Several ultraviolet spectra were obtained and these will allow the composition of the Comet's atmosphere to be determined.

These and many other results from IUE have already been extensively discussed at several international astronomical conferences in 1979, including the General Assembly of the International Astronomical Union (Montreal). There has already been one conference in 1980 devoted entirely to the results of IUE, namely 'The Second European IUE Conference', in Tübingen, Germany (26-28 March) co-organised by ESA and the Astronomical Institute at Tübingen (AIT). The Proceedings of this Conference are published this month as ESA Special Publication SP-157 and are available from ESA Scientific and Technical Publications Branch, ESTEC, Noordwijk (NL).



Comet Bradfield as seen by the fine error sensor of IUE on 11 January 1980. The bright head and extended cometary tail are clearly visible.



Hipparcos

explore the possibilities for cooperation with NASA, with a view to possible inclusion of the comet mission in the Agency's Scientific Programme, on the understanding that the schedule of the Hipparcos mission could, if necessary, be stretched to accommodate it.

Lastly, the Committee decided that ESA should issue a call for experiment proposals in order to establish a possible payload for a first Biorack mission.

New European Space Science Project Selected

At its 23rd meeting in Paris on 4 and 5 March, the Agency's Science Programme Committee selected the Hipparcos astrometry satellite as the next ESA scientific project. The other four candidates were: EXUV, an extreme-ultraviolet and soft X-ray sky-survey satellite designed to perform an unbiased survey of the celestial sphere; an international mission (ICM) combining a fast fly-by of Comet Halley in late 1985 and an extended rendezvous with Comet Tempel 2 in 1988/89; Geos-3, a magnetospheric explorer satellite dedicated to the study of the earth's geomagnetic tail; and the Biorack, a Spacelab facility aimed at providing a scientific research platform for developmental and genetic studies in cell and molecular biology.

The scientific goals of the space-astrometry mission Hipparcos are accurate measurements of the trigonometric parallaxes, proper motions and positions of about 100 000 selected stars. This information is relevant to many fundamental problems in astronomy and the Hipparcos mission could well lead to the discovery inside stars of physical processes that have hitherto escaped investigation, thereby introducing a new era in the theory of the internal structure of stars. These studies can have very many consequences for problems related to the structure and evolution of the galaxies and the structure of the universe. Hipparcos can provide astrometric data of very high quality, which will supersede nearly all existing data for the brighter stars, particularly the trigonometric parallaxes, and lead ultimately to an order of magnitude refinement in our understanding of the dynamics and structure of our galaxy.

With a mass of 376 kg (without apogee motor) including a payload of 117 kg, the Hipparcos spacecraft will be of very advanced design. It will have a lifetime of at least two and a half years in its geostationary orbit (equatorial inclination less than 3°) and it is to be launched in mid-1986 by Ariane. The total estimated cost of the project is 139.3 MAU (1 AU = ± 1.33 US$).

In addition, in its Resolution, the Science Programme Committee instructed the ESA Executive to pursue the study of a mission to Comet Halley, and to further

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table inside the back cover and using the Order Form on page 81

ESA Journal

The following papers were published in Vol 4 No 1;

THE DISTANT GEOMAGNETIC TAIL OBSERVING SATELLITE GEOS-3
KNOTT K

THE ASTROMETRY SATELLITE HIPPARCOS
BEECKMANS F

THE EXTREME-ULTRAVIOLET AND SOFT X-RAY SKY SURVEY PROJECT EXUV
PEACOCK A

THE INTERNATIONAL COMET MISSION (ICM)
REINHARD R

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SERENE B & ALBERTINOLI P

IN-ORBIT MEASUREMENTS OF OTS PAYLOAD PERFORMANCE
HUGHES C D & GOUGH R A

SPHERICAL NEAR-FIELD TESTING OF SPACECRAFT ANTENNAS
HANSEN J E

Special Publications

ESA SP-144 EXPLOSIFS ET PYROTECHNIE – APPLICATIONS SPATIALES. ACTES D'UN COLLOQUE INTERNATIONAL ORGANISE A TOULOUSE, FRANCE, 23-25 OCTOBRE 1979
W BURKE (ED)

ESA SP-157 SECOND EUROPEAN IUE CONFERENCE, PROC. INTERNATIONAL SYMPOSIUM CO-ORGANISED BY THE ASTRONOMICAL INSTITUTE, TUBINGEN AND THE EUROPEAN SPACE AGENCY, IN TUBINGEN, GERMANY, 26-28 MARCH 1980
B. BATTRICK (ED)

ESA SP-1025 CATALOGUE OF ESA PUBLICATIONS IN 1979 (APR 1980)
B. BATTRICK (COMPILER)

Technical Translations

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