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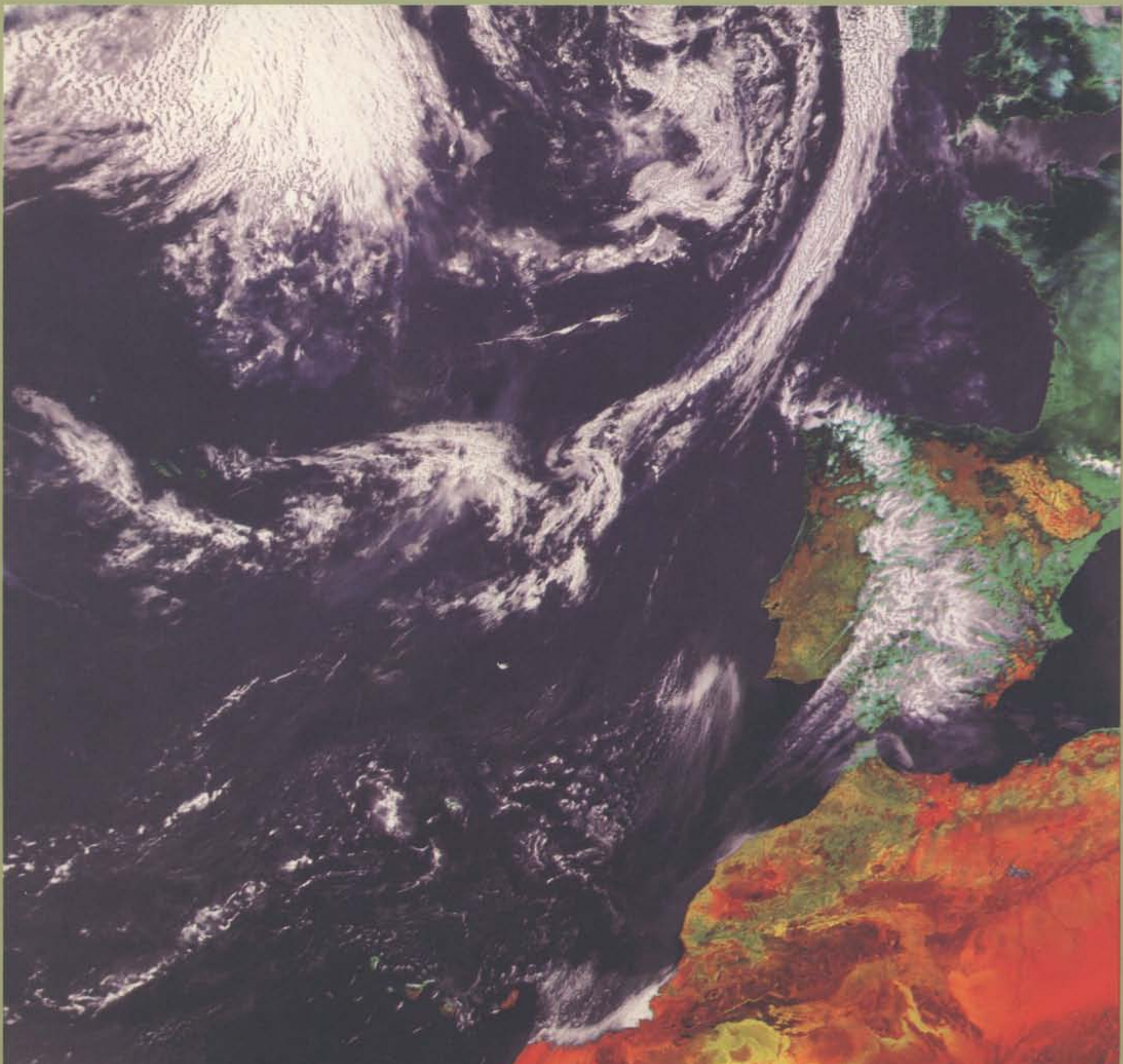

european space agency

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 Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an Associate Member of the Agency. Canada is a Cooperating State.

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 Inspector General; the Director of Scientific Programmes; the Director of the Earth Observation and Microgravity Programme; the Director of the Telecommunications Programme; the Director of Space Transportation Systems; the Director of the Space Station and Platforms Programme; the Director of ESTEC; the Director of Operations and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

THE EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE (ESTEC), Noordwijk, Netherlands.

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

ESRIN, Frascati, Italy.

Chairman of the Council: Dr. H.H. Atkinson.

Director General: Prof. R. Lüst.

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, l'Autriche, la Belgique, le Danemark, l'Espagne, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. Finlande est membre associé de l'Agence. Le Canada beneficie d'un statut d'Etat coopérant.

Selon les termes de la Convention: L'Agence a pour mission d'assurer et de développer, à des fins exclusivement pacifiques, la coopération entre Etats européens dans les domaines de la recherche et de la technologie spatiales et de leurs applications spatiales, en vue de leur utilisation à des fins scientifiques et pour des systèmes spatiaux opérationnels d'applications:

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(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 satellite 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.

L'Agence est dirigée par un Conseil, composé de représentants des Etats membres. Le Directeur général est le fonctionnaire exécutif supérieur de l'Agence et la représente dans tous ses actes.

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LE CENTRE EUROPEEN D'OPERATIONS SPATIALES (ESOC), Darmstadt, Allemagne.

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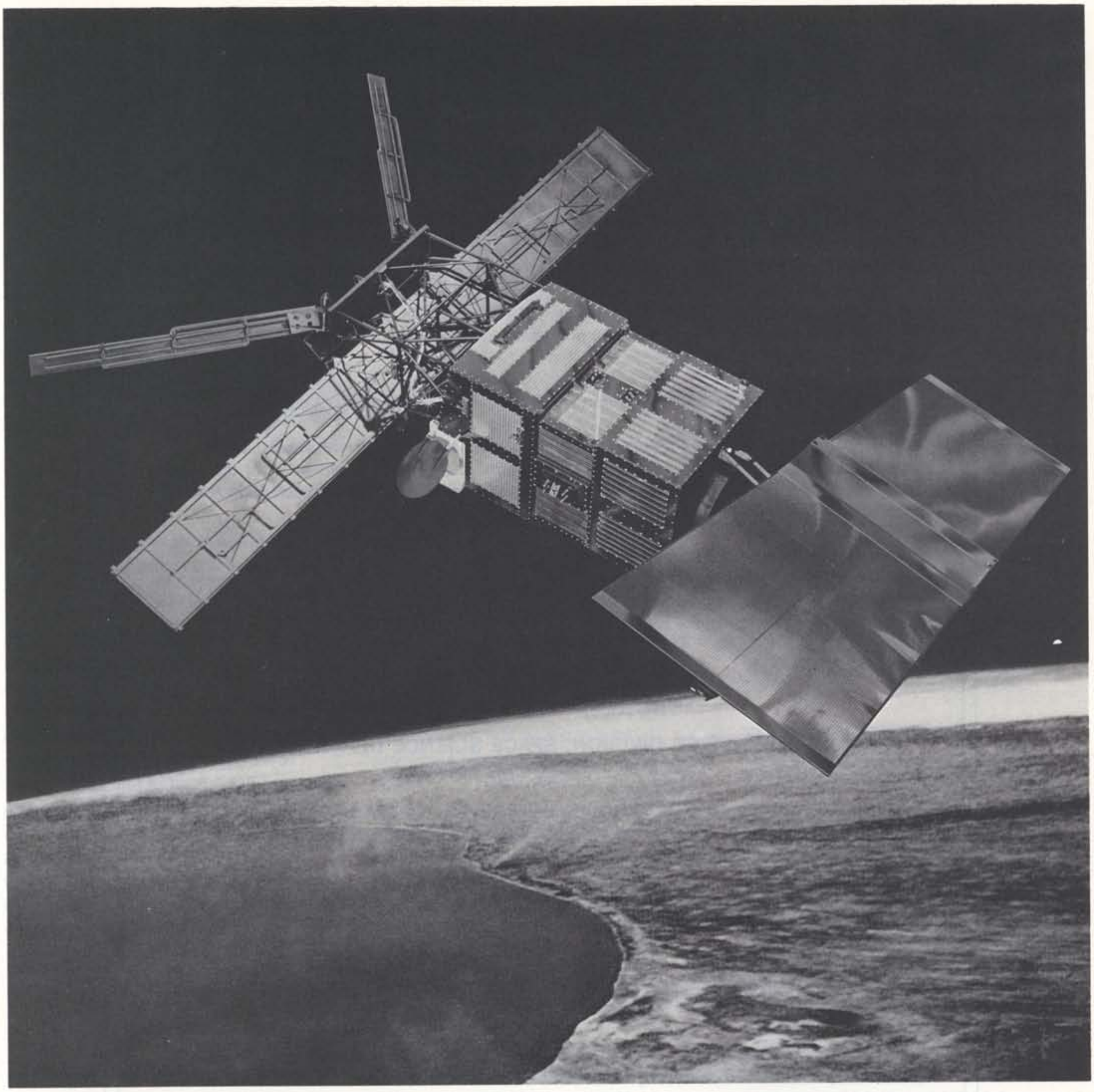


AVHRR Data Services in Europe — The Earthnet Approach

L. Fusco & K. Muirhead, Earthnet Programme Office, Frascati, Italy

In response to the increasing utilisation by Europe's remote-sensing community of data from the Advanced Very-High-Resolution Radiometer (AVHRR) on the NOAA polar-orbiting meteorological satellites, ESA/Earthnet are implementing a scheme for the coordinated acquisition, archiving, processing and dissemination of these data. The scheme will include a guaranteed historical dataset for all areas of interest, an internationally-accessible on-line catalogue, and fully-annotated user products in raw form or preprocessed to geophysical values.

* NROSS programme cancelled per January 1987.

What is Earthnet?
Earthnet is the operational earth-observation branch of the European Space Agency. It consists of a network of satellite-receiving and processing stations, and National Points of Contact coordinated by the Earthnet Programme Office in Frascati, Italy. Through this network, Earthnet acquires and processes remotely-sensed Earth imagery and then archives and distributes it both to the European user community and also worldwide. In effect, Earthnet acts as a buffer between the raw data and the end users and provides a unique interface for enquiries and ordering.

To date, Earthnet has acquired and distributed data from the US remote-sensing satellites Seasat, Heat-Capacity-Mapping Mission (HCMM) and Nimbus-7, and continues its operational service with the ongoing Landsat series. In addition, imagery is available from the Metric Camera — a photographic instrument carried on ESA's Spacelab — and from two European airborne synthetic-aperture radar campaigns (SAR-580 and Agrisar '86).

Future involvement in non-European missions will include Japan's MOS-1, the US Navy/NASA NROSS* spacecraft and Canada's Radarsat, but extensive preparations are also underway to define and implement the ground segment for ESA's own remote-sensing satellite, ERS-1, which is scheduled for launch in late 1989.

Of more immediate concern, however, is Earthnet's latest user service — namely the coordinated acquisition, archiving, processing and distribution of AVHRR data from the polar-orbiting meteorological satellites of the US National Oceanographic and Atmospheric Administration (NOAA).

The NOAA-series satellites
This series of satellites (Fig. 1), the current sequence being known as the Advanced Tiros-N (ATN) series (after the prototype), has been in continuous operation since October 1978 (Table 1). In its full configuration it consists of two satellites in complementary near-polar orbits, with one crossing the equator at local solar times of approximately 0730 and 1930, and the other at 0230 and 1430. By convention, the even-numbered satellites cover the 'morning orbit' (0730) and odd-numbered satellites the 'afternoon orbit' (1430). These are presently NOAA-10 and NOAA-9, respectively.

Unlike most Earth-observation or meteorological-satellite missions, the NOAA series may be regarded as genuinely operational, with four additional spacecraft guaranteed for the ATN sequence (the first of these will be ready for launch by December 1987) and three currently planned for the follow-on NOAA next-sequence (December 1992, March 1994 and June 1995). The NOAA series was designed primarily for meteorological applications and the two principal payload instruments serving this purpose are the Tiros Operational Vertical Sounder (TOVS) and the Advanced Very-High-Resolution Radiometer (AVHRR).

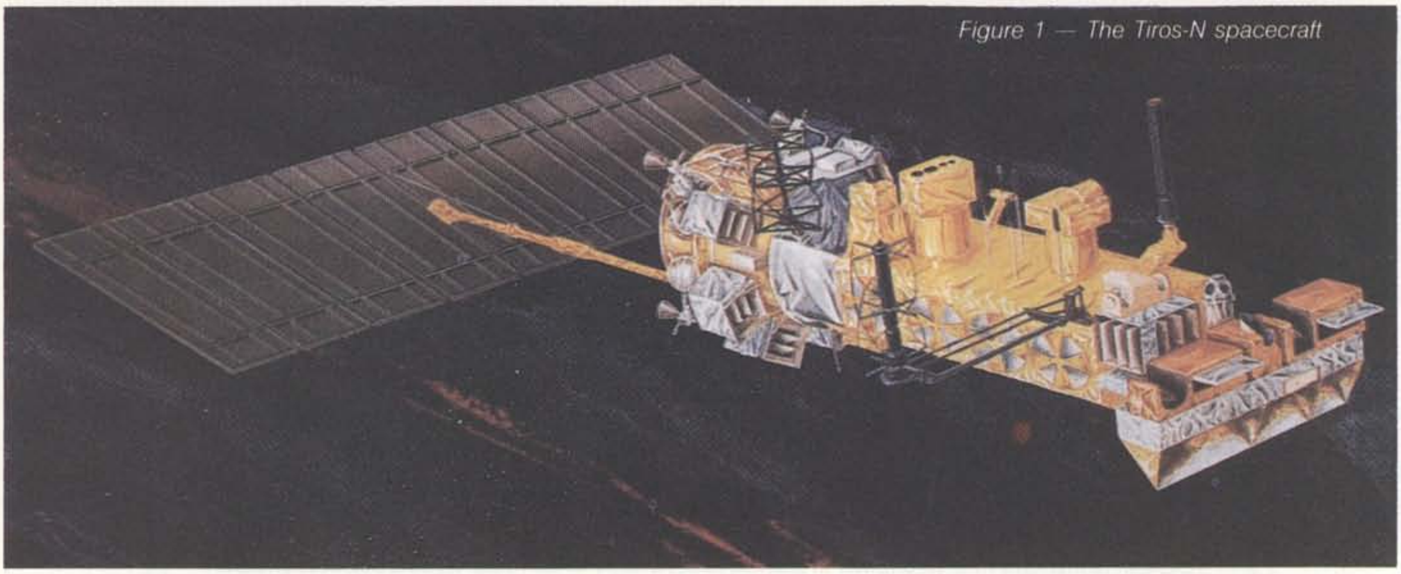


Figure 1 — The Tiros-N spacecraft

Table 1 — Characteristics of the NOAA-series satellites

Satellite	Period of operation*
Tiros-N	19 Oct. 1978 — 30 Jan. 1980
NOAA-6	27 Jun. 1979 — 30 Jun. 1986**
NOAA-7	24 Aug. 1981 — 11 Jan. 1985
NOAA-8	3 May 1983 — 6 Mar. 1986**
NOAA-9	25 Feb. 1985 — present
NOAA-10	20 Sep. 1986 — present

* These dates are approximate
** Gaps in operation, and quality suffers near end of lifetime.

Instruments (carried or planned for flight on one or more satellites)

— Advanced Very-High-Resolution Radiometer (AVHRR)
— Tiros Operational Vertical Sounder (TOVS) consisting of:
  (i) High-Resolution Infrared Radiation Sounder (HIRS/2)
  (ii) Microwave Sounding Unit (MSU)
  (iii) Stratospheric Sounding Unit (SSU)
— Space Environment Monitor (SEM)
— Data-Collection System (DCM) — ARGOS
— Earth Radiation Budget Experiment (ERBE)
— Solar Backscatter Ultraviolet Radiometer (SBUV/2)
— Search and Rescue (SAR) Demonstration System

Orbit type

Near-polar, circular, Sun-synchronous

Semi-major axis	**Nominal altitude**
7231.8 km	853.7 km
Inclination angle	**Orbital period**
98.8° (approx.) (102.3° — Tiros-N)	101—102 min

Equator crossing time

	Even-numbered satellites (6, 8, 10, etc.)	Odd-numbered satellites (7, 9, etc.)
Ascending node	1930	1430
Descending node	0730	0230

(approximate mean local solar times)

The Advanced Very-High-Resolution Radiometer

The current AVHRR is a four- or five-channel passive scanning radiometer. It has one visible channel, one near-infrared, one mid-infrared, and one or two far-infrared channels (Table 2). Its scanner sweeps out a continuous 3000 km-wide swath on the Earth's surface, with a nominal ground resolution of about 1 km square. 3000 km equates to 27.2° of longitude at the equator and the orbital characteristics are such that the equator crossings of successive orbits are separated by 25.3°. Consequently, there is no gap in coverage, so that with two satellites in operation the possibility exists for twice daily and twice nightly coverage of any point on the equator and approximately twice this (8 passes in total) at mid-latitudes such as Europe (Fig. 2).

It was this high repeat-cycle characteristic of the AVHRR, enhancing the likelihood of cloud-free imagery and facilitating useful time-series projects, which first attracted the interest of the remote-sensing community. However, it is also true that the relatively low cost of data, which is an order of magnitude less than traditional imagery such as that from Landsat, played a significant part.

Data from the AVHRR can be acquired in four distinct modes:

1. The most frequently utilised and most useful form is by direct reception at a ground station of full-resolution digital data, referred to as High-Resolution Picture Transmission (HRPT).
2. Alternatively, full-resolution data may be recorded onboard the spacecraft (up to 10 min per 102 min orbit) and

Figure 2 — AVHRR ground swath for successive northbound passes of one of the NOAA-series satellites

dumped at one of the NOAA/NESDIS (National Environmental Satellite Data and Information Service) Command and Data Acquisition (CDA) stations at Wallops Island, Virginia and Gilmore Creek, Alaska. This is termed Local Area Coverage (LAC), and is the only way to acquire 1 km resolution imagery for the large areas of the World not covered by HRPT receiving stations.

3. A third source of digital data, the Global Area Coverage (GAC), is resampled from 1 km to about 4 km resolution and recorded for an entire orbit, to be dumped at Wallops Island or Gilmore Creek. GAC data, as the name implies, allows daily imaging of

Table 2 — The Advanced Very-High-Resolution Radiometer (AVHRR)

Spectral characteristics*

	Channel-1	Channel-2	Channel-3	Channel 3A	Channel 4	Channel 5
Tiros-N	0.55—0.90	0.72—1.10	3.55—3.93	—	10.5—11.5	—
NOAA-6, 8, 10	0.58—0.68	0.72—1.10	3.55—3.93	—	10.5—11.5	—
NOAA-7, 9 and next four craft	0.58—0.68	0.72—1.10	3.55—3.93	—	10.3—11.3	11.5—12.5
(1992 onwards)	0.58—0.68	0.82—0.87	3.55—3.93 (nighttime)	1.57—1.78 (daytime)	10.3—11.3	11.5—12.5

* Wavelengths in microns

Scanner characteristics

Total field of view		110.8° (centred on nadir)	
Instantaneous Field of View (IFOV)		1.4 mrad (approx.)	
Sampled IFOV		0.95 mrad	
Samples per scan line		2048	
Scanning rate		6 Hz	
Ground resolution (km)		Along-track	Across-track
(at 1.4 mrad)	nadir.	1.1	1.1
	+/− 55.4°	2.5	7.0

Radiometric characteristics

Resolution	— 10 bit (1024 digital levels)
Full-scale signal	— 100% albedo (brightest cloud) (Channels-1, 2, 3A) — 320 K (approx.) (Channels 3, 4, 5)
Accuracy	— Signal-to-noise ratio of 3:1 at 0.5% albedo to be improved to 9:1 for AVHRR/3 Channels-1 and 2 and 20:1 for Channel-3A — NEdT of 0.12 K at 300 K

virtually the whole of the Earth's surface and, in spite of its low resolution, is being utilised for many applications, including operational sea-surface-temperature charts, continental vegetation-index maps, and even a global fire product.

4. Finally, the AVHRR provides an Automatic Picture Transmission (APT) facility, a continuously transmitted signal which may be captured and displayed by relatively inexpensive omnidirectional antennas and unsophisticated imaging equipment. APT data is a processed subset of two of the original AVHRR channels and contains analogue data with an effective resolution of about 4 km. Its primary utility, apart from the fact that it does not require elaborate equipment, is that it may be received onboard ships for real-time analyses of weather patterns and sea-surface-temperature fronts.

The improved AVHRR (AVHRR/3) of the NOAA/next-series (December 1992 onwards) will incorporate the following refinements:

1. The signal-to-noise ratio of Channels 1 and 2 will be increased from 3:1 to at least 9:1 at 0.5% albedo.
2. The spectral response of these two channels will be made more symmetrical (to approach an ideal rectangular response), with Channel 2 being considerably narrowed for improved vegetation-index calculations.
3. An additional channel at 1.6 microns (Channel 3A) will be introduced to provide better discrimination between snow and clouds and for improved measurements of plant moisture and leaf water content. Data from this spectral band is to be time-shared with the 3.7 micron channel. The 1.6 micron imagery will be transmitted during the daylight part of the orbit with the 3.7 micron data (which is essentially useful for its thermal content rather than reflectivity) being transmitted at night.

AVHRR data applications

As previously mentioned, the original mission for the AVHRR was the operational collection of meteorological data such as cloud cover/classification and sea/land surface temperatures. Today, however, the instrument is being employed for such diverse applications as:

- drought early warning
- regional and global vegetation monitoring
- snow and ice mapping
- dynamical oceanography
- hydrology
- geology
- detection of forest fires, gas flares and agricultural burning
- fire fuel mapping
- volcanology
- air and sea pollution monitoring (Fig. 3)
- continental-scale mapping (less than 1:3 000 000) (Fig. 4).

The extensive usage of AVHRR data in such a wide variety of disciplines can be attributed to a number of factors, principally:

- repetitive coverage, which is typically twice daily plus twice nightly, as opposed to twice monthly (at best) for the high-resolution satellites such as Landsat and Spot
- low data costs
- large-area coverage: a single acquisition from one station can cover 3000 km by 6000 km (cf. 185×185 km for Landsat), and the entire scene will fit onto one Computer-Compatible Tape (CCT)
- high radiometric resolution (1024 digitised levels)
- three thermal-infrared (IR) channels with absolute calibration, allowing atmospheric corrections to be made for true surface temperatures.

NOAA, the satellite operators, recognised

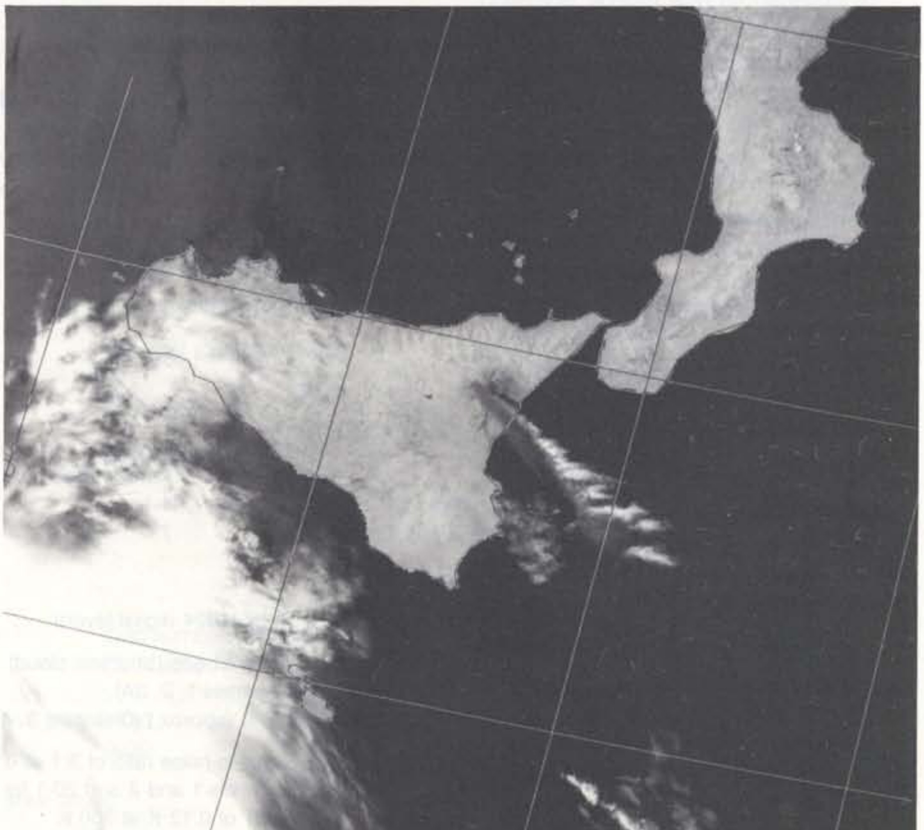


Figure 3 — AVHRR near-infrared (Channel-2) image showing smoke and ash issuing from Mount Etna on Sicily at about 13.30 GMT on 15 May 1983 (Image processed by University of Dundee)

Figure 4 — Geometrically-rectified and transformed AVHRR mosaic of Europe derived from Channels-1, 2 and 4 (visible, near-infrared and thermal infrared). The image is a composite of a number of virtually cloud-free scenes acquired between 1979 and 1985 (Image processed by RAE, Farnborough)

Figure 5 — An example of the unique AVHRR coverage of West Africa provided by Earthnet's HRPT station at Maspalomas on the Canary Islands. The scene was acquired from a northbound pass of the NOAA-9 satellite between 15.09 and 15.21 GMT on 1 July 1986. It has been processed (using Channels-1, 2, 3 and 4) to distinguish between sea, clouds, vegetation, arid and semi-arid land. Particularly evident here is the application of AVHRR imagery for both meteorologists and Earth scientists alike. For the former group, enhancement of the cloud tops has highlighted features such as the thunderstorms around the River Niger while, for the Earth scientists, the vegetation/arid-land categorisation brings out the striking transition between the Sahara Desert and the more fertile lands to the south (Image processed by DFVLR, Oberpfaffenhofen)

the AVHRR's potential for non-meteorological applications and took the decision to reduce the spectral overlap between Channels 1 and 2 immediately after Tiros-N, the prototype. This enabled the determination of vegetative biomass using the near-IR/visible differential response. Such measurements will be further enhanced for AVHRR/3 of the NOAA next sequence, when these two spectral bands are made more discrete and given a higher radiometric sensitivity. In addition, the new channel at 1.6 microns will contribute information on leaf water content, thereby providing a powerful overall package for vegetation monitoring.

Of course, the AVHRR, with its 1 km imagery, can never replace the high-resolution remote-sensing satellites. When applications do overlap, as is the case with vegetation and coastal studies, for example, the medium-resolution, high-repetitivity AVHRR data complements Landsat, Spot, MOS, etc. by providing a synoptic view and by filling the temporal gaps in coverage. The complementary nature of AVHRR and Landsat data is already being exploited in the Famine Early Warning System for Africa.

HRPT acquisition in Europe

Currently ten HRPT receiving stations with a CCT processing capability are operational in Europe. The United Kingdom and West Germany support two each, while Denmark, France, Italy, Norway, Spain (Canary Islands) and Switzerland all have one each. There is also a station at Sondre Stromfjord in Greenland. Further acquisition stations are planned for Madrid (Spain) and Norrköping (Sweden), and there are two proposals to build stations in northwest Africa — at Niamey in Niger and at Dakar in Senegal.

On the face of it, Europe is very well served for full-resolution AVHRR data, there being considerable overlaps between the acquisitions of the dozen or so stations. However, for the most part, the stations were set up to serve the real-time or near-real-time needs of their respective national meteorological services. Consequently, there was very little incentive to consider the basic requirements of remote-sensing users, namely a suitably long archive, an externally-accessible catalogue, and some degree of standardisation between stations.

The current operational stations have widely-varying acquisition and archiving strategies and the CCT formats for image distribution are different for every single station. The quantity of data archived varies from one satellite pass per day (Rudeskov, Denmark and Trømsø, Norway) to all available passes (10—16 per day) (CMS Lannion, France and RAE Lasham, England). Archiving periods are between two weeks (RAE Lasham) and indefinitely (Dundee University, Scotland).

Prompted by the ever-increasing usage of AVHRR data for non-meteorological applications, Earthnet decided that it should become actively involved in providing a service to Europe's AVHRR users. The first action was to upgrade the existing Earthnet station on the Canary Islands to receive HRPT in support of Commission of European Communities (CEC) programmes in West Africa (Fig. 5). The second was the definition, leading to the eventual implementation, of a strategy for the coordinated acquisition, archiving, processing and distribution of the data for Europe.

Earthnet's Maspalomas Station

Maspalomas is located on Gran Canaria in the Canary Islands. The station has been used for reception of the Nimbus-7 Coastal-Zone Colour Scanner (CZCS) and continues to acquire Landsat Multispectral Scanner (MSS) imagery. Under funding from the CEC, the acquisition and processing equipment was upgraded in 1986 to receive HRPT data and it became operational in July of that year. The principal attraction of Maspalomas in terms of AVHRR data lies in the unique coverage that it provides over Northwest Africa and, in particular, over the Sahel region, which is the southern transition zone of the Sahara desert (Fig. 6). A number of projects are being undertaken in this region primarily to monitor the perpetual southward growth of the desert. The CEC itself is running eight projects, collectively called 'Thematic Actions — Desertification', as part of the 'Hunger Relief in the World' programme.

AVHRR coordination strategy

The goal of this coordinated European AVHRR service (Fig. 7) is to provide an effective and widespread user service, whilst causing the minimum impact on existing facilities. This is an important consideration because the ESA/Earthnet scheme is not intended to replace individual receiving stations, but rather to complement them by feeding from their short-term archives to set up a guaranteed and extensive historical dataset and by removing the complicated burden of processing raw data into useful geophysical values. Existing facilities will continue to serve their national interests and to provide real-time data products.

Five requirements have been identified that together provide the most effective solution to an efficient service:

(i) coordinated acquisition
(ii) central user service including on-line catalogue
(iii) common long-term archive
(iv) standard tape format
(v) preprocessed user products.

Coordinated acquisition

It is hoped that very little actual 'coordinating' of receiving facilities will be required, but that the datasets for the ESA/Earthnet archive would be satisfied by the stations' existing acquisition strategies. The minimum archival requirement has been identified as one complete day and night coverage of all European areas of interest every 24 h.

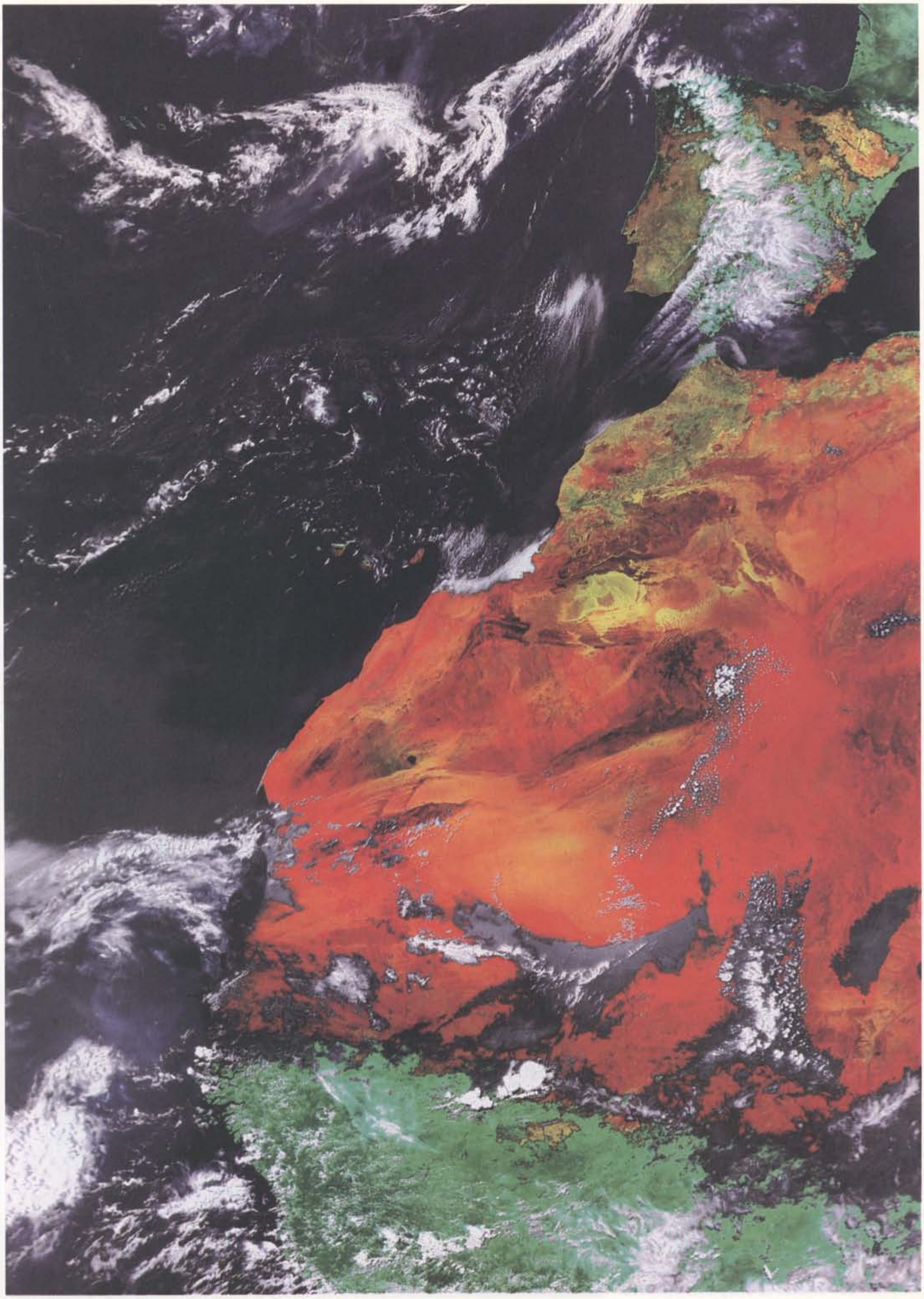


Figure 6 — Enlargement of Figure 5 covering Northwest Africa and the Canary Islands. Sparsely vegetated areas of Morocco show up in light green, but for the rest of this region (mainly the Sahara Desert) the yellows and reds represent a combination of the near-infrared (reflective) response and the thermal-infrared (temperature) response. In some areas the thermal-infrared sensors were saturated, indicating surface temperatures in excess of 50°C (Image processed by DFVLR, Oberpfaffenhofen)

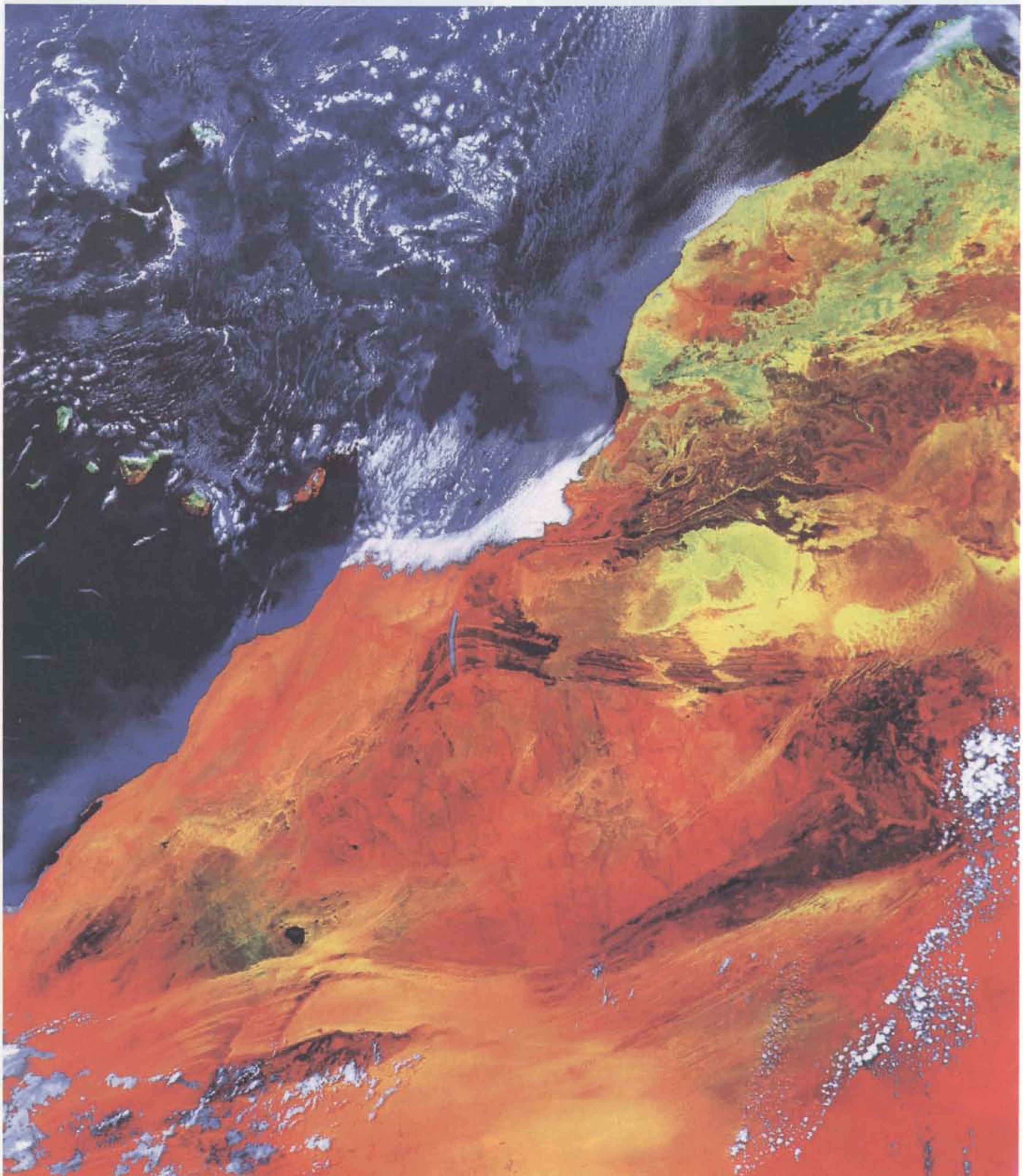


Figure 7 — Structure of the ESA/Earthnet coordination scheme for AVHRR data

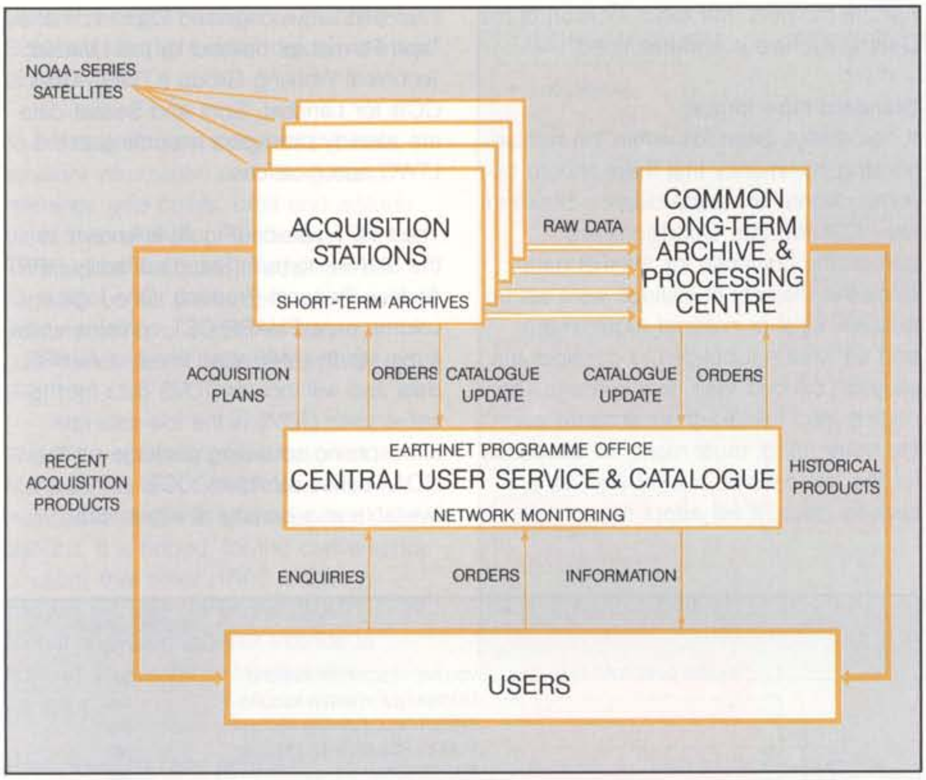
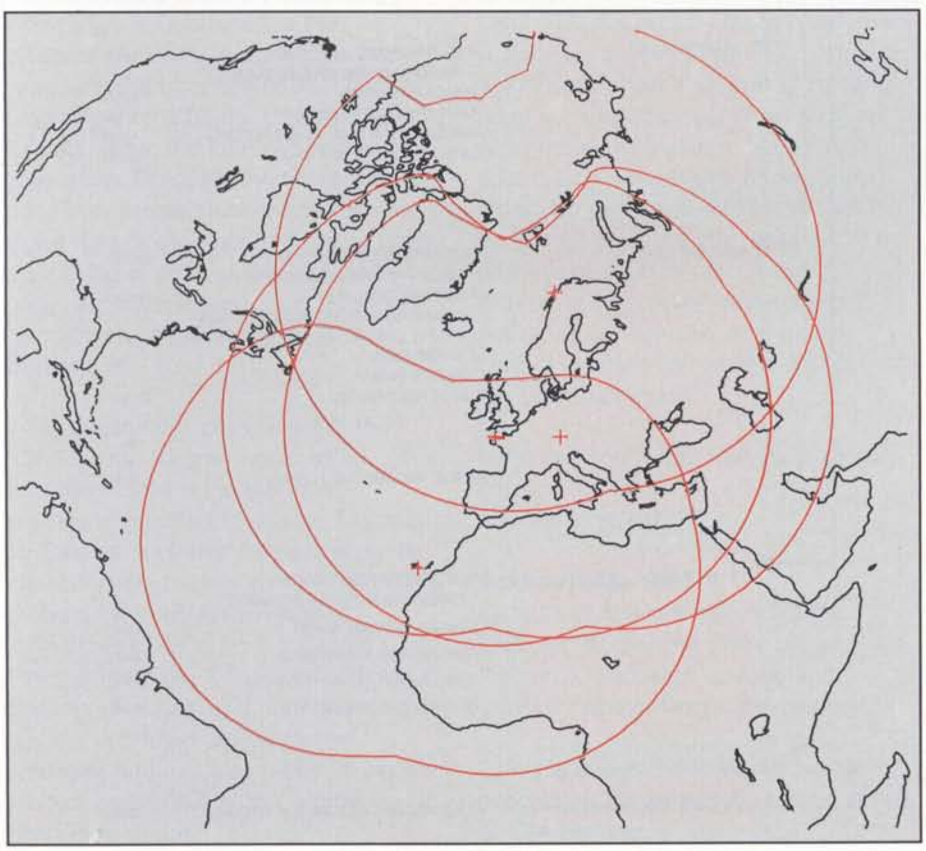


Figure 8 — Limit of AVHRR coverage from the HRPT stations at Trømsø (Norway), CMS Lannion (France), DFVLR Oberpffaffenhofen (West Germany) and Maspalomas (Canary Islands, Spain)



According to a recent user survey, the geographical interests of the European remote-sensing community encompass the entire reception limit of all Europe's acquisition stations from North Africa up to the Arctic, and from the Middle East across to the North Atlantic. As a result of the 3000 km-wide AVHRR swath, and the considerable overlap between one orbit and the next, the whole area may be covered by four successive passes of either satellite (Fig. 2). These four orbits may be acquired by only three or four strategically-located receiving stations (Fig. 8), with each taking that pass which is nearest to being overhead (i.e. with the maximum possible horizon-to-horizon duration). It is ESA's responsibility to order the appropriate dataset from each station and to piece together the acquired sections to form a complete coverage.

Present plans call for each station participating in the network to be supplied with a virtually autonomous subsystem to reformat the HRPT data and store it on optical disk. When the disk is full, or after a predefined time period (e.g. 1 week), the disk is to be posted to ESA's HRPT Common Archive Facility.

To launch this scheme, Earthnet hope to secure the cooperation of those existing HRPT stations whose acquisition strategies and processing capabilities require least intervention before that station is able to participate fully in the network.

Central User Service and catalogue
The Central User Service (CUS) is located at the Earthnet Programme Office (EPO) in Frascati. It is responsible for ensuring that the desired daily coverage of AVHRR is captured, by scheduling the network acquisition stations (and backup stations if necessary). In addition, it acts as a unique focal point for user enquiries and data ordering and provides an electronic bulletin-board of network activities and general satellite information.

Co-located with the CUS will be the on-line catalogue containing details of all archived imagery, processed products, and acquired data still to be put into archive. The Tiros catalogue will be similar to the current Landsat facility at EPO, and will be accessible on a worldwide basis via ESA's Information Retrieval Service (IRS), thereby taking advantage of an existing and very extensive communications network. It is expected to be operational by the first quarter of 1987.

During a catalogue search, the user will be able to define: one or more specific satellites, one or more acquisition stations, a single orbit, a particular temporal range, geographical area of interest, maximum view angle, and day or night passes (or both). It will also be possible to enquire on future acquisitions.

Geographical areas may be specified by: minimum and maximum latitude and longitude, single point or Landsat track/frame World Reference System (WRS-2).

Common Long-Term Archive

The Long-Term Archive, as mentioned earlier, will be fed at regular intervals from the network receiving stations. Upon receipt of an optical disk containing, for example, one week's acquisition for a single station, checks will be made on the data content and quality, and the Central Catalogue will be updated accordingly. All raw data will be archived for a minimum period of five years and probably much longer.

The Archive will also act as a Central Processing Facility, being responsible for the creation of all user products from the moment of raw data transference. The stations themselves may be regarded as short-term archives and will fulfil the more urgent user requests although, for convenience, all orders may be directed through EPO, which will relay them to the appropriate facility.

For the moment, the exact location of the Central Archive is undetermined.

Standard tape format

It has always been felt within the remote-sensing community that there should be some degree of standardisation between user CCT formats. Conditions are particularly disparate for AVHRR data, since the majority of stations were set up to serve local or national requirements and so were not obliged to consider the situation beyond their own borders. The coordinated ESA/Earthnet scheme, on the other hand, must make full allowance for the international market and, as a consequence, it will adopt the internationally-recognised Standard-Family Tape Format as defined by the Landsat Technical Working Group (LTWG). User CCTs for Landsat, Spot and Seasat data are already produced according to the LTWG specifications.

The HRPT version (Fig. 9) is known as the SHARP format (Standard-family HRPT Archive Request Product). One logical volume on a SHARP CCT contains up to 4 min worth (1440 scan lines) of AVHRR data and will include TOVS data for the entire pass (TOVS is the low-data-rate atmospheric sounding package on the NOAA-series satellites). CCTs will be available at a density of either 1600

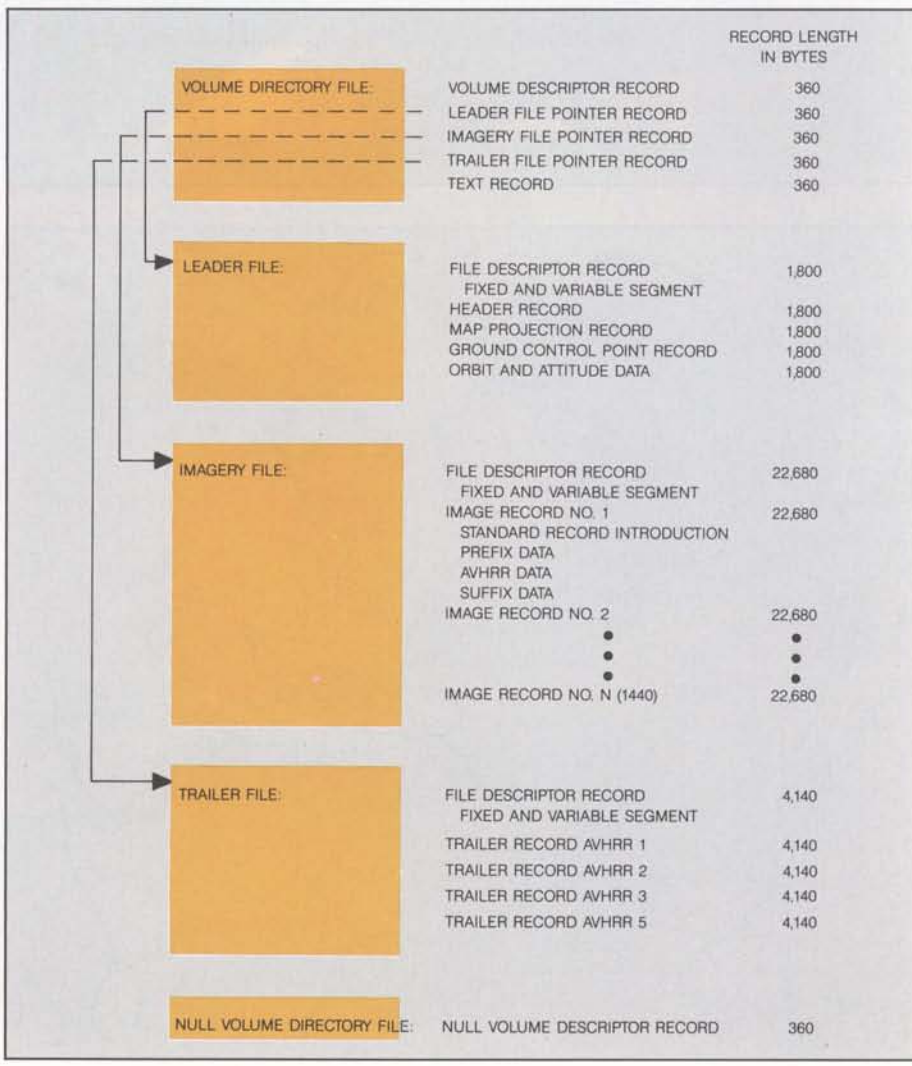


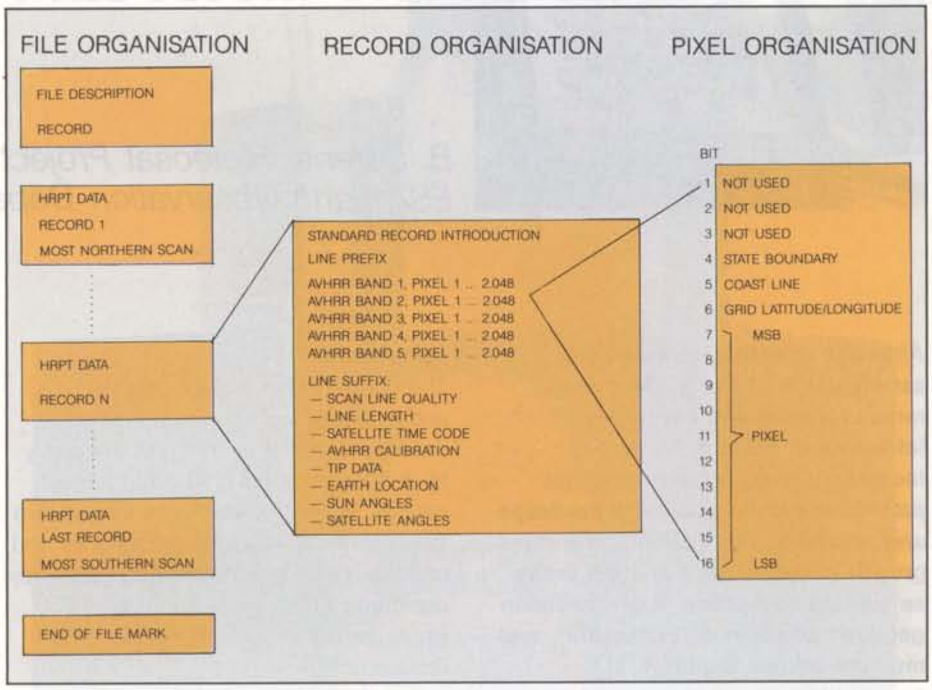
Figure 9 — Overview of the SHARP format, the HRPT version of the standard family of tape formats

bit/inch (1 logical volume plus TOVS) or 6250 bit/inch (up to four logical volumes plus TOVS).

To facilitate efficient usage of the data, auxiliary information such as ground reference grid points, orbit and attitude data, and calibration coefficients will be included on the tape. In addition, bit flags will be set within each pixel word to indicate points of coastline, state boundaries and/or latitude/longitude grids (Fig. 10).

SHARP is under implementation at Maspalomas and DFVLR and will be installed later at the other network stations. It is hoped, for the convenience of users, that other HRPT receiving stations will also adopt the SHARP format and ESA/Earthnet intends to provide assistance to facilitate this transition.

Figure 10 — Structure and content of the SHARP-format Imagery File



Preprocessed user products

Remote-sensing users are becoming increasingly sophisticated in their utilisation of satellite imagery. For many years after the inception of the Landsat programme in 1972, the greatest demand for data was in the form of basic hard-copy prints. Gradually the trend moved away from simple pictures towards raw digital data. Today, more and more users are looking to process this raw data into geophysical parameters such as surface reflectances, temperature, vegetation biomass, etc.

A highly desirable component of the ESA/Earthnet scheme would be to unburden users of the elaborate processing required to achieve this and so Earthnet is currently investigating the possibility of providing standard high-level products. With all AVHRR-related products emanating from a Central Processing Facility (co-located with the Common Archive), users are guaranteed that the very latest algorithms are employed and that they receive a uniform product irrespective of the original acquisition station.

Three levels of product processing are envisaged:
Level 1 — raw digital data with extensive supplementary information for users who wish to undertake their own processing.
Level 2 — geophysical values such as sea-surface temperature, or synthetic geophysical values such as vegetation index. No geometric rectification will be performed on these data because of the problem of choosing a suitable projection, but ground reference grid points will be included for the user.
Level 3 — maps or statistics derived from the Level-2 products.

If the demand exists, ESA/Earthnet may consider processing TOVS data in addition to AVHRR.

Acknowledgements

Keith Muirhead is employed at the Earthnet Programme Office under ESA's Research Fellowship scheme and gratefully acknowledges that support.

Credit is due to the following people for conducting the various studies on behalf of ESA/Earthnet:

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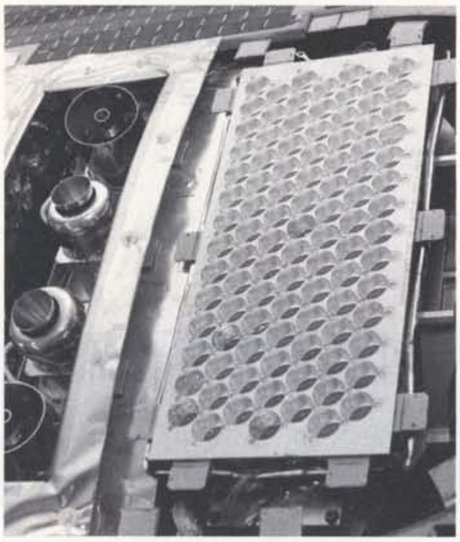
- Y. Kerr and P.Y. Deschamps of the Laboratoire d'Etudes et de Recherches en Télédétection Spatiale.



The LASSO Experiment on The Meteosat-P2 Spacecraft

B. Serene, Meteosat Project Office,
ESA Earth Observation Department, Toulouse, France

Although available services can satisfy some of the present user needs for time and frequency information, there is an ever-increasing need for services that provide improved accuracy, coverage and reliability. For example, the rapid growth in technology in such areas as precise navigation, high-precision geodetic position determination, and multiple-access digital communications, has resulted in a need for intercontinental time comparison and synchronisation down to nanosecond accuracies.

Introduction

The constant demand for greater accuracy has led to an improvement in the measurement of time and frequency by a factor of at least 10 over the past century. While the limiting accuracies are still confined to research laboratories and institutes dealing with time and frequency standards, commercial and scientific users are not far behind in their requirements:

— Digital communication	10 μs
— International telephone communication	1 μs
— Earth-based navigation	1 μs
— Deep-space navigation	20 ns
— Radio-astronomy	1 ns
— Geodesy	as accurate as possible
— Relativity	as accurate as possible
— Astronomy	as accurate as possible

Applications and research programmes already planned for the next decade will require nanosecond accuracy or better. Permanent long-baseline clock synchronisation is therefore currently of considerable practical interest.

Present users of time and frequency information have access to a variety of services and techniques for the dissemination of this information. These include the well-known high- and low-frequency broadcast services operated by various administrative bodies throughout the world, portable-clock methods, the use of television transmissions and satellite techniques (Table 1).

While existing services are undoubtedly capable of some improvement,

Table 1 — Methods currently used for time synchronisation

Method	Accuracy	Remarks
Very-Long-Baseline Interferometry (VLBI) using pulsars	1 ns	Slow, expensive ground stations
TV-type transmission via satellite	10 ns	Requires a wideband spacecraft transponder
Symphonie-B	20 ns	Requires two-way transponder
Portable clocks	30 ns	Slow
Timation-3	100 ns	Military
Loran-C	300 ns	Accuracy limited by propagation phenomena

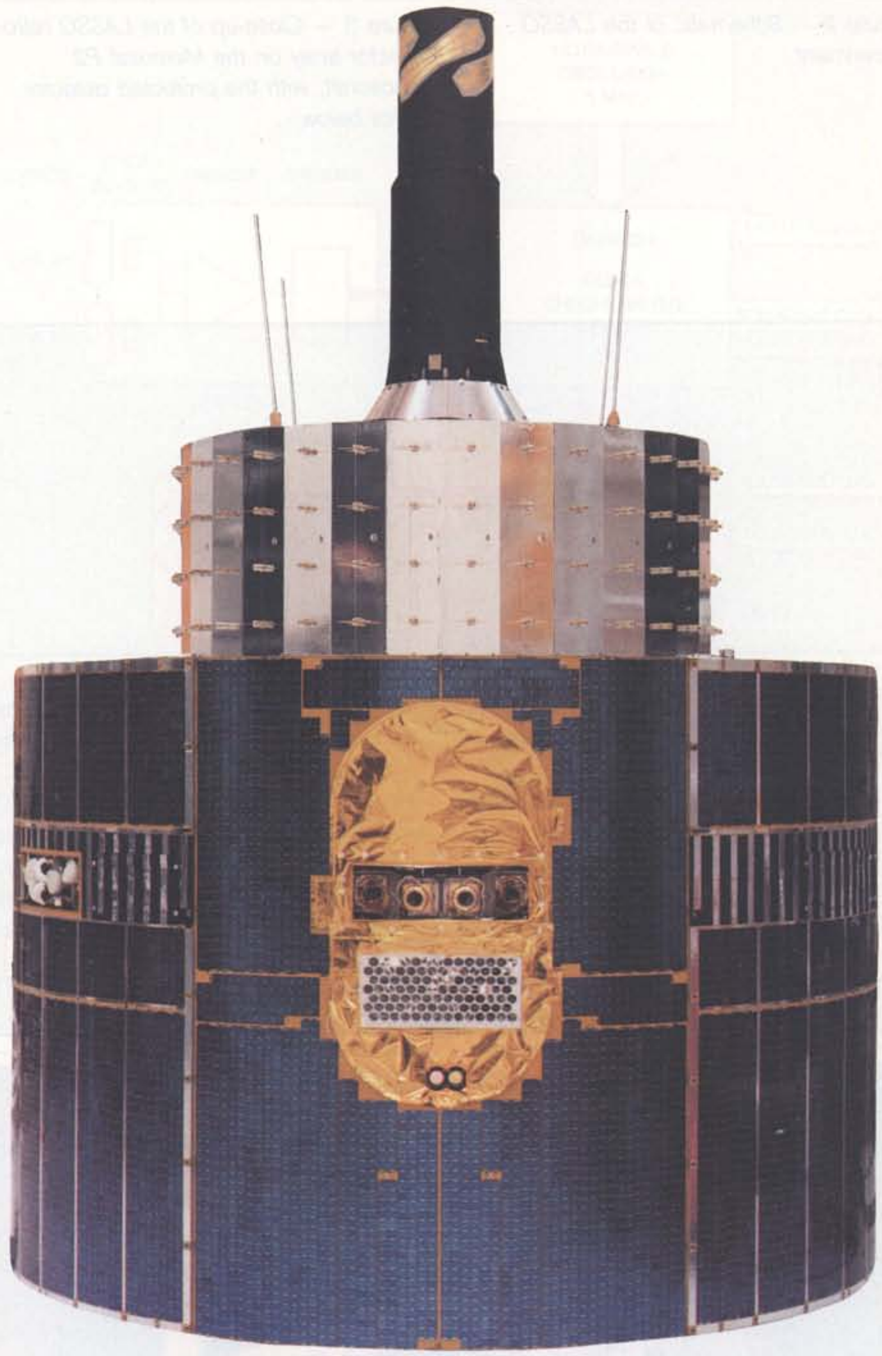


Figure 1 — View of the Meteosat P2 spacecraft showing the silver-coloured LASSO retro-reflector mounted on the solar-cell-covered main body

experience with a number of spacecraft — albeit ones that were not specifically designed for dedicated timing missions — indicates that satellite techniques are the best choice for meeting future requirements in the sub-nanosecond range. Following a proposal presented at the 1972 COSPAR Meeting in Madrid, ESA accepted a proposal from the 'Bureau International de l'Heure' (BIH) to implement an experimental space mission. It was subsequently decided to launch the LASSO — Laser Synchronisation from Stationary Orbit — payload package on the Sirio-2 spacecraft. When that spacecraft was eventually lost due to a launch failure, the Agency proposed to include LASSO on the Meteosat P2 spacecraft (Fig. 1). This was approved by the Meteosat Programme Board in March 1984. The spacecraft will be launched in mid-1987.

The mission objectives

The objectives of the LASSO mission, supported by a number of time and frequency-standard laboratories, is to provide intercontinental synchronisation of clocks with nanosecond accuracy or better. The mission will therefore enable the establishment of an improved international network of reference clocks synchronised both with each other and with the Internationally adopted Atomic Time scale (IAT).'

The LASSO mission is considered an important step towards an internationally coordinated technical assessment of such a system. It will also impact on other practical applications such as the tracking of deep-space missions, the dissemination of standard time and frequency signals to many users, and future generations of space-navigation and telecommunications systems.

The experiment

The LASSO experiment is based on laser stations emitting monochromatic light impulses at pre-defined times, which are directed towards a geosynchronous spacecraft (Fig. 2).

Onboard the spacecraft, an electronic device detects and time-tags the arrival of the laser pulses and an array of retro-reflectors sends back a fraction of the received signal to the originating laser station. Each station measures the two-way travel time of the emitted laser pulses and computes the one-way travel time between station and spacecraft, taking into account the station's geographical coordinates, the spacecraft's position and the Earth's rotation.

The time difference between the clocks, which provides the time reference for each of the laser stations, is deduced from the data coming from both the spacecraft and the stations.

The equipment

The Meteosat P2 satellite is composed of two cylindrical body elements, concentrically stacked. The main body, or 'lower platform', is covered with solar cells which supply the energy needed for the satellite to function. Most of the subsystems of this, the latest in the European series of meteorological satellites — including the high-resolution radiometer, the main instrument in the payload — are located on this platform. The second cylinder, or 'upper platform', carries an electronically despun antenna, most of the communications equipment and additional antennas.

The LASSO payload (Fig. 3), located on the opposite side of Meteosat's periphery

Figure 2 — Schematic of the LASSO experiment

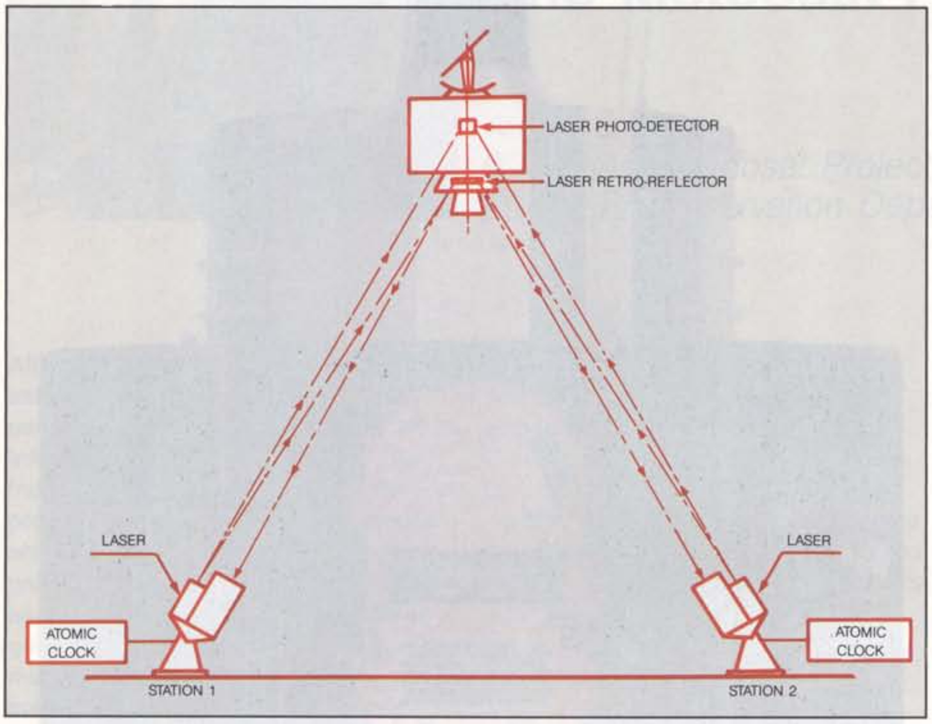
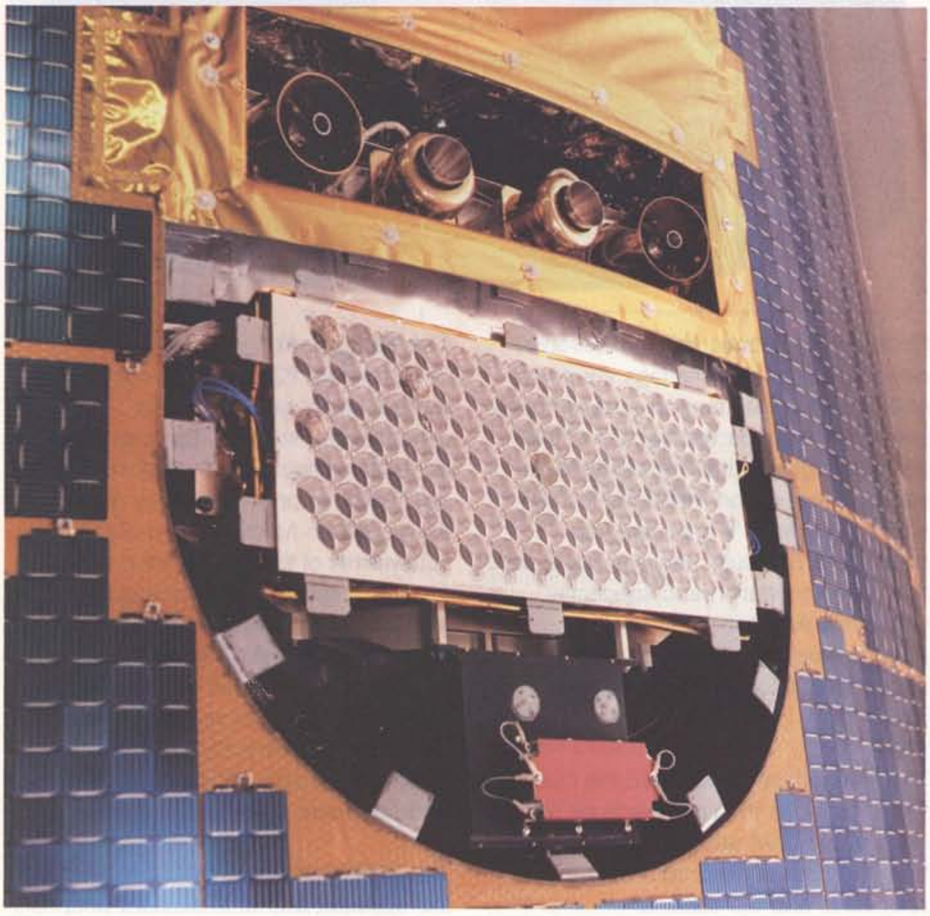


Figure 3 — Close-up of the LASSO retro-reflector array on the Meteosat P2 spacecraft, with the protected detector optics below



to the radiometer, consists of retro-reflectors, photodetectors for sensing ruby and neodyme laser pulses, and an ultra-stable oscillator/counter to time-tag the pulse arrivals. These time-tags will be encoded with spacecraft housekeeping information before transmission to the ground.

Ground segment

The laser stations

The laser stations will be connected to atomic clocks, which will provide a time reference for the electronic equipment (laser trigger and time-tagging unit). Each station will fire sequences of laser pulses towards the satellite, within the period that the LASSO detectors have that station in their field of view (FOV). The station FOV depends on its geographical location and on the position of the spin-stabilised spacecraft in its rotational cycle.

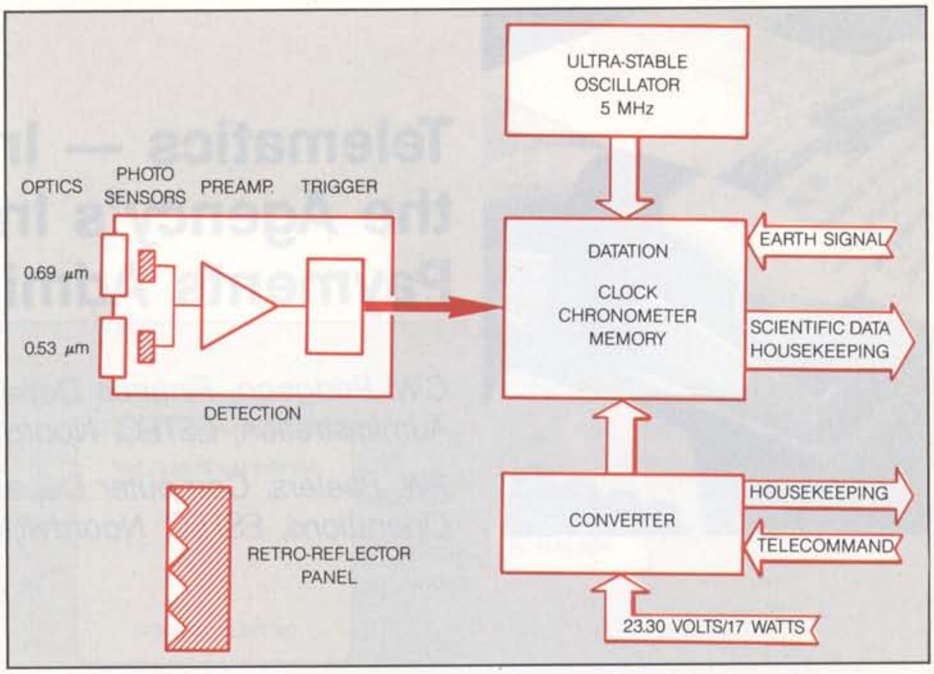
Some stations are able to adjust their firing rate to cope with variations in spacecraft spin rate. Others are only able to adjust the firing time of the first pulse and then fire at a fixed rate, which is an integer multiple of 1 s (typically 6 s). In any event, all stations participating in a LASSO session will fire in a consistent manner during the same sequence. They will either be able to adjust their firing period, or they will all fire at their predetermined multiples of 1 s.

If a given station is able to receive and detect the retro-reflected echo of its own laser transmission, it is defined as a 'two-way' laser station. If a station's uplink energy is sufficient to be detected onboard the spacecraft, but is too low to be reflected and detected on the ground, it is defined as a 'one-way' laser station.

The LASSO Coordination Centre (LCC)

The LCC, located at Fucino in Italy, will perform three main functions for each LASSO experiment session:
- scheduling
- real-time monitoring
- data pre-processing and dissemination to users.

Figure 4 — Overall block diagram of the LASSO payload



The communication system
The LASSO communication system is based on the Data Dissemination System (DDS) already developed by ESA's Information Retrieval Service at ESRIN in Frascati, Italy.

Access to the system can be by means of standard remote computer terminals, either via dedicated lines or via commercial switched telephone networks. Access by means of public telex terminals is also possible.

The DDS system will be used to exchange messages and data between the LASSO users and the LCC, as well as between the LASSO users themselves. It will also act as a mail-box system for messages or data.

Data processing
The 'Centre d'Etudes et de Recherches Geodynamiques et Astronomiques' (CERGA), with the support of the 'Bureau International de l'Heure' (BIH), will perform the final data processing to determine the time synchronisation achieved between the stations participating in the experiment. Other LASSO participants are expected to carry out similar or complementary tasks.

The operational organisation
The operational organisation will involve the following bodies:
- the scientific community and the laser stations
- the Lasso Experimenters and Users Team (LEUT)
- the LASSO Operations Coordination Group (LOCG)
- the LASSO Coordination Centre (LCC)
- the Meteosat Operations Control Centre (MOCC).

The scientific community, supported by the laser-station operators, has submitted its reply to ESA's Announcement of Opportunity for the LASSO mission. Principal investigators have been appointed and are members of the LEUT for the duration of the proposed experiment.

The LEUT, attached to the ESA project group, is responsible for the international coordination of the LASSO experiment and the establishment of its utilisation schedule for the lifetime of Meteosat P2.

The LOCG has been created by the LEUT members in order to:
- coordinate LASSO scientific activities
- provide the ESA Mission Manager with a single point of contact
- advise the ESA Mission Manager on LASSO operations.

The primary tasks of the LCC, which is the key interface between the laser stations, the MOCC and the LEUT, are as follows:
- to exchange information with the MOCC (orbit parameters, telemetry data, etc.)
- to compute laser firing times
- to exchange information with laser stations (pointing angles, firing times, time events, data, etc.)
- to select the operational mode
- to pre-process scientific data and ensure its dissemination
- to create and run the data bank
- to perform special data processing (on request).

The MOCC is in charge of spacecraft control and monitoring for a period of three years. In the LASSO context, the MOCC will:
- perform VHF ranging
- send the necessary LASSO telecommands
- monitor housekeeping information.

Conclusion
The LASSO experiment onboard Meteosat P2 is designed to prove the feasibility of synchronising clocks over intercontinental distances by means of laser stations.

The pioneering nature of this first experiment, the very limited space and power available onboard the spacecraft, and a very tight schedule, have led us to maintain a relatively simple technical solution for the design of the onboard equipment.

In addition, the fact that Meteosat P2 is spin-stabilised requires the laser-station firing times to be synchronised with the rotation of the spacecraft. This aspect makes the operational use of the system more complicated.

Nevertheless, based on the studies performed so far for the LASSO experiment on Meteosat P2, and on the results obtained during the testing of the flight-model payload, the subsequent further development of a second-generation LASSO payload able to achieve a synchronisation accuracy of less than 100 ps already seems a realistic goal.

Telematics — Introduction to the Agency's Invoicing and Payments Administration

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F.W. Peeters, Computer Department, ESA Directorate of Operations, ESTEC, Noordwijk, The Netherlands

The Agency has monitored developments in the field of telematics, i.e. communication via computer-to-computer links, to see how these could be beneficially applied in administrative areas hitherto untouched and largely unconsidered for such applications. The areas of principle concern were invoicing by Industry to the Agency and the subsequent transmission of payment orders by the Agency to its various banks situated throughout Europe. Early in 1986 it was decided that the state-of-the-art in telematics would permit a revolutionary approach to invoicing if certain specialised modifications could be introduced into existing communications packages. Similarly, the introduction of specialised software and a novel approach to account management could enable the Agency to enjoy the use of facilities that have so far been the exclusive preserves of the banks themselves. The machinery for this 'great leap forward' is now available.

The timely execution of payments is of vital concern to ESA and to Industry, and the predictability of the timing, currencies and amounts of the payments flow are of paramount importance to the Agency. This predictability affects the placing of currencies to the maximum advantage to the Agency (interest on deposits, etc.) and the minimising of the risk of exchange losses.

With these factors in mind, the Agency has been carefully monitoring developments in the field of telematics (computer-to-computer links) with a view to:
— linking its major contractors to the Agency's finance services for the transfer of invoices
— linking the Agency's finance services to its European banks for the transfer of payment orders.

At the beginning of 1986 the Agency felt confident that the sort of tools that it required were available, with some specialised modifications, to embark on this hitherto untrodden ground in the field of invoicing.

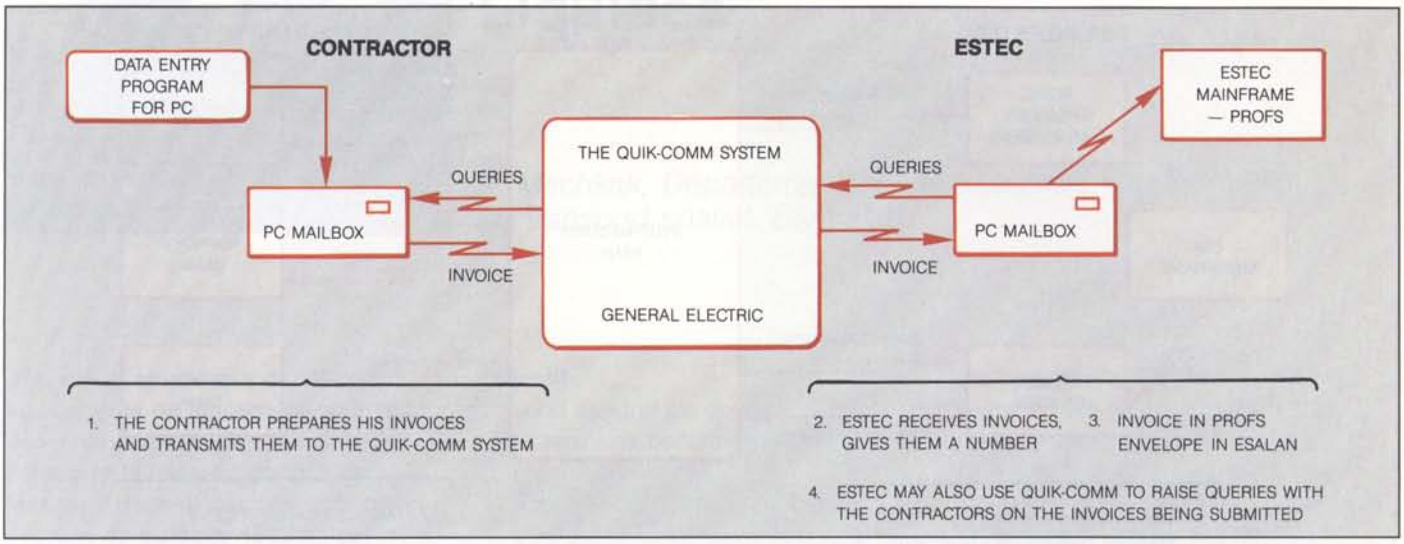
A paper on this topic was therefore presented to Industry at the Eurospace Conference in Rome in January 1986. This paper was accompanied by a questionnaire designed to test Industry's interest and willingness to participate in a most ambitious project aimed at the early introduction of telematics into invoicing and payments.

As a result of the encouraging response of its major contractors the Agency proceeded to:
— investigate the most effective and efficient means of linking these major contractors to ESA for transmission of invoices (Tele-invoicing)
— consider the use of ESA's Local Area Network (ESALAN) for internal circulation e.g. to obtain technical approvals
— examine the best means of transmitting payment instructions to the Agency's banks around Europe whilst maintaining effective central control by Treasury Management in Headquarters (Telebanking).

Tele-invoicing
Agreement has now been reached with General Electric Information Services for the use of their 'Quik-Comm' electronic mail system to enable contractors to send invoices to the Agency by computer-to-computer link. This system makes it possible to open 'mailboxes' at the contractors' premises and in ESA for the transmission of invoices and messages. Local software, called PC Mailbox, for IBM and IBM-compatible PCs is available to ensure a very user-friendly network service (Fig. 1).

A standard ESA 'tele-invoice' to meet all normal requirements has been designed and incorporated in the project's software. Amongst the many benefits of this standardisation are:
— simplified layout and format, which speed up processing
— assurance, in normal circumstances, of the provision of all details

Figure 1 — The fundamentals of tele-invoicing



necessary for processing of the invoice, thus avoiding return of the invoice or further correspondence
— automatic registration via the program software.

In order to take part in the Agency's tele-invoicing project, all that a contractor needs is one IBM-compatible microcomputer, with standard floppy disks and a suitable modem and asynchronous communications port.

Initial trials conducted internally within ESA/ESTEC have confirmed the validity of the concept. Further trials, with those contractors who responded to the questionnaire, are now underway. The Agency's major contractors for projects under development are well represented, thus the major part of the Agency's expenditure could in due course be covered by the tele-invoicing system.

Circulation of invoices within ESA
The circulation of invoices within ESA establishments is necessary primarily to obtain the approval of the appropriate technical Initiator. This requires correspondence between Finance Department and the technical authority and, from time to time, Contracts Department may also be concerned, for example if penalty clauses are to be applied.

In ESTEC, where the major development contracts are managed and where the trials on the use of telematics in this field are taking place, the universal tool for internal correspondence is PROFS (IBM's Professional Office System).

Invoices received from Industry via the tele-invoicing system will, therefore, be transferred to PROFS, after the mandatory financial checks, for transmission to and eventual approval by the technical initiator.

Tele-banking
At the present time payments are authorised in each ESA Establishment and transmitted to the Agency's Treasury Management in Paris. It is then the responsibility of Treasury Management to ensure that payment instructions are transferred to the Agency's banks in the countries concerned in order to achieve timely payment to the contractor. The means of communication with the banks varies by country and also depends upon the urgency of the payment.

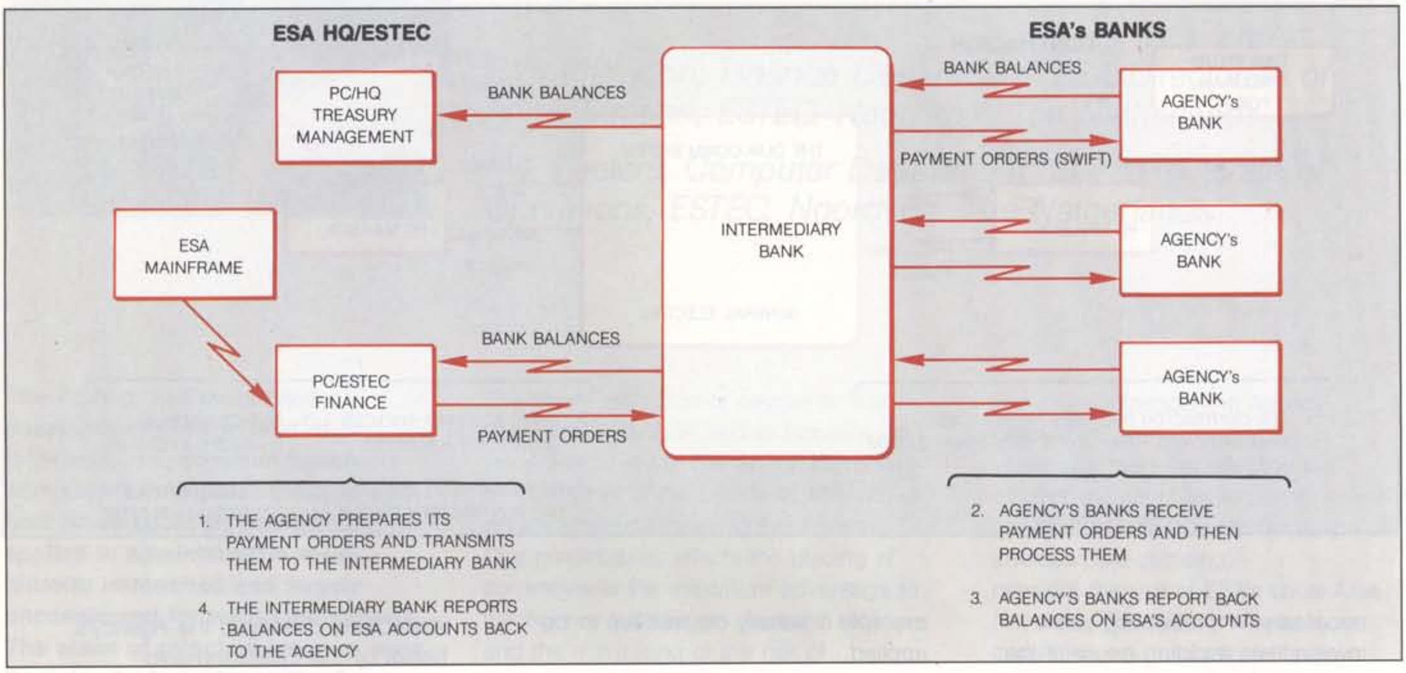
Current studies concern the improvement of Treasury/Bank communications and the possibility of transferring payment instructions directly to the Agency's banks by the Establishments.

In addition to ensuring payment on due dates, the Agency is seeking an improved flow of information by way of computerised links to provide regularly updated balances on the Agency's accounts throughout Europe. This, together with the improved control over amounts and currencies due for payment implicit in the tele-invoicing and internal circulation procedures, should provide a much improved tool for the placing and transfer of currencies.

For the moment it is not possible for the Agency to obtain or install direct computerised links with its many banks in Europe. These links already exist between banks, however, via 'SWIFT', a computerised network service currently available only to banks.

To gain the maximum advantage from the use of SWIFT, the Agency is investigating the feasibility of using one, or possibly two banks in Europe to act as intermediaries in passing the Agency's payment instructions. This would involve the transmission of payment orders by computer-to-computer link directly from the Agency to the intermediary bank, and then the onward transmission of

Figure 2 — Telematics in payments



these orders from the intermediary to the Agency's banks using SWIFT. The whole operation (Fig. 2) could be achieved within a very short space of time and would considerably enhance the Agency's ability to pay on due dates.

Every morning the Agency's banks would communicate to the intermediary bank, via SWIFT, the new balances after the previous day's transactions. This information would be available to the Agency's Establishments to provide a final check before release of further payment orders (the Agency's accounts must be kept in credit in all normal circumstances). It would also be available to Treasury Management in Headquarters for cash-management purposes via computer-to-computer link.

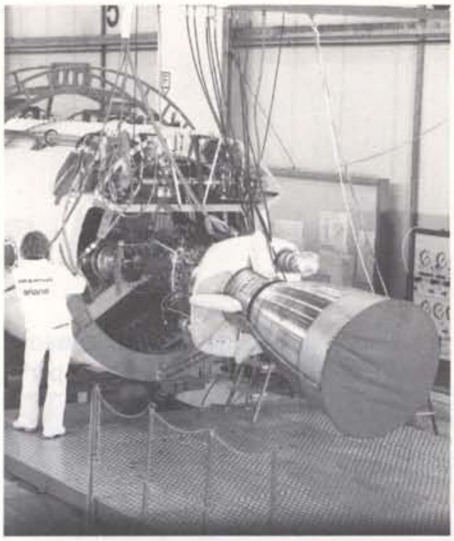
Tele-banking in The Netherlands

The Agency's regulations currently allow its establishments to make all disbursements in the currency of the country in which they are located via bank accounts managed locally. For ESTEC, Dutch guilder payment orders are forwarded by Finance ESTEC to the Agency's bank in The Netherlands, the Algemene Bank Nederland (ABN). These orders then pass through two offices of the ABN, being transcribed in the process into a suitable format for further transmission to the Bank Giro Centrale (BGC) which is the central point for data processing of banking transactions in The Netherlands.

Trials are under way to avoid this payment chain by connecting Finance ESTEC directly to the Bank Giro Centrale. Connection can be made through the medium of magnetic tape, punched card, floppy disk etc. The Agency has opted for a more ambitious approach, however, by linking the ESTEC mainframe computer directly (remote job entry) to the BGC mainframe in Amstelveen. Payment to the recipient is guaranteed within 24 h of the transmission from ESTEC with immediate debit to the ESA/ESTEC account with the ABN.

Conclusion

The development of computer-to-computer links through telematic means has reached a stage where the Agency can see distinct advantages for both Industry and the Agency itself in establishing such links for invoicing and payments. The elimination of a very heavy paper-load, the promptness of transmission of both invoices and payment instructions and the new degree and quality of information which will be available to the principal participants all prompt the Agency to press on with the trials to find the most cost effective and secure applications of telematic links in this, hitherto, very traditional area of financial activity.



Ariane-4 — Le développement des Propulseurs d'Appoint à Liquides

A. Mechkak, Département Ariane, Direction des Systèmes de Transport spatial, ESA, Paris

Afin d'être en mesure de répondre aux besoins de lancement pour la décennie à venir, l'Agence a décidé l'étude et la mise au point d'un lanceur Ariane-4, aux performances accrues de quelque 1500 kg par rapport à Ariane-3 pour une charge utile placée sur orbite de transfert (200—36 000 km). Pour atteindre cet objectif de 4200 kg de charge utile, en plus de l'augmentation de la durée de poussée du premier étage qui est passée de 135 s environ à quelque 210 s, il a été nécessaire de doubler la valeur de la poussée du lanceur pendant les 140 premières secondes du vol.

Cette dernière amélioration est obtenue au moyen de nouveaux propulseurs d'appoint, venant se fixer sur le premier étage, et que l'on éjecte après utilisation. Conçus pour fonctionner avec les mêmes ergols que ceux utilisés avec les premier et deuxième étages (N_20 + UH25), ils sont communément désignés par le sigle 'PAL' (Propulseurs d'Appoint à Liquides).

Objectif

L'objectif assigné est double:
- Obtenir une performance de propulsion donnée
- Respecter un certain nombre de contraintes spécifiques, liées à la conception des matériels.

La performance de propulsion est déterminée par l'utilisation d'un moteur Viking existant déjà sur le premier étage d'Ariane-3 (légère adaptation de la tuyère version Viking 6), et par une durée de fonctionnement nominale de 140 s.

Les contraintes principales sont les suivantes:
- Etre capable d'embarquer une masse totale d'ergols de 36 900 kg
- Avoir des caractéristiques géométriques et massiques (masses sèches) données
- Comporter deux réservoirs séparés, identiques, pour les ergols (UH25 et N_2O_4)
- Comporter les dispositifs d'éloignement du corps principal après séparation (ensemble de fusées)
- Etre alimenté par le corps principal (L220) en fluides de servitude et en eau
- Enfin pour certains éléments, être conçus au moyen de la méthode 'CCO' (Conception à Coût Objectif).

Description

Le PAL est constitué essentiellement d'un bâti destiné à transmettre la poussée du moteur Viking 6 qui est fixé au-dessous et dont la tuyère a une inclinaison permanente de 10°, l'ensemble étant surmonté des réservoirs UH25 et N_2O_4 reliés mécaniquement entre eux par une jupe inter-réservoirs. Ces deux réservoirs identiques et indépendants sont en acier inoxydable et comportent chacun un dispositif de diffusion des gaz de pressurisation des ergols à l'avant, et dans le fond, un ensemble filtre et antivortex.

La jupe inter-réservoirs, constituée principalement d'une virole en alliage léger renforcée par des cadres et des nervures, est terminée par deux brides destinées à la liaison avec chaque réservoir.

Une jupe avant assure la continuité structurale entre le réservoir N et le cône avant; elle est composée d'une virole cylindrique en alliage léger terminée par des brides, et d'un caisson circulaire pour la reprise des efforts introduits par le dispositif d'accrochage au corps principal du lanceur. Six fusées servant à l'éloignement du PAL sont implantées sur la jupe. Le cône avant, d'angle au sommet 30°, est en matière plastique renforcée par de la fibre de verre.

L'ensemble de ces éléments structuraux (bâti-moteur, réservoirs principaux, jupes de liaison et cône) sont assemblés, via des brides, au moyen de boulons longitudinaux en acier, permettant de réaliser cinq liaisons identiques.

Pour ces structures principales, les innovations par rapport à Ariane-1 et 3 résident dans l'utilisation d'acier inoxydable pour les réservoirs principaux ainsi que d'une protection thermique nouvelle (PROSIAL).

L'ensemble propulsif ne présente pas d'innovation marquante par rapport à celui du premier étage d'Ariane-3 dont il utilise le moteur Viking qui fonctionne avec les mêmes ergols, le péroxyde d'azote N_2O_4 (ou N) comme oxydant et un mélange de diméthylhydrazine dissymétrique et d'hydrate d'hydrazine (UH25 = 75% en masse d'UDMH pour 25% de HH). Le fluide de refroidissement du système de propulsion est l'eau qui est prélevée dans le réservoir d'eau du L220, et qui passe de celui-ci au PAL par l'intermédiaire d'une prise d'interface 'Fluides et Electriques', qui véhicule également un autre fluide, l'azote destiné à assurer la pression pilote pour la régulation de la combustion et la commande des vannes pneumatiques, ainsi que l'activation du systèmes correcteur POGO. Cette prise permet également le transit des ordres et signaux électriques soit nécessaires à l'initiation des chaînes pyrotechniques de destruction ou de séparation, soit en provenance des circuits de télémesure et acheminés vers l'émetteur localisé dans la case à équipement.

Comme pour le premier étage, la pressurisation des réservoirs est obtenue avant allumage des moteurs par mise en pression à l'azote au moyen des installations de la Base de Lancement lors de la chronologie finale, et pendant le vol, par production de gaz chauds issus d'un générateur de gaz fonctionnant avec les mêmes ergols que le moteur du propulseur.

Des prises implantées à l'arrière de la baie de propulsion, appelées prises culot, permettent d'effectuer le remplissage ou la vidange du réservoir, la prépressurisation, ainsi que l'assainissement et la ventilation de différents circuits ou compartiments du PAL.

L' accrochage au corps central est assuré à l'arrière par une rotule fixée sur le bâti-moteur du PAL, celui du L220 recevant la cage de rotule, et par des bielles accrochées d'une part sur la jupe avant du PAL et d'autre part sur la jupe inter-réservoirs du L220. Ces deux dispositifs sont respectivement désignés sous les abréviations DAAR et DAAV, (Dispositif Accrochage ARrière/AVant).

Le largage du PAL est réalisé par découpe pyrotechnique des éléments de liaison au L220 et l'éloignement est assuré par la mise à feu de six fusées à poudre.

La destruction du PAL provoquée par découpe pyrotechnique du bas de la virole de chaque réservoir peut être soit commandée du sol pendant son fonctionnement, soit automatique cinq secondes après séparation, par l'intermédiaire d'un relais retard.

Le tableau ci-après donne les principales caractéristiques du PAL, comparées à celle du deuxième étage du lanceur, qui a des performances voisines (Tableau 1).

En résumé, on peut constater que la conception générale du PAL s'inspire fortement des techniques et technologies déjà utilisées sur Ariane 1 et 3. Cette politique délibérement choisie a permis de se mettre à l'abri des aléas propres à toute innovation.

Développement

Logique de développement

Elle s'inspire de celle déjà utilisée pour d'autres ensembles de même nature développés dans le passé. Elle comporte deux types d'essais:

- Essais de catégorie I effectués sur tout ou partie du PAL
- Essais de catégorie II, faisant intervenir d'autres éléments du lanceur.

De plus, il a été considéré que le développement du cône avant pouvait être réalisé indépendamment du reste du PAL, et que les recherches des modes locaux effectués au moyen de la 'maquette dynamique' réalisée au niveau système, pouvaient dispenser le projet d'en réaliser une pour le PAL seul. De même, étant donné la simplicité des circuits fluides et des systèmes électriques, il n'a pas été réalisé de 'maquette d'aménagement', les travaux correspondants étant conduits sur les différents modèles de développement.

Enfin, il faut mentionner que le programme de développement comporte, outre la fourniture des 'étages' destinés aux essais de mise au point et qualification, deux exemplaires destinés au vol de démonstration Ariane-4, et qui permettent de roder et figer les procédures d'intégration et de recette des matériels. Le planning ci-après (Tableau 2) résume très succinctement les principales phases du développement:

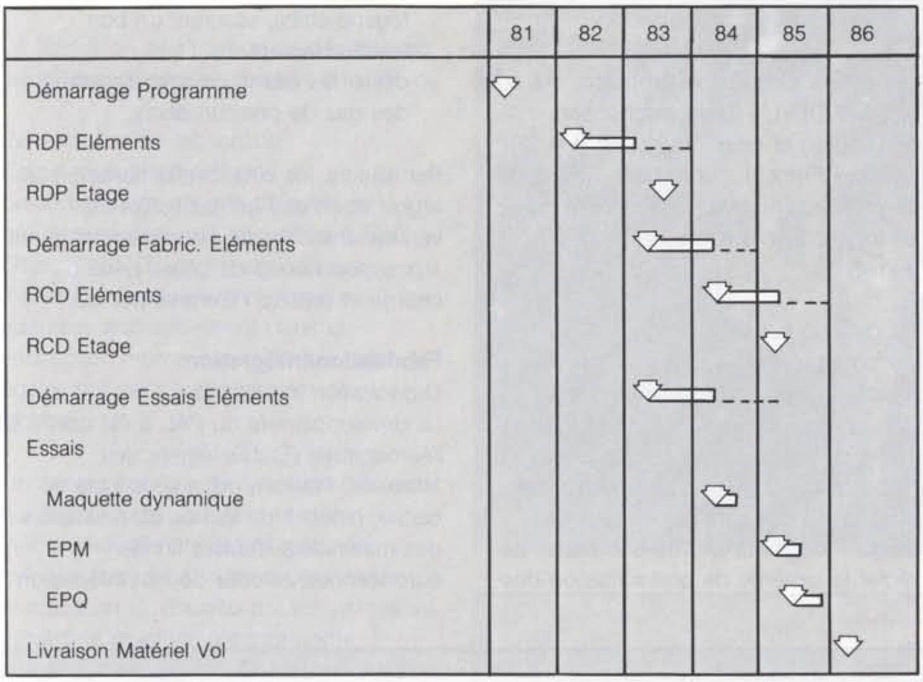
Etudes et essais de mise au point et qualification

Pour Ariane-1 et 3, on avait développé des modèles dynamiques:

Tableau 1

	PAL	L33
Longueur (m)	12,5(+3,5) cône avant	11,5
Diamètre (m)	2,2	2,6
Masse totale (t)	43,3	38,4
Masse ergols (t)	39	34,6
Durée fonctionnement (s)	140	123
Pression foyer (bars)	58,5	58,5
Poussée (kN)	692 (sol)	786 (vide)

Tableau 2



- 'latéraux' pour les études de pilotage et les efforts généraux,
- 'longitudinaux' pour les études POGO et études dynamiques.

Pour Ariane-4, du fait de la présence des PAL, il a été nécessaire de développer un modèle 'tridimensionnel' permettant d'affiner les études POGO.

Maquette dynamique (MD)
Les essais effectués sur une maquette représentant la partie basse du lanceur, constituée des matériels suivants à l'échelle 1:
- une baie de propulsion 1er étage avec moteurs tronqués
- un réservoir U surmonté d'un réservoir d'eau
- une jupe inter-réservoirs et un fond N
- des circuits fluides externes au 1er étage
- deux PAL et leur système d'attache

ont permis:
- de valider les modèles mathématiques (longitudinal, latéral, tridimensionnel et sous-ensembles)
- de déterminer les amortissements
- d'étudier les comportements locaux (déformation, modes)
- d'obtenir les informations nécessaires aux études POGO (pressions lignes, déplacements organes propulsifs...).

Ces essais se sont déroulés dans les installations de l'IABG à Ottobrunn sous la conduite de l'Aérospatiale, architecte industriel.

Propulsion
La mise au point des systèmes de propulsion comporte plusieurs étapes, répondant chacune à des objectifs précis.

Comme on le verra en étudiant le plannigramme des différentes étapes du développement du système de propulsion, le respect de ces contraintes a orienté l'architecture du PAL et du L220 vers des solutions quasi obligatoires, amenant notamment à centraliser dans le 1er étage un certain nombre de matériels.

Ainsi l'objectif fixé pour l'obtention d'un coût récurrent aussi faible que possible, a conduit naturellement à essayer d'utiliser pour le L220 et le PAL, qui ont des moteurs identiques (à l'exception de la tuyère), des éléments communs qui sont regroupés dans le 1er étage. Ce sont:
- le réservoir d'eau
- les systèmes de commande d'ouverture des vannes principales du moteur, et de régulation de sa pression foyer (GOC)
- le système correcteur pogo (SCP).

L'adjonction des PAL au corps central a imposé
- de faire de nouvelles études du comportement hydrodynamique de l'ensemble propulsif inférieur (PAL + L220) et d'effectuer des essais de caractérisation pour définir les réglages des systèmes correcteurs POGO;
- de tenir compte des nouvelles ambiances vibratoire, acoustique et thermique, conduisant à définir un ensemble propulsif modifié, pour lequel le développement de matériels nouveaux s'est avéré nécessaire, et notamment:
  système de pressurisation gaz chauds (PGC)
  nouvelle prise de culot (PC)
  nouvelle vanne de remplissage (VR)
  nouvelle vanne principale (VP).

Ces nouveaux matériels ont été soumis, individuellement et intégrés dans l'ensemble propulsif, à des essais de mise au point et de qualification. Pour respecter l'allocation d'un taux global de fiabilité de 0,9 pour le lanceur, on a évité la mise en série d'un nombre trop élevé d'équipements et cherché à réduire les points critiques connus et à mieux cerner les marges dont on disposait sur les matériels. Pour ce faire, on a effectué notamment des essais d'endurance (jusqu'à 300 s de fonctionnement continu du moteur pour un temps nominal de 140 s pour le PAL et 210 s pour le L220) et des expertises complètes et

Figure 1 — Logique de développement des systèmes de propulsion du PAL

minutieuses permettant de connaître l'état des différentes pièces du moteur après essai.

Les éléments du PAL et le PAL lui-même ont été soumis aux différentes revues de projet classiques prévues dans les spécifications de gestion du programme Ariane-4. Ces revues (en grisé dans le plannigramme, Fig. 1) sont dans l'ordre chronologique:

- La Revue de définition préliminaire (RDP, uniquement pour les matériels nouveaux ou fortement modifiés)
- La Revue critique de définition (RCD)
- La Commission de qualification (CQ)
- La Revue de configuration du premier article (RCPA), qui compare le premier modèle de vol à celui qui a fait l'objet de la qualification
- La Revue d'aptitude au vol (RAV), qui autorise l'envoi des matériels au Centre de Lancement.

Les essais d'ensemble propulsifs ont eu lieu à la DFVLR (Lampoldshausen, Allemagne) et ceux du moteur à la SEP (Vernon, France), sur le banc PF2 qui a dû être modifié pour permettre la durée de fonctionnement requise de 300 s (Fig. 2).

Au delà de la vérification des performances propulsives du moteur (pression foyer, rapport de mélange, gabarits de poussées au démarrage et en fin de propulsion) pour lesquelles on n'attendait pas de grandes différences avec celles des moteurs du premier étage, il s'agissait lors de ces essais de régler le système de pressurisation des gaz chauds afin de:

- fournir des débits au démarrage et en régime établi, assurant un bon fonctionnement
- définir les débits de refroidissement des gaz de pressurisation.

Par ailleurs, les circuits d'alimentation en ergols et en eau ont fait l'objet de vérifications de leurs performances quant aux aspects coup de bélier, perte de charge et pression d'entrée pompe.

Fabrication/Intégration

Organisation industrielle

Le développement du PAL a été confié à l'Aérospatiale (Etablissement des Mureaux, France), qui a sous-traité un certain nombre de tâches de réalisation des matériels à d'autres firmes européennes, et celle de leur intégration

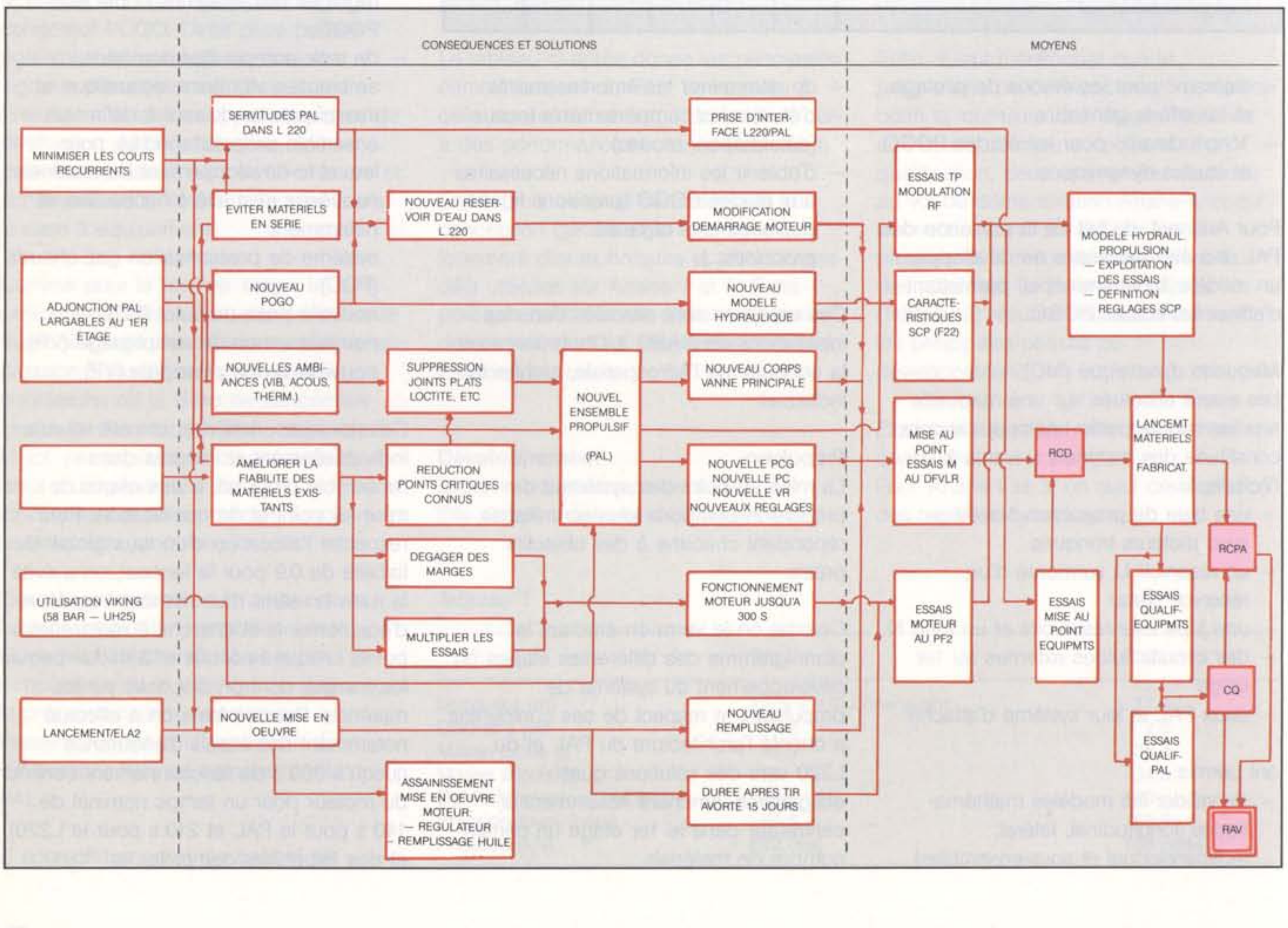


Figure 2 — Les essais du PAL à la DFVLR, Lampoldshausen, Allemagne

Figure 3 — Organisation industrielle pour le développement du PAL

à la Société MBB-ERNO (Etablissement de Brême; Allemagne).

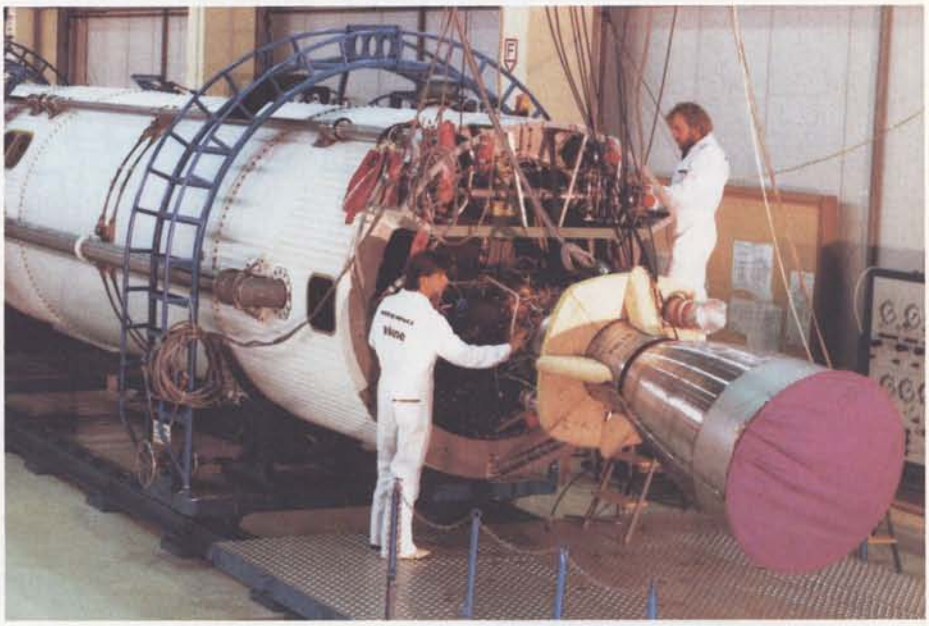
La répartition des travaux se décompose selon l'organigramme ci-après (Fig. 3).

Particularités de fabrication
Comme il a été mentionné précédemment, un des objectifs du programme était la 'Conception à Coût Objectif' (CCO); ceci a conduit à rechercher les solutions les mieux adaptées non seulement dans la conception même des matériels, mais également dans les méthodes de fabrication.

Un certain nombre de types de matériels qui étaient habituellement réalisés mécano-soudés ont été obtenus en fonderie (corps de vannes, coudes de canalisation...), d'autres ont été usinés au moyen de machine à commande numérique tel que le bâti-moteur réalisé dans les ateliers de la société SABCA (Belgique); l'utilisation de la technique 'repoussage-fluotournage' pour la réalisation des fonds des réservoirs principaux est issue à la fois des exigences techniques imposées par les caractéristiques métalliques du matériau employé (acier Uranus) et par le souci de garder le prix de revient le plus possible.

Parmi les particularités, il faut signaler également la première utilisation pour les programmes Ariane, d'un nouveau revêtement (PROSIAL), qui a l'avantage de pouvoir être déposé au les surfaces à protéger par projection au pistolet, ce qui permet de s'affranchir des difficultés rencontrées lorsqu'il s'agit de couvrir des surfaces comportant de nombreuses aspérités, et ainsi de réduire de façon considérable les coûts de main d'oeuvre. Il est cependant à noter que ceci se fait au prix d'une augmentation de la masse, ce matériau étant un peu plus lourd que celui jusqu'alors utilisé (Norcoat).

A noter également que les réservoirs



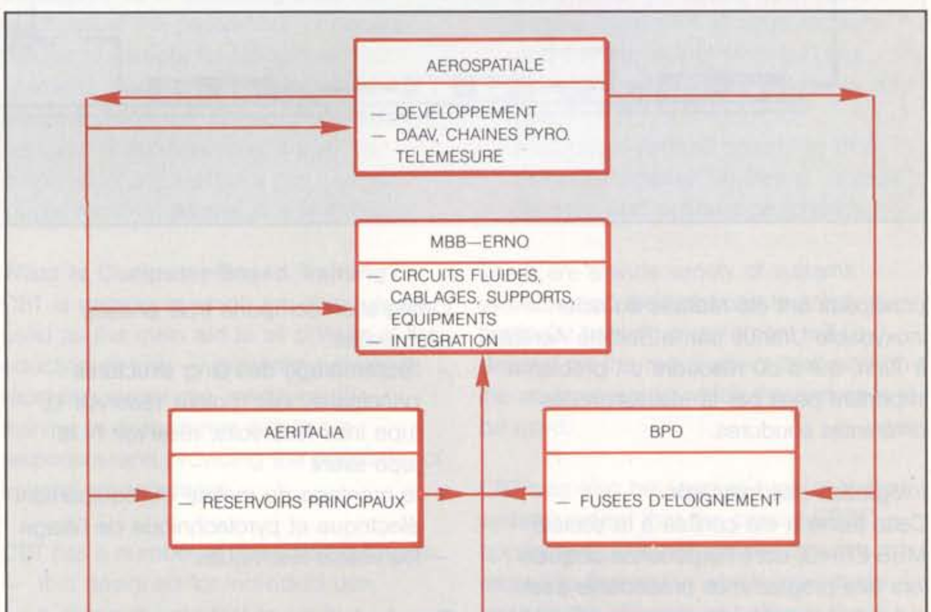
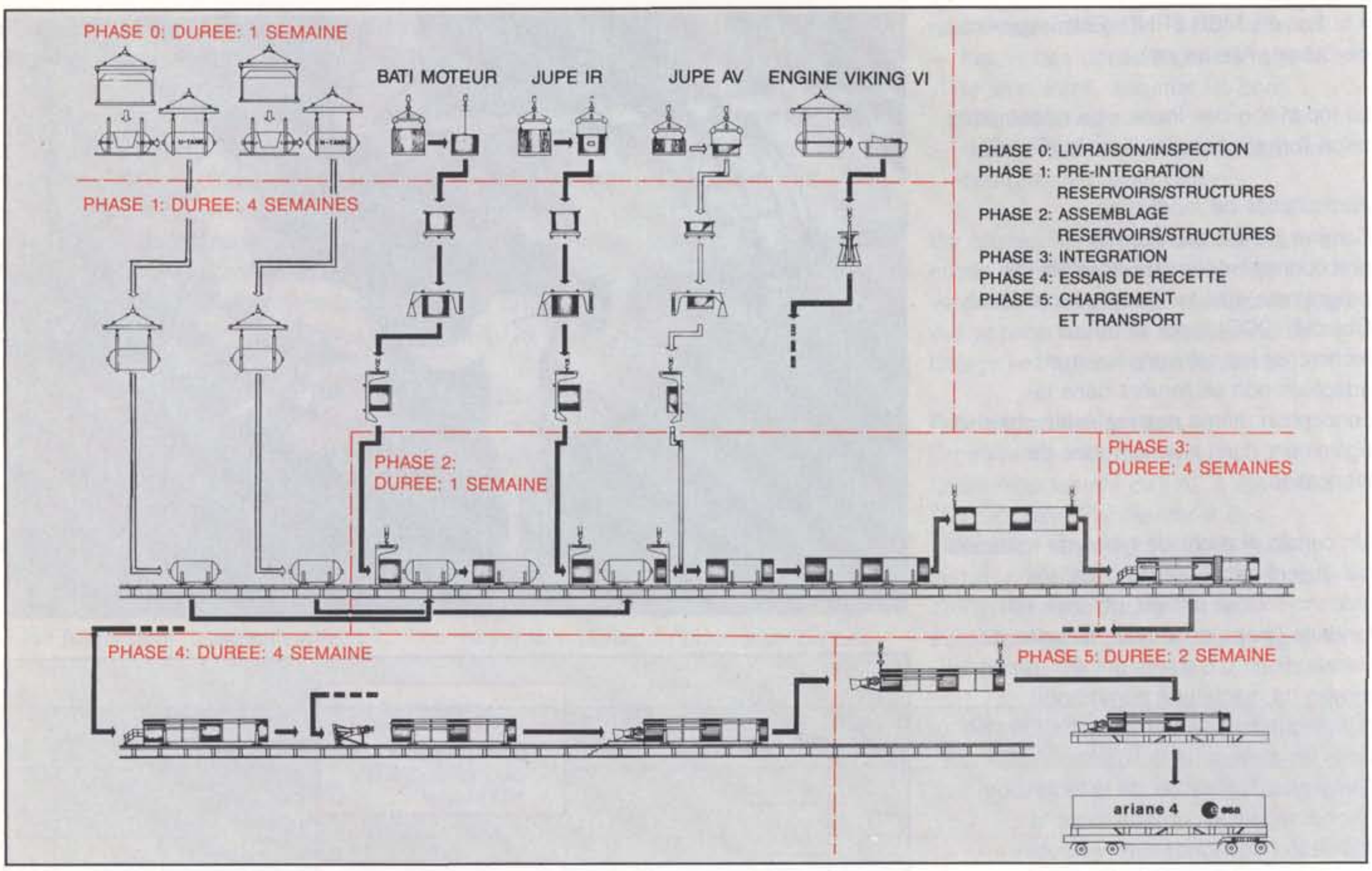


Figure 4 — Schéma d'intégration et d'essai du PAL



principaux ont été réalisés en acier inoxydable Uranus par la Société Aeritalia à Turin, qui a dû résoudre un problème important posé par la réalisation des différentes soudures.

Intégration des matériels
Cette tâche a été confiée à la société MBB-ERNO, dont l'expérience acquise lors des programmes précédents s'est avérée très profitable, puisque dans la conception du banc d'intégration, l'équipe de projet a apporté une idée tout à fait originale au programme, en proposant et réalisant un banc d'intégration à l'horizontale, alors que jusqu'à présent, pour les étages à ergols liquides, cela était réalisé à la verticale. Le coût d'une telle installation, qui permet de travailler sur 3 PAL complets et 2 réservoirs différents en même temps, est 3 à 4 fois moins cher qu'un stand vertical (Fig. 4).

L'intégration comporte trois phases essentielles:
- l'assemblage des cinq structures principales: bâti-moteur, réservoir U, jupe inter-réservoirs, réservoir N et jupe avant
- le montage du moteur et l'équipement électrique et pyrotechnique de l'étage
- les essais électriques.

Conclusion
A l'issue du développement des PAL, il convient de faire le bilan des objectifs affichés au début du programme et des résultats obtenus.

Pour ce qui concerne les caractéristiques de propulsion, on a vu au cours éde cet article que l'utilisation du moteur du premier étage a permis de limiter le programme de développement PAL et qu'il n'y a pas eu de difficultés majeures à surmonter.

En ce qui concerne les contraintes spécifiques liées à la conception des matériels, elles ont toutes été respectées, notamment les réservoirs du PAL sont capables d'embarquer jusqu'a 39 t d'ergols UH25/N_2O_4 en quantités compatibles avec le rapport de mélange défini nominalement.

Par ailleurs, l'objectif CCO a été chaque fois que possible pris en compte et, au-delà de la définition de l'étage lui-même, l'équipe d'intégration MBB-ERNO a également fait sienne cette préoccupation, en concevant un banc original permettant d'atteindre ce but.

Computer-Based Training at the European Space Operations Centre

F.W. Stainer, Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany

Certain characteristics of the training requirements of ESOC's Operations Department make Computer-Based Training (CBT) an attractive proposition. The Department's interest in the use of CBT started about two years ago, with the collection of information on the available authoring systems and evaluation of their potential applications in the ESOC environment. As a result, an authoring system was purchased, and a short demonstration program was prepared and tested.

Introduction

The use of computers for training purposes is not new. Computer-Based Training (CBT) was being introduced on a number of mainframe machines in the early seventies. It is only recently, however, that this aid to training has become a really practical proposition. This is partly due the recent developments in 'authoring systems', which make the preparation of course programs feasible for trainers without specialist computer skills. Secondly, the availability of small, cheap, stand-alone personal computers means that the preparation and use of a program no longer requires access to a mainframe.

What is Computer-Based Training?

CBT is training in which the computer is used as the main aid to all phases of the educational task — presenting material, receiving responses, modifying the training in accordance with those responses and providing the possibility of training management.

CBT has a number of distinct advantages:
- It is designed for individual use.
- It allows the student to work:
  - at his or her own pace
  - at a time when it is convenient
  - without the stress of obvious difficulties in front of his or her colleagues
  - repetitively until the desired training objectives have been met.
- It is able to provide immediate personal and graded help.
- It can provide diagnosis of difficulties, analysis of errors, and feedback on progress.
- It enables the instructor to follow the student's progress, identify problem areas and provide additional support if necessary.
- Course material is easily updated.

A CBT system is made up of two main elements:
- A development system, consisting of a computer, an authoring program, display, keyboard, storage medium and optional peripherals such as video tape, video disc, mouse or light pen.
- A student interface consisting of a computer, display, keyboard, storage medium and optional peripherals.

There are a wide variety of systems available and the right one to satisfy a particular training requirement will depend on the requirement itself and on the environment in which the system is to be used.

CBT can also be seen as type of 'expert system', except that the current ESOC application does not include features related to the way in which individuals learn or the differences between the learning requirements of individuals. In other words, although the CBT system is adaptable to a small range of student abilities, it does not learn from the student's responses, and in this sense is not an expert system. Such expert systems are under study in other areas of the Agency.

Choice of system

Any CBT system must be appropriate to the particular characteristics of the target student audience. In the case of ESOC's Operations Department, the users are located at the Centre itself and at a number of remote ground-station locations around the World. They cannot be easily assembled as a group for formal training and the times at which they are able to undertake training are widely different. This is due both to time-zone differences, and the fact that many of them work to a shift roster. These are characteristics that lend themselves particularly well to the CBT method of training.

In addition, the number of participants is rather small compared to many other training requirements, and in most cases the subject matter is not fixed for a long period. Both equipment and procedures are regularly updated to satisfy new mission requirements.

All of the locations for students referred to above are connected to the ESOC Operations Control Centre (OCC) by data-quality communications links. This helps considerably in the task of distributing and updating the training material, and can overcome the disadvantage of a changing course content.

With this dipersed training environment in mind, the IBM PC was selected for both the authoring system and the student interface. The advantages of using this machine are:
— It is an ESA-standard PC.
— No special extras are required to use it for CBT (though use of some of the recommended peripherals may mean additional cost).
— There is good hardware and software support for it.
— It is not part of the equipment configuration used for operational purposes at the Control Centre and ground stations.
— There is a good choice of authoring systems which use it.
— The development system and student interface use the same machine.

The particular IBM PC that has been used so far is fitted with a Hercules high-resolution graphics card, monochrome display and Epson FX80 printer. For comparison purposes, part of the demonstration program was also produced for the medium-resolution colour display.

Choice of language

There are a large number of authoring systems available. These were reviewed, first by studying the available literature and then by discussion with suppliers and by attending demonstrations of specific systems, including systems already in use in the space industry.

As a result of these investigations, the TenCORE authoring system was selected. The main characteristics that made it attractive are:
— It is designed for use on an IBM or IBM-compatible PC.
— It has a good graphics capability.
— It has a student record system.
— It operates in English.
— It has good documentation and training backup.
— It has a good development record.

The TenCORE system is a complete programming environment specially enhanced for implementing computer-based training material. The author language has complete facilities for display creation, response input and analysis, and data manipulation in a structured program environment. It uses command words similar to other languages (e.g. IBM Basica, Hbasic), but they are extremely powerful for use in CBT course preparation.

An example of a lesson 'frame' is shown in Figure 1. It includes examples of commands for routing, text, graphics, questions and answers.

Demonstration program

Why 'Orbital Elements'

The considerable amount of effort required to produce CBT lessons means that it is essential that the lessons chosen are suitable for a wide student audience and that the subject material has a long validity. In considering subjects that might be suitable for a short demonstration program, it was also necessary to choose one that would fully exercise the facilities provided in the authoring system.

After considering a number of alternatives, 'satellite orbits' was chosen as an appropriate subject, and 'orbital elements' as a lesson. This choice meant that a reference manual on the subject, produced in ESOC, could be used as the source of 'expert' information, without the necessity for full involvement of subject experts.

The object of the lesson was:
— to teach the parameters required for the definition of a satellite's orbit.

At the end of the lesson, the student should:
— know the terms necessary for describing a satellite's orbit

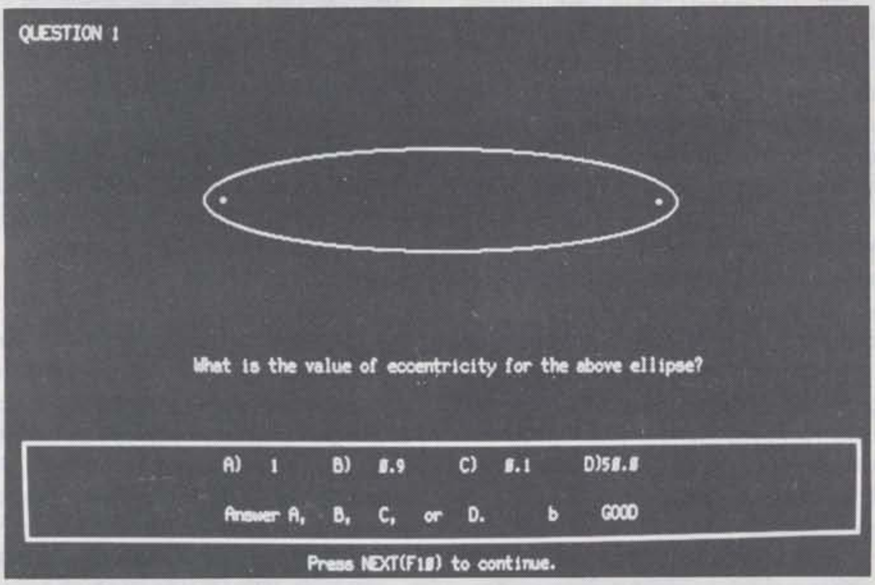
and be able to:
— list the six parameters that describe a satellite's orbit
— define each parameter in terms of the Earth's three coordinate axes and the other parameters
— calculate the orbit's eccentricity from values of apogee distance or perigee distance, and semi-major axis.

Program structure

The overall structure of the program is shown in Figure 2. The full program envisaged three separate lessons on the topics of: Orbital Elements, Geostationary Orbits, and Orbital Calculations. Only the Orbital Elements lesson has been completed for demonstration purposes.

Most of the main characteristics of TenCORE have been incorporated within this completed lesson. The graphics editor has been used extensively for the diagrams and the character set for the introduction of non-standard symbols.

Figure 1 — Example of a lesson frame




```
*--ques114a
QUIT                       $$*
quit                       $$**
next     ques114c          $$*** LESSON ROUTING
back     frame114          $$**
help     ques114b          $$*
at       1:1
write    QUESTION 1
at       7:46              $$**
ellipse  208,48            $$*** DRAW AN ELLIPSE
at       7:70              $$*
circle   2                 $$**
at       7:22              $$*** DRAW CIRCLES
circle   2                 $$**
at       14:19             $$*** GIVE QUESTION **********************
write    What is the value of eccentricity for the above ellipse?
do       box3
at       18:22
write    A)  1      B)  0.9      C)  0,1      D)  50.0

         Answer A,  B,  C,  or  D.
if       tries=0
.        calc   start==zclock
endif
long     1
arrow    20:56             $$*** WAIT FOR ANSWER
holdno
holdok
putlow
answer   b                                          $$*
.        calc   quest1==1                           $$**
.        calc   tries1==tries+1                     $$***
.        calc   tries==0                            $$**** ANSWER CORRECT
.        calc   time1==(zclock-start)/1000          $$***
.        at     20:64                               $$**
.        write  GOOD                                $$*
wrong    (a,c,d)                                                   $$*
.        calc   tries==tries+1                                     $$**
.        at     180,0                                              $$***
.        write  HELP(F8) available or NEXT(F10) to try again!      $$* ANSWER WRONG
.        at     20:60                                              $$***
.        write  SORRY - YOU'RE WRONG                               $$**
ignore                                                             $$*
endarrow
at       at     180,0
erase    60
at       22:31
write    Press NEXT(F10) to continue.
```

Branching commands have been fully incorporated, including access to a HELP facility from all but a few frames.

Two sets of questions are included. The program calculates the time spent on each question, the number of attempts at the question, and the final result. This information is provided as feedback to the student. Remedial frames are included for each question.

The TenCORE Student Record System was fully incorporated in the program. This is a stand-alone program designed to keep track of a student's progress (for both student and instructor) and to provide a friendly routing system.

The lesson, as tested, used 50 frames and took 30—40 min for the student to complete. In order to complete the lesson, each student requires two floppy discs (one for the student record system and one for the program) and a template for the keyboard function keys.

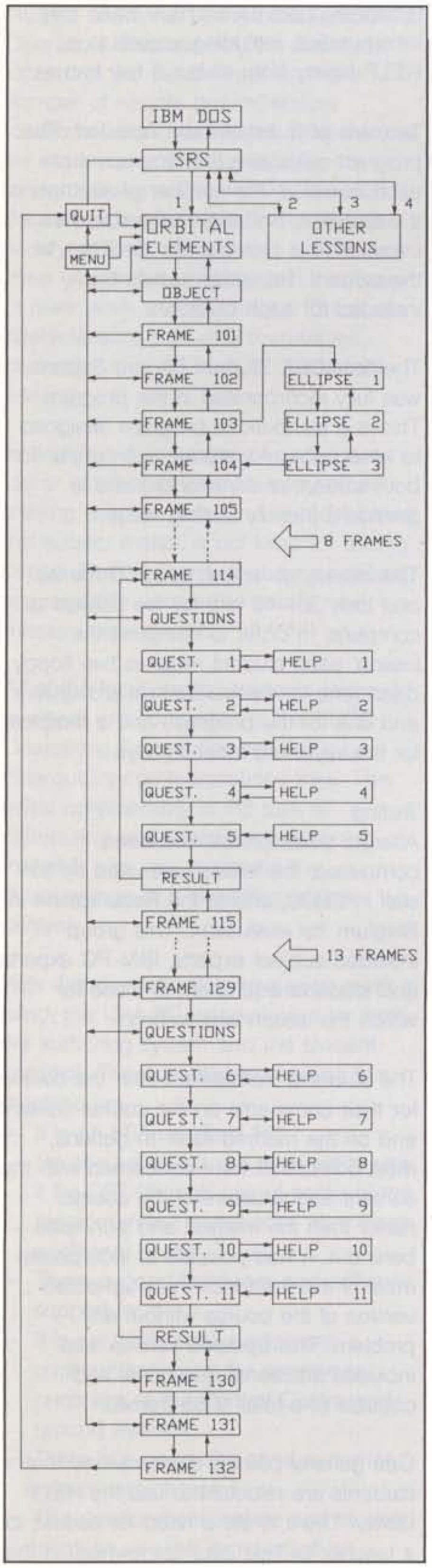
Testing

After its development had been completed, the lesson was used by 31 staff in ESOC, and at the Redu station in Belgium, for evaluation. This group included subject experts, IBM PC experts and students equivalent to those for which the lesson was written.

The students were asked after the course for their comments on the course content and on the method itself. In general, most comments were concerned with the content and structure of the course, rather than the method and principles behind it. It was possible to incorporate most of this feedback in an up-dated version of the course without any problem. This updated version also includes additional questions, and consists of a total of 65 frames.

One general point is clear, namely that students are reluctant to use the HELP facility. There is still a need for access to a teacher or instructor somewhere in the

Figure 2 — Overall structure of the 'Orbital Elements' program



system. This should not detract from the fact that a large part of the teacher's role has been programmed and that the advantages described above have been gained. Overall, the program has been very favourably received and has generated a good deal of interest.

Program development

Because the demonstration program described above was the logical progression of a general investigation into CBT, it is not possible to give accurate figures for program preparation time and costs. However, the following figures are best estimates of the time taken, excluding those preliminary investigations:

- Training in the use of the selected authoring system: one week at the supplier and one week in-house.
- Lesson preparation: two weeks.
- Using TenCORE to construct a lesson: three to four weeks.
- Testing and modification (excluding the time used by the test group): one week.

From the above it can be concluded that the ratio of time required for the preparation of a CBT course to the time taken for a student to complete the course is of the order of 330:1. This ratio would undoubtedly be lower if an experienced TenCORE programmer were used.

It is of interest to compare this ratio with figures for other forms of training:

Type	Ratio	Source
CBT	310:1	Aircraft industry experience
CBT	140-200:1	Reported research projects
8 mm film	370:1	ESOC Ops. Dept. experience
Video tape	180:1	ESOC Ops. Dept. experience

The figures quoted are extremely variable and therefore can be taken only as a guideline. Nevertheless, the ratios are very high.

In considering the requirements for preparation of CBT courses, it should be borne in mind that the best combination of expertise for the preparation of training programmes is: subject expert, training expert, and TenCORE programming expert.

Conclusion

CBT has been added to the range of training aids available in the Department and a demonstration course has been produced to show its main characteristics. The CBT system chosen proved to be appropriate and the TenCORE language comprehensive and easy to use.

On the basis of our experience, the following conclusions can be drawn:

- CBT is a powerful and appropriate training method for the particular environment of ESOC's Operations Department.
- The amount of effort required to produce CBT programs means that care must be taken to use them only for those subjects where the number of students and the stability of the subject matter make them fully justifiable.

As with all training aids, care must also be taken to ensure that the choice is not made on the basis of novelty, but from a proper analysis of the specific training requirements and all available means of satisfying those requirements.

Acknowledgement

Most of the detailed TenCORE programming work was done by Mr K.W. Loske of the Fach-Hochschule, Munich.

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'Spacecommerce' — Montreux

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La commercialisation de l'espace a été engagée à la fin des années soixante dans le domaine des télécommunications par satellite et, une décennie plus tard, dans le domaine des moyens de lancement avec la création en Europe de la société Arianespace, première société privée de transport spatial en date dans le monde. Alors que s'engagent aujourd'hui des programmes ambitieux dans le domaine des infrastructures orbitales (station spatiale et plates-formes), des voix se font de plus en plus pressantes pour retirer des bénéfices économiques de ce nouveau secteur de croissance qu'est devenue l'industrie spatiale.

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Introduction

A l'initiative de la Délégation aux affaires économiques de la ville de Montreux (Suisse), la manifestation Spacecommerce — première manifestation de ce genre, qui s'est déroulée du 17 au 20 juin 1986 sur les bords du lac Leman — se présente comme un carrefour où professionnels de l'espace et industriels utilisateurs potentiels confrontent leurs vues et informations afin d'aider les décideurs à faire en temps opportun les choix économiques qui s'imposent.

La genèse

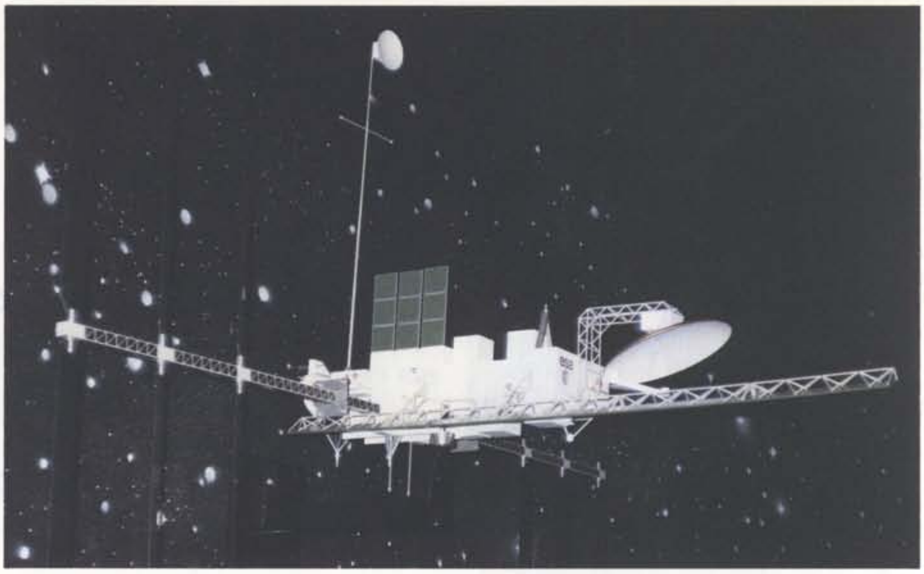
La recherche spatiale a débuté voici bientôt trente ans avec les lancements de Sputnik par l'Union Soviétique en 1957 et d'Explorer par les Etats-Unis en 1958. L' exploitation commerciale des satellites a commencé dix ans plus tard, dans le domaine des télécommunications avec les satellites de l'Organisation internationale de télécommunications par satellite — INTELSAT. L'exploitation commerciale des moyens de lancement, elle, n'a vu le jour qu'en 1984 avec le lancement, par Arianespace depuis le Centre Spatial Guyanais de Kourou, du satellite Spacenet de la société américaine GTE. Depuis lors, Arianespace a réalisé neuf autres lancements pour ses clients parmi lesquels Eutelsat (Organisation européenne de télécommunications par satellite), Brazilsat, Arabsat, la société américaine RCA-Astro, le CNES français, notamment pour son satellite d'observation de la terre SPOT, l'Agence spatiale suédoise et bien entendu l'Agence spatiale européenne dont le satellite Giotto était lancé le 4 juillet 1985 à la rencontre de la comète de Halley. A noter que si l'exploitation des moyens de lancement reste généralement une activité des agences gouvernementales, la tendance est aujourd'hui à la privatisation, particulièrement aux Etats-Unis.

Aujourd'hui...

Dans le domaine des vols habités, les quinze dernières années ont été marquées par les fructueuses missions soviétiques Soyuz rejoignant les stations spatiales Salyut et MIR, le programme américain Skylab, et plus récemment les quatre premières missions du laboratoire européen Spacelab emporté à bord de la Navette spatiale américaine et mis en oeuvre par des astronautes. Avant la fin du siècle, on devrait assister à la mise en place de stations spatiales permanentes (Columbus par exemple), dans lesquelles des astronautes pourront séjourner plusieurs mois, ainsi que de porte-instruments récupérables (Eureca) et de plates-formes qui pourront être régulièrement desservies par des véhicules spatiaux et notamment par le futur avion spatial européen Hermes. La mise en place de ces grandes infrastructures spatiales ne se justifie que par l'utilisation qui en sera faite et qui nécessitera la mise en oeuvre d'une large gamme d'équipements, d'installations et de procédés de fabrication. Outre les activités de recherche proprement dites, l'environnement unique de l'espace offre des possibilités de fabrication plus intéressantes non seulement de produits déjà connus, mais encore de produits nouveaux qui viendront s'ajouter sur le marché. Et ceci est vrai dans nombre de

Figure 1 — Au stand de l'ESA: modèle de la plate-forme autonome de Columbus

Figure 2 — Modèle du module habité de Columbus



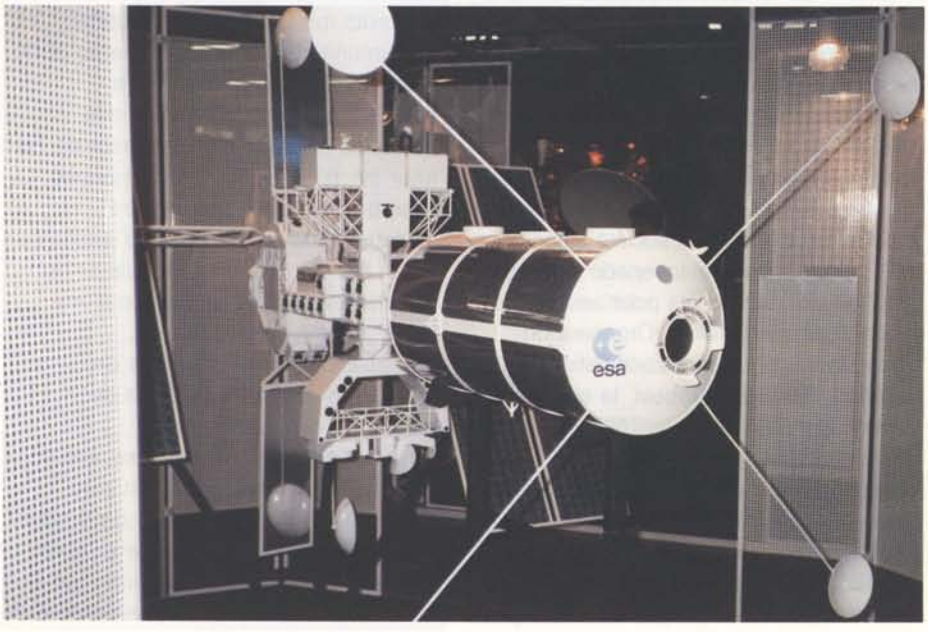
disciplines, allant de la chimie et la pharmacie à la biologie, en passant par la métallurgie et l'électronique (fabrication des composants), sans oublier les produits commerciaux qui relèvent de l'observation de la terre.

Et demain...

Cela, la recherche l'a abondamment démontré. Reste à informer les responsables des divers secteurs industriels des avantages que leur offre l'espace, et à les convaincre, tant sur le plan technique qu'économique, de l'intérêt pour leur industrie de s'orienter vers l'espace. D'où la nécessité d'un dialogue entre les responsables des industries des différents secteurs et ceux qui sont à même de les informer sur les possibilités offertes par l'espace et les conditions techniques et économiques de les utiliser. C'est précisément l'objectif que s'est fixé la Délégation aux affaires économiques de la ville de Montreux lorsqu'elle propose aux principales agences spatiales d'Europe et des Etats-Unis d'organiser la conférence et l'exposition Spacecommerce qui, après deux années de préparation par un bureau et un comité consultatif composés d'experts des milieux spatiaux gouvernementaux et industriels, a connu un grand succès à Montreux.

Près de cinq cents participants, dont une centaine représentant l'industrie traditionnelle, le secteur bancaire et les assurances, ont pu entendre plus de cinquante communications, allant de la définition des caractéristiques et des propriétés de l'environnement spatial aux modalités de financement des projets, en passant par la concurrence naissante sur le marché des moyens de lancement où s'affrontent désormais les constructeurs de lanceurs européens, américains, chinois, japonais et soviétiques.

La préparation de 'Spacecommerce 88' a commencé. La manifestation est prévue à Montreux du 21 au 25 février. L'objectif de cette deuxième manifestation est de réunir autant de représentants des industries non spatiales que ceux des milieux traditionnels de l'espace. Les associations professionnelles des différents secteurs industriels seront consultées et un effort sans précédent d'information de leurs membres sera engagé.



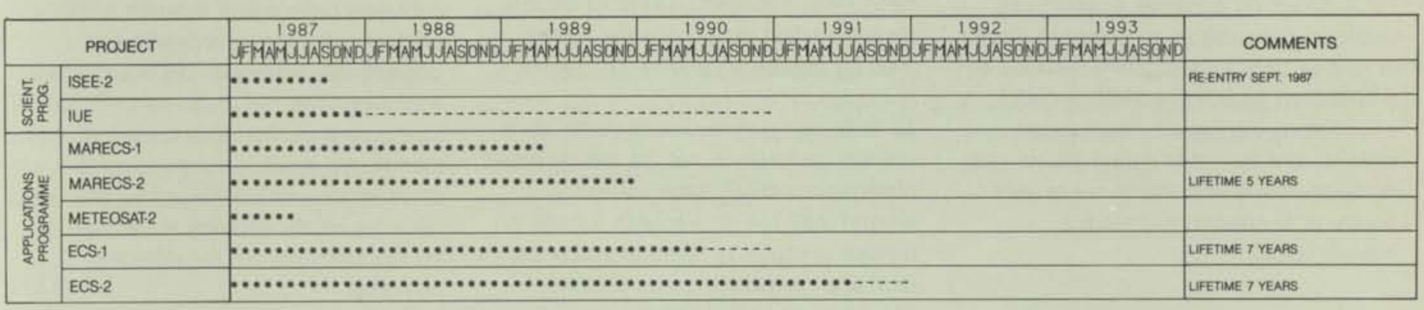
Conclusion

Les agences spatiales, tant nationales qu'internationales, remplissent bien leur mission, c'est-à-dire qu'elles démontrent la faisabilité et expérimentent des projets et activités où les risques sont trop grands pour que des capitaux privés puissent être engagés. Elles sont les mieux placées pour expliquer l'intérêt d'avoir recours à l'espace pour telle ou telle activité industrielle existante ou nouvelle, en particulier dans le cadre de l'utilisation des infrastructures orbitales futures. Comme dans le domaine des télécommunications et des lanceurs aujourd'hui, il faudra, au fur et à mesure que de nouvelles activités se développent, tenir les utilisateurs potentiels constamment informés des perspectives commerciales et des possibilités d'expansion de l'industrie spatiale.

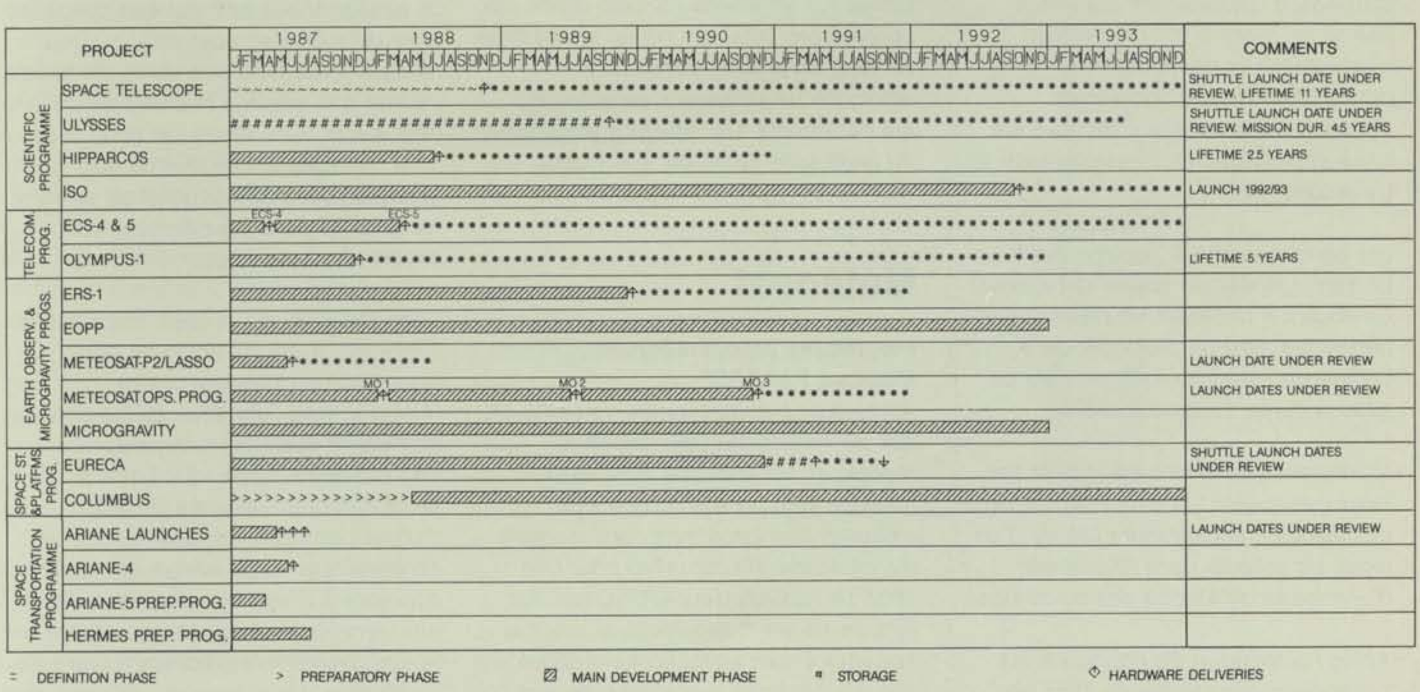
Sommes-nous à la veille d'une nouvelle révolution industrielle? Il appartient aux entrepreneurs et aux décideurs de répondre à cette question et de faire pour leurs entreprises les choix économiques correspondants en temps opportun. Spacecommerce est le forum par excellence où ils devraient pouvoir s'exprimer sur ce sujet et trouver tous les éléments de réponse à leurs questions, établir les contacts et engager les dialogues qui permettent de prendre les bonnes décisions.

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

In Orbit / En orbite



Under Development / En cours de réalisation



ISEE

Les résultats d'ISEE-3 (plus tard rebaptisé ICE, Explorateur Cométaire International) après sa rencontre avec la Comète Giacobini-Zinner en 1983 ont constitué une partie du programme de la 20e conférence ESLAB organisée par l'Agence à Heidelberg fin octobre. L'engin poursuit son évolution dans l'espace interplanétaire.

Le couple ISEE-1 et ISEE-2 a continué de fonctionner, tirant profit de sa configuration orbitale favorable par rapport à d'autres engins spatiaux (Viking, IMP-8 et DE-1) pour poursuivre ses observations au cours du printemps 1986.

ISEE-1 et ISEE-2 continueront à fonctionner à la charge de la NASA, l'ESA offrant en échange à IMP-8 des services d'acquisition de données. Après la rentrée dans l'atmosphère d'ISEE-1 et d'ISEE-2 en septembre 1987, la NASA envisage de poursuivre l'exploitation d'IMP-8, qui restera le seul à fournir des renseignements importants sur le vent solaire et le champ magnétique interplanétaire.

IUE

IUE fonctionne à présent depuis plus d'un an avec deux gyroscopes. Au cours de cette période, des progrès importants ont été faits en ce qui concerne le côté opérationnel de ce système de stabilisation. L'expérience acquise a permis de redéfinir les paramètres d'exploitation et de modifier les programmes de fonctionnement. Actuellement le satellite a retrouvé ses capacités antérieures à la défaillance du gyroscope no. 3.

Les performances du système électrique de bord (générateur solaire et batteries) continuent à dépasser les prévisions et permettent ainsi de prolonger, sauf défaillance catastrophique, au-delà de 1990 la durée de service prévue.

Maintenant que le fonctionnement des deux gyroscopes est bien maîtrisé, on a commencé à entreprendre l'étude d'un mode de secours dans l'éventualité d'une future défaillance des gyroscopes.

Après l'autorisation de poursuivre les observations du satellite en 1987, un appel aux propositions a été lancé pour la 10e année des opérations orbitales, qui débutera en juin 1987.

Les travaux sont en bonne voie en ce qui concerne l'élaboration sous une forme compacte (ULDA) des archives d'IUE et seront terminés courant 1987. Ces nouvelles archives devraient rendre une partie des données d'IUE encore plus faciles d'accès qu'actuellement. D'autres réalisations dans l'infrastructure de Villafranca, telles que la création du Centre de calcul scientifique, sont également en bonne voie.

Au chapitre des grands moments scientifiques, il faut signaler la grande précision de poursuite d'IUE, qui a permis de déceler la présence de soufre neutre à 3 secondes d'arc du satellite de Jupiter Io. Cela représente une découverte importante du point de vue de l'interaction du plasma de Jupiter avec ce satellite unique en son genre.

La vaste campagne d'observation de la comète de Halley a pris fin, les dernières observations d'IUE ayant eu lieu à environ 2,57 UA du périhélie. Le champ d'étude presque symétrique autour de ce dernier a permis de mieux pénétrer l'évolution des phénomènes de dégagement gazeux lors du réchauffement et du refroidissement de la comète.

Une campagne d'observation très réussie, étalée sur deux semaines, a permis d'autre part de repérer des taches sur les étoiles RS CnV. Grâce aux observations faites sur l'étoile symbiotique BF Cyg, on a pu identifier sans ambiguité les différentes composantes qui contribuent à la structure complexe du continuum formé par ces objets.

Météosat

Programme préopérationnel

Météosat P2/LASSO

Après avoir subi des essais de sensibilité aux décharges électrostatiques, le modèle de vol Météosat P2 a été à nouveau entreposé chez le maître d'oeuvre. Son lancement dans le cadre du vol Ariane 401 est prévu pour l'été 1987. Le rétroréflecteur LASSO qui doit être monté sur le satellite juste avant le lancement reste également entreposé afin d'éviter toute dégradation de son pouvoir réfléchissant. Dans l'intervalle, le réaménagement du centre de coordination LASSO de Fucino s'est poursuivi.

Une première réunion du groupe de coordination des opérations LASSO a eu lieu en France en septembre. La quatrième réunion du groupe des utilisateurs de l'expérience LASSO s'est tenue en décembre à Washington D.C. conjointement à une réunion du groupe chargé de la détermination précise du temps et des intervalles de temps.

Programme opérationnel

Secteur spatial

Les activités du maître d'oeuvre et des co-contractants ont été essentiellement consacrées à la livraison et à l'intégration des équipements destinés au premier exemplaire de vol. Des sous-systèmes sont déjà prêts à être intégrés à MOP-I, premier satellite du programme opérationnel Météosat. Les équipements sont livrés avec un revêtement afin de leur assurer de bonnes conditions thermiques avant le montage sur la structure du satellite. Quelques anomalies dans les interfaces entre le câblage et les équipements ont été détectées et corrigées.

La fabrication du matériel destiné aux exemplaires de vol ultérieur progresse également et devance même dans certains cas les prévisions.

Secteur terrien

Performances du satellite

Le satellite Météosat-2 qui était conçu, au point de vue ressources non renouvelables, pour une durée de service de trois ans, effectue depuis près de cinq ans et demi sa double mission de prise d'images et de diffusion de données. Une nouvelle stratégie a même été mise au point pour le faire durer encore plus longtemps.

Cette stratégie, qui consiste entre autres à effectuer avant fin 1986 une petite manoeuvre d'inclinaison, inclut l'élaboration et l'utilisation de logiciels de rectification des images capables de s'accommoder d'une inclinaison du satellite pouvant atteindre 2° (plan d'orbite par rapport au plan équatorial). En prenant soin par ailleurs de ne pas dépasser 0,1° en ce qui concerne les mouvements en longitude du satellite, on pourra maintenir la précision actuelle de rectification des images et prolonger ainsi

ISEE

The results from the ISEE-3 (later renamed ICE, the 'International Cometary Explorer') pass of Comet Giacobini-Zinner in September 1983, formed part of the programme of the Agency's 20th ESLAB Symposium, held in Heidelberg in late October. The spacecraft continues to cruise in interplanetary space.

The ISEE-1 and ISEE-2 pair of spacecraft have continued their operations, with advantage being taken of the fortunate orbital configurations of these two spacecraft with others (Viking, IMP-8 and DE-1) to run a coordinated campaign in the Spring of 1986.

ISEE-1 and ISEE-2 will continue to be operated free of charge by NASA in return for ESA providing data-acquisition services to IMP-8. After the re-entry of ISEE-1 and ISEE-2 in September 1987, NASA plans to continue operations of IMP-8, which will then be the only spacecraft available to provide important information on the solar wind and interplanetary magnetic field.

IUE

IUE has now been operating in two-gyro operational mode for more than a year. During this period, significant improvements have been made to the operational aspects of this attitude-control system. The experience gained has allowed operating parameters to be redefined and operational programmes to be modified. The present spacecraft performance is essentially back to that prior to the failure.

The performance of the spacecraft's power system (solar panels and batteries) continues to be better than predicted, allowing extension of the projected lifetime, in the absence of catastrophic failure, beyond 1990.

Now that the functioning of the two-gyro system is fully understood, work has slowly started on the design of a back-up operational mode in preparation for a possible future gyro failure.

After the approval of IUE's extension for 1987 observations, the Call for Proposals has been issued for the 10th year of orbital operations, which will start in June 1987.

Work has been progressing on the development of a compact form of the IUE archive (ULDA) and this will be completed in the course of 1987. The availability of this new archive is expected to make part of the IUE data even more accessible than at present. Further improvements in the VILSPA infrastructure, such as the establishment of the VILSPA Scientific Computing Centre (VSCC), are still in progress.

In terms of scientific highlights, the extremely precise tracking of IUE has allowed the detection of neutral sulphur within 3 arcsec of the Jovian moon Io. This represents an extremely important finding vis-a-vis the interaction of the Jovian plasma with this unique satellite.

The extensive Halley observation campaign has finished, the last IUE observations of Halley being made at about 2.57 AU perihelion distance. The nearly symmetric coverage obtained around perihelion passage is expected to provide important insight into the evolution of outgassing phenomena during comet heating and cooling.

A very successful two-week observing campaign has also been performed allowing the 'mapping' of spots on RS CnV stars. Observation of the symbiotic star BF Cyg has allowed unambiguous identification of the various components that contribute to the complex continuum distribution of these objects.

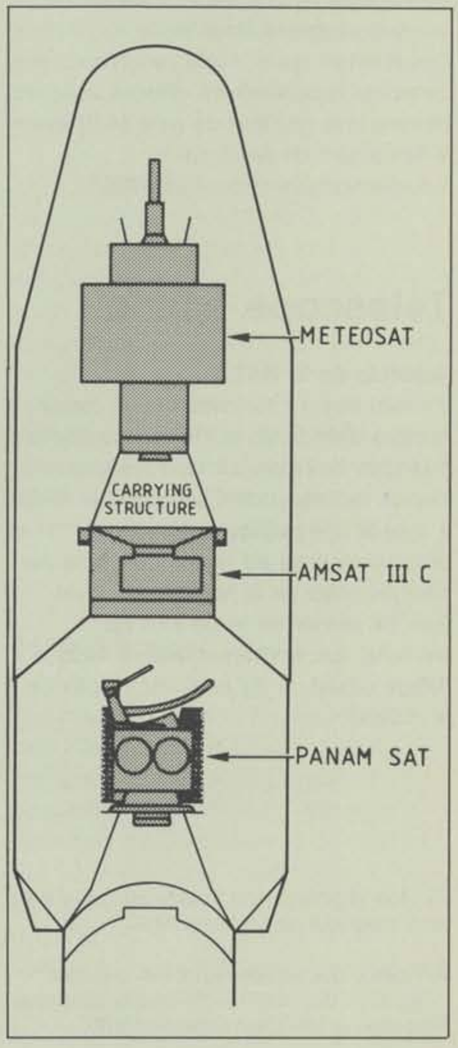
Meteosat

Pre-operational programme
Meteosat P2/LASSO
After undergoing testing for electrostatic-discharge sensitivity, the Meteosat P2 flight model has been put back into storage at the Prime Contractor's facility. Launch on Ariane flight 401 is foreseen for the summer of 1987. Similarly, the LASSO retro-reflector, which will be mounted on the satellite just before launch, remains in storage to prevent degradation of its optical reflectivity. Meanwhile, refurbishment of the LASSO Coordination Centre at Fucino has continued.

A first meeting of the LASSO Operating Coordination Group was held in France in September. The fourth meeting of the LASSO Experiment Users' Group was held in conjunction with a meeting of the Precise Time and Time Interval Group in Washington DC, in December.

Operational programme
Space segment
The work at prime and co-contractor level has centred on the delivery and integration of equipment items for the first flight unit. Subsystems are now available to start the integration of MOP-1, the first satellite in the Meteosat Operational Programme (MOP). When delivered, the equipment units are coated to ensure proper thermal behaviour before being installed on the satellite structure. A few anomalies in the interfaces between harness and equipment have been detected and corrected.

Construction of hardware for the subsequent flight units is also progressing and is, in some cases, ahead of schedule.



Aménagement des charges utiles pour le vol Ariane 401

Payload configuration for Ariane flight 401 *la durée de service du satellite jusqu'au début 1989, à condition toutefois que les effets de vieillissement ne viennent pas dégrader d'autres sous-systèmes.*

Traitement des données météorologiques
L'étude des techniques susceptibles d'améliorer la qualité des produits météorologiques s'est poursuivie. Les premiers résultats de ces analyses ont été fort bien accueillis lors de leur présentation aux utilisateurs scientifiques de Météosat qui se sont réunis à Amsterdam du 25 au 27 novembre 1986. Les travaux se poursuivent.

La validation d'un nouveau produit, l'indice de précipitation ESOC, s'est poursuivie et une coopération en la matière avec d'autres groupes scientifiques est envisagée. Des discussions dans ce sens ont été engagées pendant et immédiatement après la réunion des utilisateurs scientifiques à Amsterdam.

Réaménagement du secteur terrien
On a profité de l'annonce des reports de lancement pour modifier le planning de réaménagement du secteur terrien. La nouvelle programmation exige l'achèvement de la station, y compris des capacités exclusivement utilisées pour les besoins des satellites de type MOP, avant le lancement de Météosat-P2 actuellement prévu pour juin 1987.

Télescope spatial

Activités de la NASA
Il a fallu retirer pour réfection un certain nombre d'éléments du Télescope spatial à la suite de l'essai en vide thermique. Depuis l'accident de Challenger, la NASA a adopté une politique plus précautionneuse en ce qui concerne les charges utiles de la Navette et est en train de passer en revue tous les éléments susceptibles d'endommager l'étage orbital ou de nuire au succès de la mission.

Un essai supplémentaire d'impédance mécanique sur les éléments de raccordement Télescope spatial/étage orbital est en préparation. Le nouveau manifeste de lancement de la Navette décrit le Télescope spatial comme la cinquième charge utile et prévoit un lancement le 17 novembre 1988.

Générateur solaire
Les ailes du générateur ont été fixées sur le Télescope spatial en novembre 1986. A la suite du problème de centrage rencontré avec une de celles-ci, on a temporairement eu recours à des cales. Ce problème, ainsi que d'autres difficultés ayant trait aux verrous montés sur le flanc de l'engin, nécessiteront la dépose des ailes début 1987.

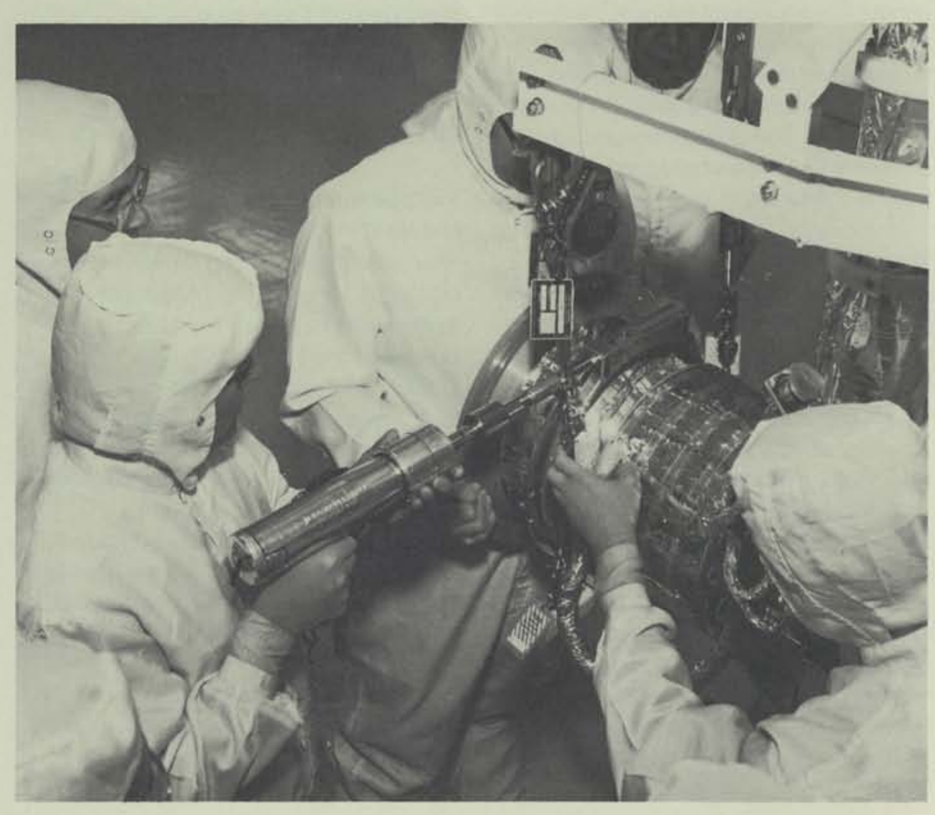
Chambre pour objects faibles
La Chambre pour objets faibles a été le seul des cinq instruments à ne pas avoir besoin d'être retiré du Télescope spatial pour réfection après l'essai en vide thermique.

Ulysse (ISPM)

L'événement principal de la fin 1986 a été la décision prise par l'Administrateur de la NASA de remplacer l'Etage Supérieur Centaure à ergols liquides par une fusée à poudre. Après examen de plusieurs solutions, le choix s'est porté sur l'emploi d'un Etage de changement d'orbite (IUS) combiné à un Module d'appoint propulsif (PAM-S). Jusqu'ici ces matériels n'avaient été utilisés que séparément comme étage supérieur avec l'étage orbital de la Navette. D'autre part, l'emploi d'un bouclier pare-flamme destiné à protéger le générateur thermoélectrique à radio-isotopes en cas d'accident n'a pas été jugé nécessaire.

Le problème essentiel d'organisation, qui n'a d'ailleurs pas encore été résolu, est celui de la date de lancement envisagée. En ce qui concerne les vols planétaires, deux dates ont été assignées, l'une fin 1989, l'autre fin 1990 à condition toutefois que les lancements de la Navette reprennent en février 1988. Il y a deux candidats pour la première, Ulysse et un engin spatial de la NASA, baptisé Galileo, qui doit être mis sur orbite autour de Jupiter. Chacune des équipes de projet a des priorités à faire valoir, mais la décision ne sera prise qu'au cours des premiers mois de l'année 1987.

Côté satellite, il n'y a guère d'activité, Ulysse demeurant entreposé en milieu d'azote sec chez Dornier System. Cependant, l'équipe Ulysse de l'ESA, désormais fort réduite, travaille activement avec les collègues de la NASA et du JPL à la préparation d'un lancement en 1989 avec le nouvel étage supérieur. Il a fallu



EVA tool checks during Space Telescope flight wing integration at Lockheed/MSC

Vérification des équipements EVA pendant l'intégration des ailes du générateur solaire du Télescope spatial chez Lockheed/MSC

Ground segment

Satellite operations

The Meteosat-2 satellite, which was designed, in terms of non-renewable resources, for an operational lifetime of three years, has now been supporting both the image-acquisition and data-dissemination missions for almost 5½ years. A new strategy has recently been developed to extend its lifetime even further.

This strategy, which includes a small inclination manoeuvre to be performed before the end of 1986, involves the development and use of image-rectification software that can cope with a satellite inclination of up to 2° (orbital plane with respect to the equatorial plane). By simultaneously controlling the satellite's longitudal movements to within 0.1°, the current image rectification accuracy can be maintained, thereby extending the satellite's lifetime until early 1989 (provided ageing effects do not degrade other satellite subsystems).

Meteorological data processing

Techniques to improve the quality of the meteorological products have been further studied. Preliminary results of these analyses were presented at the Meteosat Scientific Users meeting in Amsterdam on 25—27 November 1986, where they received a very positive response. Work in this area continues.

The validation of a new product, the ESOC Precipitation Index, has continued and cooperation with other scientific groups is envisaged in this area. Discussions on this subject were held during, and immediately after, the Amsterdam Scientific Users Meeting.

Ground-segment refurbishment

Advantage has been taken of the announced launch delays to replan the ground-segment refurbishment work. The new planning calls for station completion, including those capacities only required in support of the MOP-type satellites, before the launch of Meteosat-P2, presently scheduled for June 1987.

Space Telescope

NASA activities

The Space Telescope has had a number of units removed for reworking following the thermal-vacuum test. Since the Challenger accident, NASA is following a more conservative approach for Shuttle payloads and all elements that could damage the Orbiter or affect mission success are being reviewed.

An additional structural impedance test on Space-Telescope/Shuttle Orbiter attachment fittings is being prepared. The new Shuttle launch manifest shows the Space Telescope as the fifth payload, with a projected launch date of 17 November 1988.

Solar array

The solar-array wings were fitted to the Space Telescope in November 1986. An alignment problem was experienced with one wing and temporary shims had to be fitted. This problem and additional problems with the latches on the spacecraft side will require the removal of the wings in early 1987.

Faint-Object Camera

The Faint Object Camera was the only instrument of the five which did not need to be removed from the Space Telescope for reworking after the thermal-vacuum test.

Ulysses (ISPM)

The major event during the latter part of 1986 for Ulysses was the decision by NASA's Administrator to replace the liquid-fuelled Centaur Upper Stage by a solid rocket. The choice, following evaluation of several alternatives, was to use an Inertial Upper Stage (IUS) in combination with a PAM-S (Payload Assist Module). Each of these rockets has been used separately as an upper stage with the Shuttle Orbiter, but never before in combination. It has also been decided that a blast shield to protect the Radio-isotope Thermoelectric Generator (RTG) in the event of an accident is not necessary.

The most important management decision, as yet unresolved, is the prospective launch date. On the assumption that Shuttle launches will be restarted in February 1988, two launch slots have been assigned for planetary launches, one in late 1989 and the other in late 1990. There are two contenders for the earlier date, Ulysses and a NASA spacecraft named Galileo, to be put into orbit around Jupiter. Each project can give reasons why it should have priority, and a decision is anticipated during the first months of 1987.

On the satellite side there has been little activity, with Ulysses remaining in storage in a dry-nitrogen environment at Dornier System. However, the ESA Ulysses team, now much reduced in size, has been actively working with our NASA and JPL colleagues on establishing the foundation for a launch in 1989 with the new upper stage. This has involved considerable analysis of the new environment, since solid-motor characteristics show marked variations from those of liquid-fuelled motors, and also revision and modification of the extremely large number of documents involved in a launch with the Shuttle.

There has been one meeting of the Science Working Team, the first since soon after the Challenger accident. This discussed a variety of topics, including the revised launch environment and the problems caused by the numerous delays (Ulysses was originally scheduled to be launched in 1983). They passed a resolution for forwarding to ESA's Director General and NASA's Administrator in which they press for Ulysses to be allocated the late 1989 launch opportunity.

All in all, 1986 has been a sad year, starting with high hopes for a launch, which were dashed at the end of January when Challenger exploded. Much of the rest of the year has been taken up by NASA coming to terms with the new realities and deciding how to proceed. In the final months there has been marked progress, and it is hoped that in 1987 we will be able to build on this foundation towards a successful launch for Ulysses in 1989.

Hipparcos

The planned series of environmental tests on the structural/thermal model of the spacecraft were successfully completed in the middle of the year, permitting the spacecraft to be released from its mechanical qualification activities and to be transported to Aeritalia (I) to fulfil the role of engineering model. The spacecraft has since been equipped with engineering-model subsystems, previously assembled and tested on the *pour cela longuement étudier le nouvel environnement car les caractéristiques des moteurs à poudre différaient très nettement de celles des moteurs à ergols liquides; il a fallu d'autre part réviser et modifier le très grand nombre de documents dont s'accompagne un lancement par la Navette.*

Une réunion de l'équipe de travail scientifique a eu lieu, la première depuis l'accident de Challenger. Différents sujets étaient à l'ordre du jour, entre autres le nouvel environnement et les problèmes dus aux nombreux retards (le lancement était à l'origine prévu pour 1983). Il a été adopté une résolution à l'intention du Directeur général de l'ESA et de l'Administateur de la NASA pour leur demander instamment de fixer la date de fin 1989 pour le lancement d'Ulysse.

Au total, 1986 a été une année malheureuse, qui a vu réduits à néant les grands espoirs d'un lancement à la fin du mois de janvier lors de l'explosion de Challenger. Le reste de l'année a été en grande partie occupé par les efforts de la NASA en vue de faire face à cet état de choses et de trouver une nouvelle marche à suivre. On a enregistré de nets progrès dans les derniers mois et on espère pouvoir repartir sur ces nouvelles bases en 1987 pour réussir enfin le lancement d'Ulysse en 1989.

Hipparcos

La série d'essais d'ambiance prévue sur le modèle mécanique et thermique du satellite s'est achevée avec succès en milieu d'année, ce dernier etant déclaré qualifié pour la partie mécanique et expédié chez Aeritalia pour remplir le rôle de modèle d'identification. Il a été depuis lors doté de sous-systèmes de niveau correspondant, préalablement montés et testés sur le modèle électrique de préintégration, et il s'est avéré fonctionner de façon satisfaisante.

Parallèlement, la charge utile du modèle d'identification a été soumise à une série d'essais de stabilité et de vérification des performances optiques et mécaniques, effectués en grande partie sous vide. Ses caractéristiques se sont révélées conformes aux exigences de conception. Elle a ensuite été expédiée chez Aeritalia, où elle a été intégrée au modèle d'identification du satellite. Les essais des sous-systèmes intégrés du satellite sont actuellement en cours, les essais au niveau du système tout entier devant débuter en janvier 1987. Le programme d'essais du satellite devrait prendre fin en avril 1987.

Les activités relatives à l'intégration et aux essais sont en bonne voie en ce qui concerne les deux éléments principaux de la charge utile du prototype-modèle de vol. L'ensemble du télescope destiné à ce dernier a été construit et il a subi avec succès les essais sous vide dans l'installation FOCAL de l'Institut d'Astrophysique de Liège en Belgique. D'autres essais sur les propriétés optiques ont été effectués, et leurs résultats laissent présager d'excellentes performances de la charge utile une fois en orbite.

L'intégration et les essais de l'ensemble au plan focal de la charge utile sont presque terminés. Les essais de fontionnement et vérification des performances déjà effectués ont donné des résultats excellents qui confirment ceux précédemment enregistrés sur le modèle d'identification. Les deux ensembles devraient être intégrées début 1987 pour former la charge utile du modèle de vol-prototype.

D'autre part, les activités scientifiques sont en bonne voie, les interfaces entre les consortiums de données scientifiques et le Centre Européen d'Opérations Spatiales (ESOC) étant définies de façon très détaillée. Le catalogue d'entrée donnant la liste des étoiles à observer comprend à présent quelque 120 000 étoiles. Il devrait être livré à l'Agence en juillet 1987.

ISO

L'offre de fourniture officielle relative au satellite a été approuvée au début de l'année par le Comité de la politique industrielle (IPC), ce qui a permis d'adresser aux industriels l'appel d'offres concernant la définition détaillée du véhicule spatial, la conception des systèmes et sous-systèmes ainsi que les coûts correspondants (Phase B). L'objectif de la Phase B est de définir en détail le satellite, notamment ses interfaces avec le lanceur Ariane, de façon à permettre d'entreprendre la réalisation et les essais du matériel début 1988 (Phase C/D).

La réponse à l'appel d'offres a été reçue en juin et mise à l'examen en juillet. Cet examen a révélé qu'il y avait un chevauchement entre les activités de Phase B et une grande partie des activités de phase C/D que l'Aérospatiale, maître d'oeuvre du consortium industriel, jugeait nécessaire si l'on voulait que le lancement puisse avoir lieu à l'automne 1992. On a alors décidé de ne plus exiger un lancement à cette date vu le risque technique et financier inacceptable que cela aurait représenté. On a donc demandé aux industriels de remanier leur offre relative à la Phase B sans se préoccuper de la date de lancement.

La nouvelle offre a été reçue début octobre et derechef soumise à examen. Une proposition de contrat pour la Phase B du projet a alors été établie à l'intention du Comité de la politique industrielle. L'accord de celui-ci pour l'attribution du contrat de Phase B a été obtenu le 26 novembre 1986, la réunion de démarrage avec le Consortium industriel ayant lieu la première semaine de décembre.

Le Consortium industriel pour la Phase B est dirigé par l'Aérospatiale (France) et il comprend cinq co-contractants principaux, CASA, ETCA, Fokker, MBB et Selenia, plus sept sous-contractants.

L'équipe scientifique ISO (IST) composée des principaux chargés d'expériences et des scientifiques attachés à la mission, s'est réunie en septembre 1986. Elle a passé en revue l'avancement des travaux sur le satellite et les instruments et discuté d'un certain nombre de sujets précis ayant une incidence sur la productivité scientifique de la mission. Il s'est agi entre autres de l'orbite d'ISO, de l'étendue et du niveau des services que le secteur sol de l'observatoire devra fournir aux observatoires.

Les quatre groupes responsables de l'appareillage scientifique ont poursuivi leurs activités d'étude et de réalisation détaillées des instruments destinés aux différentes expériences. Des progrès considérables ont été enregistrés dans la préparation des documents d'interface des expériences, décrivant en détail les interfaces entre chaque expérience et le satellite.

electrical-preintegration model, and has been demonstrated to function in a satisfactory fashion.

In parallel, the engineering-model payload was subjected to a series of optical and mechanical performance and stability tests, largely conducted under vacuum conditions. It showed characteristics in line with design requirements. The payload was subsequently shipped to Aeritalia, where it has been assembled onto the engineering-model spacecraft to form the integrated engineering-model satellite. Satellite integrated subsystem testing is currently underway, with integrated system-level testing due to start in January 1987. The satellite testing programme is scheduled to be completed in April 1987.

Integration and test activities are in progress on the two major elements of the Proto-Flight Model (PFM) payload. The PFM telescope assembly has been built and has been successfully tested in vacuum at the FOCAL facility of the Institut d'Astrophysique de Liege, in Belgium. Further optical-property tests have been conducted, the results of which indicate a high probability of very satisfactory payload performance in orbit.

The focal-plane assembly of the payload is approaching completion of integration and testing. Functional and performance tests already completed indicated nominal performances and confirm results previously recorded on the engineering model. The two assemblies are planned to be integrated to become the proto-flight model payload early in 1987.

Scientific activities are progressing well, with the interfaces between the scientific data consortia and ESA's European Space Operations Centre (ESOC) being defined in considerable detail. The Input Catalogue that defines the stars to be observed has increased in content to about 120 000 stars, and remains on schedule for delivery to ESA in July 1987.

ISO

Early in the year, the formal procurement proposal for ISO was approved by the Industrial Policy Committee (IPC), which cleared the way for the issue to industry of the Request for Quotation for the spacecraft's detailed definition, system and subsystem design, and costing (Phase-B). The objective of Phase-B is to define the satellite in detail, including its interfaces to the Ariane launcher, to a level that will permit the commencement of hardware development and testing (Phase-C/D) at the beginning of 1988.

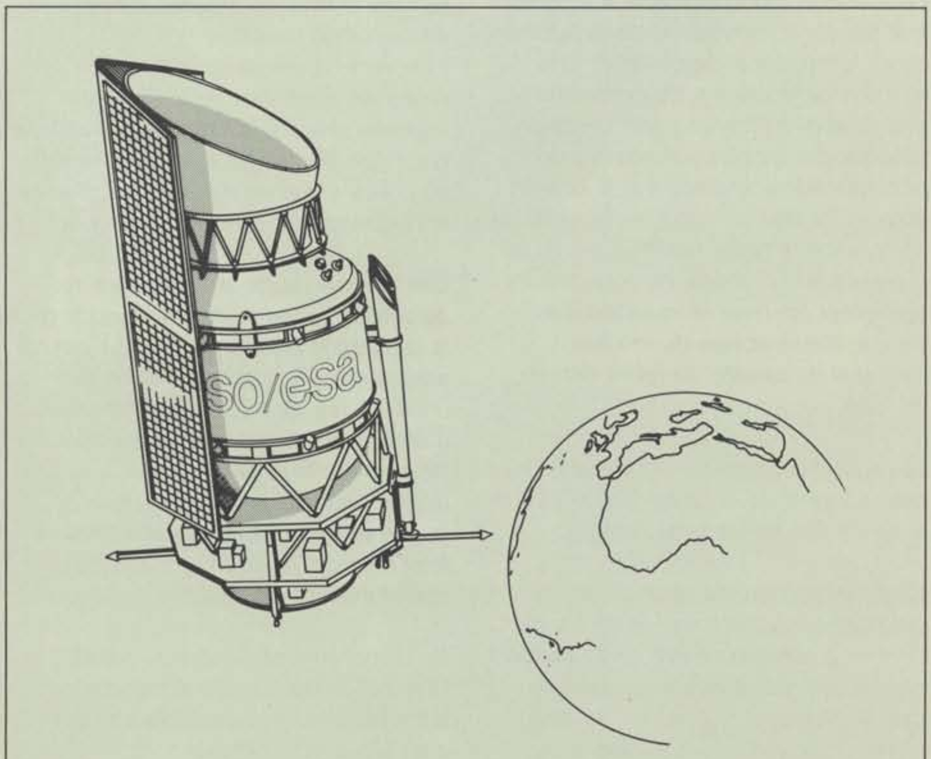
The industrial offer that formed the response to the Request for Quotation was received in June, and evaluation of this proposal was carried out during July. This evaluation revealed an overlap between the Phase-B activities and a substantial part of Phase-C/D, which Aerospatiale, as Prime Contractor of the industrial consortium, deemed necessary in order to comply with the requirement to launch ISO during the autumn of 1992. It was decided to remove this requirement as it was felt that this overlap represented an unacceptable technical and financial risk. Industry was therefore requested to make a revised submission of their Phase-B proposal without a constraint on the launch date.

This revised offer was received in early October and evaluated again, as a result of which a contract proposal for Phase-B of the ISO project was prepared for the Industrial Policy Committee. Approval from the IPC to place the Phase-B contract was obtained on 26 November 1986, which led to the kick-off meeting with the Industrial Consortium being held during the first week of December.

The Industrial Consortium for Phase-B is headed by Aerospatiale France as Prime Contractor and involves five major co-contractors: CASA, ETCA, Fokker, MBB and Selenia, and seven subcontractors.

The ISO Science Team (IST) consisting of the experiment Principal Investigators and the Mission Scientists, met in September 1986. In addition to reviewing progress on the satellite and the instruments, the IST discussed a number of specific topics that have an impact on the scientific return of the mission. Principal among these were the orbit for ISO, and the range and level of services to be provided to observers by the ground segment of the observatory.

The four instrument groups continued with the detailed design and building of engineering models of their experiments. Considerable progress has been made in the preparation of the Experiment Interface Documents, which describe the interface between each experiment and the satellite in detail.



Vue imaginaire d'ISO

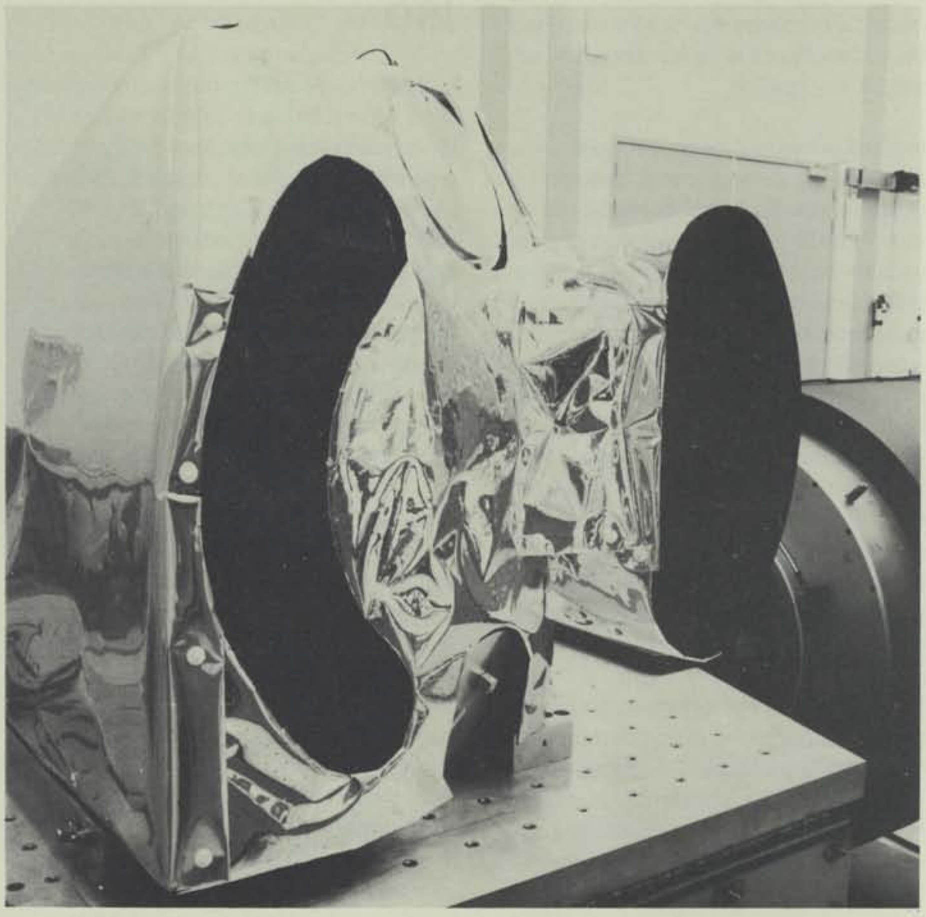
Artist's impression of the ISO spacecraft

ECS

Suite à l'échec d'Ariane V18, le programme ECS a été prolongé pour s'adapter au nouveau calendrier de lancement qui sera établi à la suite des investigations et mesures correctives entreprises par les responsables du lanceur.

ECS-4, qui devait être lancé par Ariane V19 à la mi-86, le sera maintenant au cours du premier semestre 87. De même, le lancement d'ECS-5 est reporté au premier semestre 88.

Bien que certains équipements d'ECS-1 et -2 aient souffert de dégradations mineures, ces satellites ont, de par leur conception, des marges de sécurité et des redondances suffisantes qui leur permettent de continuer à fournir les mêmes services. A ce jour, ils ont assuré environ 500 000 heures repéteurs essentiellement pour la retransmission de programmes de télévision. En décembre 86, ECS-1 est parvenu à mi-course de sa vie opérationnelle prévue.



The Along-Track Scanning Radiometer for ERS-1, photographed during structural-model vibration testing at ESTEC

Le radiomètre à balayage dans le sens du déplacement du satellite (ATSR) au cours des essais de vibrations du modèle de structure à l'ESTEC

ERS-1

Le contrat de Phase C/D a été signé par le maître d'oeuvre Dornier et l'Agence fin octobre.

L'élaboration des instruments a progressé à la fois sur le modèle de développement et sur le modèle d'identification. Une attention particulière a été consacrée au problème des dépassements de délais attendus par rapport aux besoins pour plusieurs éléments situés sur le chemin critique. La date de livraison de plusieurs composants à haute fiabilité destinés au programme du modèle de vol a également été mise en question. Les travaux d'assemblage du modèle structurel du satellite devraient débuter fin 1986.

La revue des bases de référence de la mise sur pied de la station sol de Kiruna a donné des résultats satisfaisants.

Côté campagnes, les résultats de la campagne méditerranéenne en bande C, dont on a précédemment rendu compte, ont été communiqués depuis peu. Ils sont en bon accord avec les résultats antérieurs et confirment la validité du modèle établi pour la bande C. C'est ainsi, par exemple, que les résultats des mesures de vitesse de vent fort cadrent tout à fait avec l'extrapolation du modèle déjà mis en circulation.

La campagne qui avait été prévue au Brésil a dû être annulée, l'autorisation de survoler le territoire brésilien n'ayant pas été accordée. Toutefois, une mini-campagne d'une semaine a été organisée au-dessus de la Guyane française grâce à un appareil Do 228 de la DFVLR, équipé de deux diffusiomètres en bande C fournis par le CRPE (France) et l'Université de Brême (Allemagne).

Une analyse rapide laisse apparaître qu'une part importante des objectifs de la campagne brésilienne d'ERS-1 ont été atteints grâce à cette campagne de courte durée. Les résultats obtenus en première lecture montrent également l'invariabilité et la stabilité de la rétrodiffusion au-dessus de la forêt guyannaise, qui serait très semblable à la forêt tropicale brésilienne. L'analyse approfondie se poursuit.

En ce qui concerne l'utilisation d'ERS, l'Exécutif a reçu un grand nombre de réponses à l'offre de participation qui avait été lancée; celles-ci sont actuellement à l'étude.

Dans le cadre du programme de développement, l'Agence est présentement en pourparlers avec les industriels en vue d'obtenir les renseignements nécessaires à la préparation de l'offre de fourniture d'un second exemplaire de vol du satellite ERS-2.

Microgravité

L'exécutif étudie actuellement la possibilité d'adopter un programme de travail intérimaire destiné à pallier la limitation draconienne des occasions de vol à bord de la Navette jusqu'à l'avènement de la Station spatiale.

C'est ainsi qu'on a entrepris une étude de toute la documentation technique et financière disponible concernant les mini-missions, les systèmes récupérables, les vols paraboliques et surtout les solutions

ECS

Following the failure of the Ariane V18 launcher, the ECS programme has been extended to be compatible with the most probable new launch schedule following the investigation and corrective actions carried out by the Ariane vehicle authority.

ECS-4 was due to be launched on Ariane V19 in mid-1986, and this launch will now take place in the first half of 1987. The launch of ECS-5 is similarly delayed until the first half of 1988.

ECS-1 and 2 have both suffered minor equipment failures, but since the spacecraft are designed with performance margins and redundant systems to cope with such events, the in-orbit performance of the spacecraft has not been reduced. To date, these two spacecraft have provided about half a million transponder hours, mostly for the distribution of TV. ECS-1 reached the half-way mark in its design lifetime in December 1986.

ERS-1

The ERS-1 Phase-C/D contract was signed by the Prime Contractor Dornier and the Agency at the end of October.

Instrument development has progressed on both the development model and engineering model. Special attention is being paid to the identification of improvements in the schedules of several elements on the critical path whose planned delivery dates have slipped beyond the need dates. The same applies for the delivery of several high-reliability components for the flight-model programme. The ERS-1 structural-model satellite assembly programme is on schedule to start at the end of 1986.

The Kiruna ground-station Development Baseline Review has been held, with satisfactory results.

Concerning campaigns, the results of the previously reported C-band Mediterranean Campaign have recently been released. They show a good correlation with the results of earlier campaigns and confirm the C-band model. In particular, the high wind-speed measurement results fit quite well with the extrapolation of the previously released model.

The foreseen Brazilian campaign had to be cancelled because authorisation to overfly Brazilian territory was not obtained. However, a reduced one-week campaign was carried out over French Guyana with the DFVLR D0228 aircraft equipped with the two C-band scatterometers of CRPE (France) and Bremen University (Germany).

From quick-look analysis, it is believed that a significant part of the ERS-1 Brazilian campaign objectives have been met with this reduced campaign. The quick-look results also show the invariance and stability of the backscatter from the French Guyana forest, considered to be very similar to the Brazilian Rain Forest. Detailed analysis is still in progress.

Regarding the utilisation of ERS, the Executive has received a large number of replies resulting from the ERS Announcement of Opportunity and these are presently under evaluation.

Within the development programme framework, the Agency is presently in discussions with industry in order to obtain the necessary information for the preparation of the proposal for procuring a second flight model spacecraft, ERS-2.

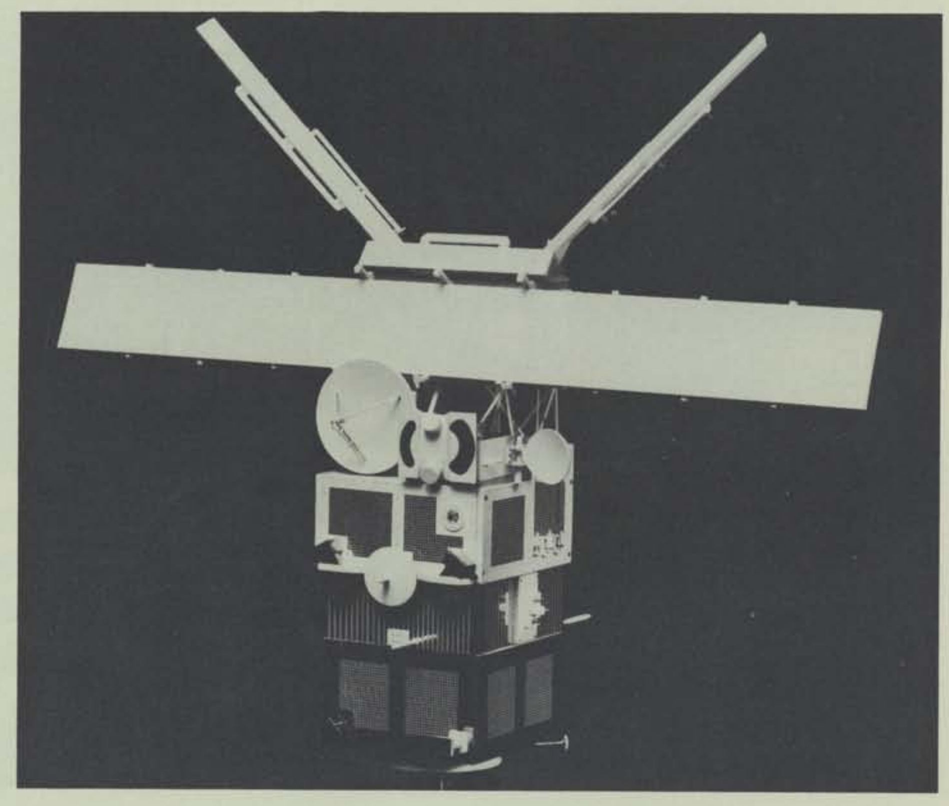
Microgravity

The Executive is currently investigating the feasibility of introducing an interim programme of work to bridge the gap left by the severely limited Shuttle flight opportunities from now until the Space-Station era.

Consequently, studies were initiated into all available technical and cost information on mini-mission aspects, retrievable systems, parabolic flights and especially on alternative launch opportunities.

In the meantime work has continued on the approved Phases 1 and 2 of the programme, but at a somewhat reduced pace in some areas.

In the context of the Space Sled, several scientific reviews of the status of neuro-physiological research were held in September 1986 at ESA and NASA. Extensive results are available which



Maquette en grandeur réduite du satellite ERS-1 (photo Dornier)

Scale-model of the ERS-1 spacecraft (courtesy of Dornier) *de remplacement possibles pour un lancement.*

Dans l'intervalle, les travaux se sont poursuivis au sujet des phases agréées (phases 1 et 2) du programme, bien qu'à un rythme quelque peu ralenti dans certains secteurs.

En ce qui concerne le Traîneau spatial, plusieurs tours d'horizon scientifiques sur l'état de la recherche neuro-physiologique ont eu lieu en septembre 1986 à l'Agence et à la NASA. L'ampleur des résultats dont on dispose ouvre des perspectives intéressantes pour la recherche future dans ce domaine.

Les essais du Biorack réaménagé se sont achevés en cours d'année. Une revue de recette du matériel a été organisée avec le contractant industriel; seuls quelques points en suspens du programme des travaux ont été recensés et ont depuis lors reçu une solution.

Les travaux relatifs à la Phase C/D du Module autonome de physique des fluides ont progressé conformément aux prévisions.

En ce qui concerne les occasions de vol de courte durée, les préparatifs du nouveau vol du module ESA sur Texus 14B se sont poursuivis sans encombre. Les modules ESA destinés au vol suédois Maser 1 en février 1987 ont été achevés; cependant quelques perfectionnements ont été demandés suite au report du vol d'octobre 1986 à février 1987.

Spacelab et IPS

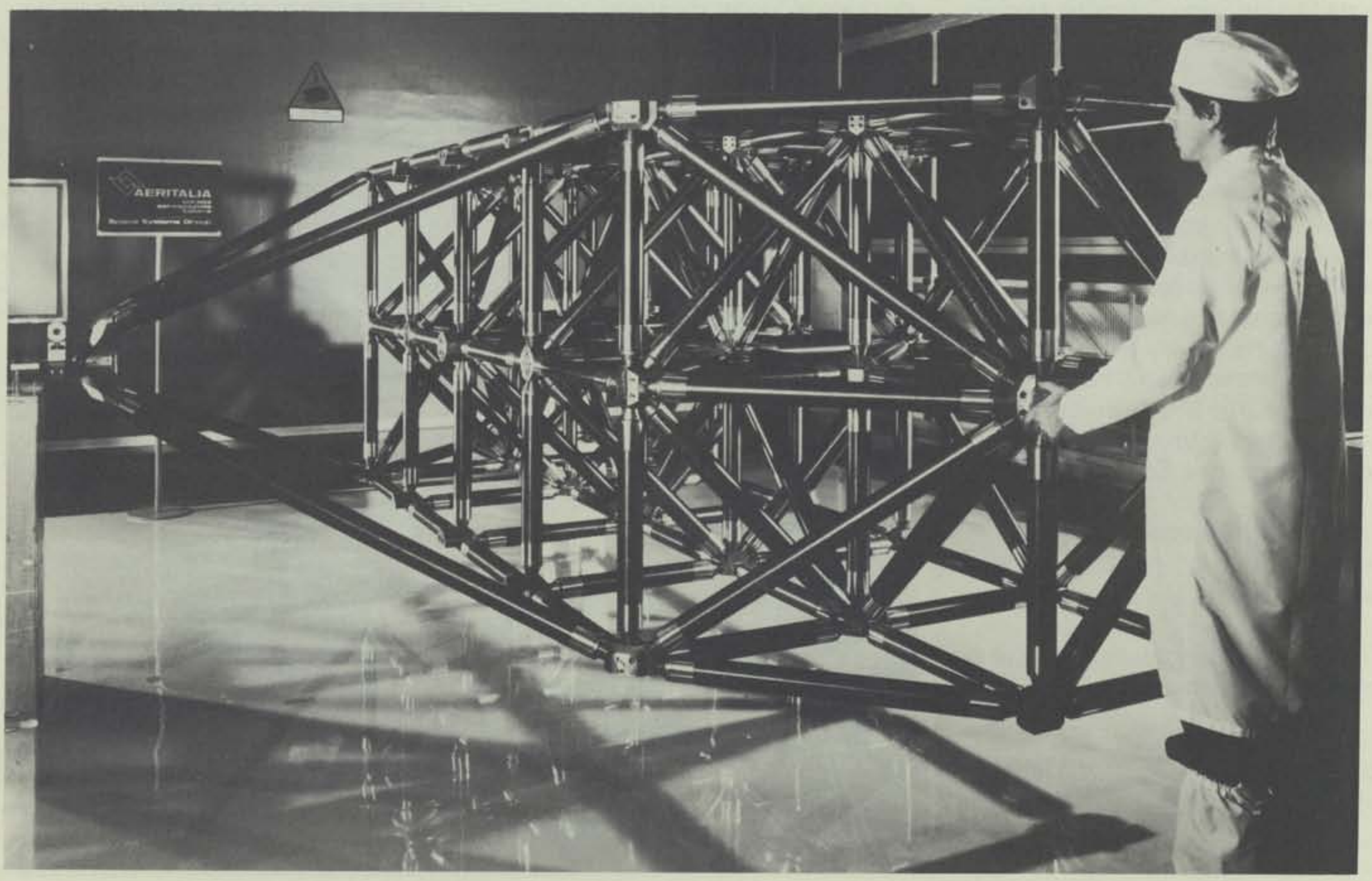
Les travaux se poursuivent sur les derniers points en suspens. En ce qui concerne le Spacelab, les activités de liquidation des contrats sont vérifiées périodiquement et surveillées dans leur progression. La qualification de l'adaptateur d'interface de charge utile (PIA) est presque terminée et la fabrication des unités de vol se poursuit. On enregistre cependant un retard important par suite des problèmes relatifs à certains composants électroniques. C'est ainsi qu'une unité d'affichage de données est encore en réparation chez le fournisseur.

En ce qui concerne le Système de pointage d'instruments (IPS), on progresse dans la liquidation des points en suspens enregistrés au cours de la qualification et de la recette officielles de Phase C/D. Le contractant a encore reporté la livraison de l'ensemble de détection optique.

Production ultérieure
Les tâches relatives aux services d'assistance au Centre de vols spatiaux Marshall (MSFC) de la NASA sont assurées sur demande par l'Agence à une échelle relativement modeste. Les derniers éléments de rechange à livrer dans le cadre du contrat de production ultérieure conclu entre l'ESA et la NASA, à savoir les actionneurs du Système de pointage d'instruments, ont été réparés et sont en train de subir de nouveaux essais.

Eureca

Malgré les reports de lancement envisagés après l'accident de la Navette en début d'année, les travaux de développement consacrés à Eureca se sont activement poursuivis.



Primary flight-unit structure for Eureca, manufactured by Aeritalia

La structure principale de l'unité de vol d'Eureca, fabriquée par Aeritalia open an interesting perspective for future research in this area.

The testing of the refurbished Biorack was completed during the reporting period. A Hardware Acceptance Review was conducted with the industrial contractor and only a few open work items were identified. These have since been cleared.

Work on Phase C/D of the autonomous Fluid-Physics Module has progressed according to plan.

As regards short-duration flight opportunities, preparations for the reflight of the ESA module on Texus 14B continued without difficulty during the reporting period. The ESA modules for the Swedish Maser 1 flight in February 1987 have been completed, although some improvements have been requested in view of the postponement of the flight itself from October 1986 to February 1987.

Spacelab and IPS

Work is continuing on the tasks remaining open for both Spacelab and the Instrument Pointing System (IPS).

Contract close-out activities for Spacelab are being periodically checked and reviewed for progress. Qualification of the Payload Interface Adaptor (PIA) is nearly complete and flight-unit production is proceeding. There is, however, a significant delay due to problems associated with electronic components. One Data Display Unit (DDU) is still at the supplier for repair.

On IPS, progress is being made in closing items recorded as open during the formal Phase-C/D qualification and acceptance. The delivery of the Optical Sensor Package by the contractor is further delayed.

Follow-On Production

Support services tasks for NASA/MSFC are being performed by ESA on request on a relatively small scale. The last FOP spares items to be delivered under the ESA/NASA FOP contract, the IPS actuators, have been repaired and are undergoing retesting.

Eureca

Despite the expected launch delays following the Shuttle accident at the beginning of the year, the development work on Eureca has progressed at a high rate.

Engineering models are now available for nearly all subsystems and payloads. The primary structure of the Eureca flight unit has been delivered by Aeritalia, Turin to BPD, Colleferro so that integration of the hydrazine propulsion and cold-gas attitude control subsystems can commence.

The joint CNES/ESA Design and Qualification Review of the Magnetic Bubble Memory (MBM) is in progress and the ESA-furnished Overall Check-Out (OCOE) station is installed at the MBB/ERNO integration site. The first interface tests between the OCOE and the on-board Data Handling Subsystem (DHS) hardware are in progress, in order to make up the Payload Test Facility (PTF) ready for payload interface testing in January 1987.

However, a slowdown in activities is now planned from 1987 onwards, because NASA has notified ESA that current planning of the Shuttle manifest foresees launch of Eureca no earlier than April 1991. ESA's Director General has approached NASA in the meantime to discuss the possibility of advancing the launch to April 1990. As that would now be the earliest possible launch date, discussions are in progress at Programme-Board level to provide the necessary bridging finances.

Space Station/ Columbus

The Phase-B2 proposal from MBB/ERNO, received at the end of August 1986, was evaluated and found to need major improvement before it could be deemed acceptable. A modified proposal was subsequently submitted by industry at the beginning of October which fulfilled ESA's requirements. Final negotiations were then started to adjust some industrial-return imbalances and to reassess the communications-subsystem team arrangements.

As a result, a two-step approach was chosen. Firstly, existing work packages would be increased in scope and funding and immediately included in the Phase-B2 baseline. As a second step, additional work packages — enhancing the objectives of Phase-B2 — would be initiated as contract changes in January 1987. The restructuring of the communications-subsystem team resulted in Selenia Spazio being overall team leader and BTM assuming a lead role in three of the five major subassemblies.

Industry started the Phase-B2 work on 3 November at its own risk, and received the approval of ESA's Industrial Policy Committee (IPC) on 12 November. The Columbus Programme Board met on 27/28 November and approved the two-step approach, subject to certain conditions being met for Step-2, but did not yet approve the bridging phase considered to be necessary between the end of Phase-B2 and the start of Phase-C/D. An alternative proposal is now being elaborated for this purpose. A first Phase-B2 progress meeting was held at MBB/ERNO at the end of November and the Phase-B2 contract was signed in early December.

The utilisation studies are continuing as planned. The mid-term review was held at DFVLR in mid-September. The Space-Station User Panel attended a meeting with their counterparts from Canada, Japan and USA in Ottawa at the end of September.

The new Columbus operations studies were kicked off at the end of September. The Reference Flight-Operations Concept was reviewed in mid-November.
The technology programme has progressed steadily. Efforts are now underway to harmonise the study results with the industrial proposal for Phase-C/D.

Two joint ESA/NASA meetings took place at JSC and at ESTEC within the framework of the joint Man-Tended Free Flyer (MTFF) study and a number of agreements on technical and operational aspects were reached. Views on user benefits remain divided. NASA released the draft Request for Proposal for the Space Station at the end of November and expects to send out the final version in January 1987. Meanwhile ESA is intensifying final negotiations with NASA with a view to producing a Memorandum of Understanding by Spring 1987.

Presque tous les modèles d'identification des sous-systèmes et des charges utiles sont prêts. Aeritalia (Turin) a livré à BPD (Colleferro) la structure principale de l'unité de vol d'Eureca, et l'intégration des sous-systèmes de propulsion à hydrazine et de commande d'orientation par gaz froid peut désormais commencer.

La revue conjointe CNES/ESA de conception et de qualification de la mémoire à bulles magnétiques continue de progresser et la station de vérification générale (OCOE) fournie par l'Agence a été mise en place au lieu d'intégration chez MBB/ERNO. Les premiers essais d'interface entre les équipements de vérification générale et le matériel du sous-système de gestion des données à bord sont en cours, de telle sorte que l'installation d'essai des charges utiles soit prête pour les essais d'interface de ces dernières en janvier 1987.

Un ralentissement des activités est cependant prévu à partir de 1987, la NASA ayant informé l'Agence que selon le calendrier actuel des capacités d'emport de la Navette, le lancement d'Eureca ne pourrait avoir lieu avant avril 1991. Entretemps, le Directeur général de l'Agence a pris contact avec la NASA pour voir si le lancement ne pourrait pas malgré tout se faire en avril 1990.

Comme il n'est pas question d'envisager un lancement avant cette date, des discussions sont actuellement en cours au niveau du Conseil directeur du programme pour se procurer les fonds nécessaires dans l'intervalle.

Station spatiale/ Columbus

L'offre de MBB—ERNO concernant le Phase B2 a été reçue fin août 1986 et elle s'est avérée, après examen, nécessiter d'importantes améliorations avant de pouvoir devenir acceptable. L'offre modifiée présentée ensuite par les industriels a répondu aux souhaits de l'Agence. Les dernières négociations ont pu alors démarrer en vue de régler certains déséquilibres dans le retour industriel et de réviser la composition de l'équipe chargée du sous-système de communications, en suite de quoi une démarche en deux temps a été adoptée. Le premier consiste à accroître l'ampleur et le financement des lots de tâches existants et à inclure immédiatement ceux-ci dans les bases de référence de la Phase B2; le second consiste à entreprendre en janvier 1987, à titre de remaniements contractuels, des tâches supplémentaires destinées à mieux servir les objectifs de la Phase B2. A la suite de la restructuration de l'équipe responsable du sous-système de communications, Selenia Spazio a pris la tête de l'ensemble de l'équipe, BTM se voyant attribuer un rôle de premier plan dans trois des cinq sous-ensembles principaux.

Les industriels ont entamé les travaux relatifs à la Phase B2 le 3 novembre de leur propre initiative et ont reçu le feu vert de l'IPC le 12 novembre. Le Conseil directeur du programme Columbus s'est réuni les 27 et 28 novembre; la démarche en deux temps dont il est question plus haut a obtenu son agrément sous certaines conditions en ce qui concerne la 2e étape, mais il n'a pas encore donné son accord sur la phase intermédiaire jugée nécessaire entre la fin de la Phase B2 et le début de la Phase C/D. Pour cette raison, une proposition de rechange est à l'étude. Une première réunion sur l'état d'avancement de l'étude s'est tenue chez MBB/ERNO fin novembre et le contrat de Phase B2 a été signé début décembre.

Les études relatives à l'utilisation se poursuivent comme prévu. La revue de milieu d'étude a eu lieu au DFVLR à la mi-septembre. L'ensemble des utilisateurs de la Station spatiale ont assisté à Ottawa, fin septembre, à une conférence avec leurs homologues canadiens, japonais et américains.

Les nouvelles relatives aux opérations de Columbus ont démarré fin septembre. Le concept de référence des opérations de vol a fait l'objet d'une revue à la mi-novembre.

Le programme technologique (PSTP) a régulièrement progressé. On s'efforce actuellement d'harmoniser les résultats des études avec la proposition industrielle relative à la Phase C/D.

Deux réunions conjointes ESA/NASA ont eu lieu au JSC et à l'ESTEC dans le cadre de l'étude relative à la plate-forme en vol libre sous surveillance humaine (MTFF), et un certain nombre d'accords sur les aspects techniques et opérationnels ont été réalisés. Les opinions continuent de diverger en ce qui concerne les avantages à attendre pour les utilisateurs. La NASA a émis le projet d'appel d'offres pour la Station spatiale fin novembre et compte lancer l'appel d'offres définitif en janvier 1987. En attendant, l'Agence s'active aux dernières négociations avec la NASA en vue d'établir un Protocole d'Accord dès le printemps 1987.

The Flight of ESA's Vestibular Sled on the German Spacelab D1 Mission

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In the year that has passed the ESA Sled facility was launched aboard Space Shuttle 'Challenger' for its first flight as part of the German Spacelab D1 Mission, a great deal has been learned about human perceptual and physiological adaptation to weightlessness. This article outlines the research programme that was established for the mission by scientists from four European countries, the USA and Canada and highlights the scientific results to date.

Introduction

The ESA Sled facility was originally designed for flight with the First Spacelab Payload (FSLP). However, due to payload resource problems, the Spacelab Programme Board decided on 31 March 1980 to 'descope' the Sled facility from FSLP, on which only a very limited number of vestibular experiments were subsequently conducted in late 1983.

In December 1980, ESA's Council accepted an offer from the German authorities to fly the Sled and its full complement of vestibular experiments on the German D1 Mission, which was designed primarily as a 'microgravity mission' for research in material and life sciences. The Principal Investigators (PI) for the D1 vestibular experiments were: Prof. R. v. Baumgarten of Mainz University (for the European experiments) and Prof. L. Young of MIT (for the US/Canadian experiments).

Vestibular experiments

Man's perception of orientation and motion is inferred from the cues provided by three sensory systems:

- the visual system
- the vestibular receptor system (part of the inner ear that plays no role in hearing), and
- the somato-sensory system (mechano-receptors in the skin, the joints, and other supporting tissues).

The most important sensors are the eyes and the vestibular receptors. The vestibular system has two anatomically and functionally distinct types of receptors: the semi-circular canals, stimulated by angular acceleration, and the otolith (ear-stone) organs, stimulated by linear acceleration.

The weightless environment of space has a direct effect on the interpretation of signals from the otolith organs – signals that are used by the brain to control spatial orientation, posture, and compensatory eye movements. Due to the absence of a sensed gravity vector — i.e. a gravitational 'sense of down' — the signals from the otolith and the somato-sensory receptors no longer match the expected patterns learned in Earth's gravity. Sensory information from the eyes and the semicircular canals however, is not substantially altered in microgravity. It is this mismatch in sensory information about body movement and orientation that is believed to be the principal cause of the space motion sickness from which so many astronauts suffer (some 50%) during the first two to three days of orbital flight.

The series of interrelated European/US/Canadian experiments (Tables 1 and 2) that were conducted with the Vestibular Sled during the D1 mision, as well as before and after the flight were designed to investigate the contributions of the different sensory systems to spatial orientation by applying controlled stimuli and examining the various responses to assess human sensory motor adaptation to weightlessness.

The Vestibular Sled concept

The D1 configuration

The 3.5 m long Sled structure was

Table 1 — European flight and Baseline Data Collection (BDC) experiments

Experiment	Institutes	Objectives and methods
Determination of Threshold for Perception of Linear Oscillation	Institute for Aviation Medicine (IAM), Farnborough, UK Physiol. Inst., Univ. Mainz	Measurement of threshold sensitivity to discrete sinusoidal linear movements having linear acceleration levels within the range 0.01 to 0.32 m/s^2
Linear Vestibulo-Ocular Reflex (VOR)	Physiol. Inst., Univ. Mainz	Study of reflex eye movements evoked by linear acceleration, i.e. effect of stimulation of otolith organs.
Opto-kinetic Response	CNRS, Paris Klinik Großhadern (Neurol.) München Univ. Tübingen (Neurol.)	Study of eye movements (nystagmus) and subjective sensations (perceived self-motion) in response to dynamic visual stimuli acting either in isolation or in combination with whole-body linear sinusoidal oscillation.
Caloric Stimulation	Klinikum Steglitz (HNO), FU Berlin	Test of the present-day theory on caloric nystagmus (systematic jerks of the eyes as response to stimulation of the outer-ear canals with air or water, warmer or cooler than body temperature), which is based on thermo-convective fluid shift in the inner ear, and its validity in the microgravity environment, in which there is practically no thermo-convection.
Provocative Stimulation	Physiol. Inst., Univ. Mainz	Head movements made during first days in microgravity provoke space motion sickness. Isolated otolith stimulation is applied to test if this is sufficient to induce the space motion sickness or whether a more complex motion stimulus with both angular and linear acceleration components is necessary.
Posture	CNRS, Paris Klinik Großhadern (Neurol.), München, Univ. Tübingen (Neurol.)	Study of postural activity and its modification by visual stimuli; a test of visual-vestibular interactions.
Oscillopsia and Active Vestibulo-Ocular Reflex (VOR)	CNRS, Paris Klinik Großhadern (Neurol.) München Univ. Tübingen (Neurol.)	Determination of the gain and phase of VOR induced by voluntary sinusoidal head oscillations in yaw and in pitch. Head and eye movements are recorded and the apparent motion of a fixed target is indicated.
Neck Receptor Test	Physiol. Inst., Univ. Mainz	Influence of neck receptors on eye movements and the subjective (egocentric) vertical. Neck receptors are stimulated by swaying the subject's body whilst the head is fixed. Perceived position is indicated by resetting of the target cross with the joystick.
Baseline Data Collection* Luminous Line Test	Physiol. Inst., Univ. Mainz	Study of graviceptor function by measurement of ability of subject to set the subjective vertical when tilted about the roll axis.
Baseline Data Collection Ocular Counter-Rolling	Physiol. Inst., Univ. Mainz	Test of otolith organ function by recording static ocular counter-rolling during re-adaptation to Earth's gravity. Static OCR is measured at 15° intervals between 0° and 90° of tilt to each side.
Baseline Data Collection Tilting-Room Expt.	TNO, Soesterberg (NL)	Extended tests of changes in postural control during re-adaptation to Earth's gravity compared to the pre-flight baseline. The subject attempts to maintain an upright position while standing on a stabilometer inside a dynamically tilting visual display.

* Note: The 'BDC' expts. were carried out pre- and post-flight only on the ground — all other experiments in the table were carried out pre-, in-, and post-flight.

Figure 1 — Sled-experiment training in progress, with astronaut Wubbo Ockels wearing the European helmet

Figure 2 — Astronaut Ernst Messerschmid working at the Sled Control Rack during a training session at DFVLR

attached to the centre aisle of Spacelab's floor (Fig. 1). All other associated equipment was accommodated in two dedicated Spacelab single racks at the aft end of the Module and in special stowage areas. The 'Sled Control Rack' (Fig. 2) contained the Sled and experiment electronic units for the control and monitoring of the Sled and the European and US/Canadian experiments by the test operator. The Sled 'Stowage Rack' contained smaller items of experiment hardware, cameras, sensor assemblies etc. which had to be stowed for launch and landing.

The Control Rack also included support structures to which the 'Rotating Dome' and the 'T-handle' for the Hop and Drop Station could be mounted (see below).

Movement of the Sled carriage along the 3.2 m rails running the length of the module was provided by a DC electric motor. The carriage seat could be oriented in any one of three mutually orthogonal directions: with the Test Subject (TS) facing the direction of motion, facing sideways or facing upwards.

The Sled facility provided linear acceleration stimuli as a result of pre-programmed velocity trajectories (sinusoidal and triangular wave forms, with the facility to select continuous oscillatory motion for a given number of cycles or single half-cycles in the fore or aft direction).

The European experiment package
The main element of the European experiment package was the 'Vestibular Helmet', a multi-purpose device which restrained the head of the astronaut during the dynamic Sled experiments, but which could also be worn when not seated on the Sled.

It contained, interalia, a small television screen and associated optics to present either optokinetic patterns (moving bar gratings) to the astronaut's right eye, or a cross for eye-movement calibration. There was also an infrared TV camera in front of the astronaut's left eye to record its movements. A caloric stimulation unit was available to blow air into the astronaut's ears at controlled temperatures between 15°C (cold) and 44°C (warm).

Another important tool was a joystick control box that was operated by the astronaut either to indicate his perceived direction of Sled movement, or to control a target displayed on the helmet TV monitor.

The overall suite of European experiment hardware was provided by DFVLR (Germany), with contributions from CNES, Toulouse (France) and CENG, Grenoble (France). The main industrial contractor was Kayser-Threde, Munich (Germany).

The US/Canadian experiment package
These experiments also used a 'helmet assembly', which completely enclosed the astronaut's head to exclude cues from his Spacelab environment (Fig. 3). The US/Canadian experiment hardware was controlled by the Experiment Control and Data System (ECDS), located in the Sled Control Rack.
To measure eye counter-rotation, the US Sled experiments used a motorised 35 mm camera. Horizontal and vertical eye movements were recorded by electrodes and Sled movements by accelerometers, as in the European experiment.

Rotating-dome experiment
In the rotating-dome experiment, the astronaut viewed the dot-patterned inside of a drum or 'dome' (Fig. 4), which rotated at different, pre-programmed speeds (30°, 45° or 60° per sec) about his roll axis. The head was fixed by a bite board and ocular torsion was recorded by a video camera mounted to the rear of the dome. The test-subject indicated any illusion of rotation with a potentiometer, while body sways were measured with a second video camera. Responses were recorded either when the test subject's body was restrained only by the bite board, or when it was restrained by elastic cords which simulated the tactile forces when standing on Earth.

Hop-and-drop station
The hop-and-drop station was designed

Table 2 — US/Canadian flight and Baseline Data Collection (BDC) experiments

Experiment	Institutes	Objectives and methods
Visual—Vestibular Interaction (Dome)	MIT, Cambridge (USA)	Exploration of central integration of conflicting visual/vestibular/tactile sensory cues by measuring roll self-motion and compensatory eye and head movements induced by large-field visual stimuli.
Otolith—Spinal Reflex (Hop and Drop)	McGill Univ., Montreal	Study of the otolith—spinal reflex which normally prepares one for a landing from a fall by measuring EMG-activity of the muscle during footward acceleration provided by stretched elastic cords.
Awareness of Orientation and Limb Position	Inst. of Environmental Medicine, Ontario	Test of suspected alterations of awareness of body and limb orientation by pointing at known targets and identifying limb position while blindfolded, and also upon awakening.
Motion-Sickness Susceptibility	MIT, Cambridge	Characterisation of space-sickness symptoms and their relationship to head movements (measured by head-mounted accelerometer package), visual and tactile cues.
Perception of Linear Acceleration	MIT, Cambridge	Determination of the threshold and time to detect the onset and direction of small step linear accelerations (0.001 g to 0.03 g).
Eye Movements during Linear Acceleration	MIT, Cambridge Payload Systems Inc., Boston	Test of the adaptation of the vestibulo-ocular system in generating compensatory eye movements (torsional, lateral and vertical) in response to sinusoidal accelerations of different frequencies (0..2 and 0.8 Hz).
BDC Closed-Loop Otolith Assessment Test	MIT, Cambridge Payload Systems Inc., Boston	Measurement of the performance of a closed-loop nulling task which requires the subject to actively null a random linear-motion stimulus both with and without visual information by using a joystick.
BDC Posture Control	MIT, Cambridge	Post-flight measurement of degradation in postural stability, performed using narrow rails and a posture platform.
BDC Nystagmus Dumping	MIT, Cambridge	Assessment of interaction between the semicircular canals and otoliths by study of the modification of the decay of post-rotatory nystagmus produced by head pitch.
BDC Rod and Frame	MIT, Cambridge	Test of static visual-field dependence to determine if putative increased dependence on static visual cues for orientation in space would carry over post-flight.

Figure 3 — Astronauts Ulf Merbold and Reinhard Furrer preparing at DFVLR for the US Sled experiments

Figure 4 — The Rotating Dome experiment being performed by astronaut Ernst Messerschmid during Mission Sequence Testing at Kennedy Space Center

to expose the astronaut repeatedly to sudden unexpected footward acceleration with stimulus amplitudes of 1.0, 0.67 and 0.33 g. Figure 5 shows the test subject holding the T-handle, which was released at random after a variable delay of one to four seconds on receipt of 'ready' signal from him. Calf-muscle activity in response to the fall was recorded by body-surface electrodes.

The complete US/Canadian experiment hardware package was delivered by MIT, Cambridge (USA), with components coming from MIT itself, NASA/Johnson Space Center and SPAR Aerospace of Canada.

Data and communication interfaces
The data from the Vestibular Sled were evaluated by the experimenter teams in the Payload Operations Control Center (POCC) and in the Science Monitoring Area (SMA) at Johnson Space Center (JSC), Houston, Texas, because limitations on the trans-Atlantic data link prevented the transfer of the high-rate data to the German Space Operations Centre (GSOC) in Oberpfaffenhofen. Onboard voice and television were also transmitted via the Tracking and Data Relay Satellite System (TDRSS) to the Mission Control Center in Houston, and from there via the Domsat spacecraft to Goddard Space Flight Center (GSFC) for relay via an Intelsat satellite and Raisting ground station to GSOC. For the Vestibular Sled team's own coordination, dedicated voice loops were established between JSC and GSOC.

Crew training
The successful conduct of the 14 different Sled experiments, involving many different hardware configurations and substantial instrumentation of the crew members themselves (sensor electrodes, etc.) called for careful training of the D1 Mission and Payload Specialists in a realistic environment. Replicate models of the Sled and of the associated European and US experiment hardware were therefore installed in

Figure 5 — Astronaut Guy Blueford training for the Hop and Drop Experiment

DFVLR's Simulation and Training Assembly (STA) in Cologne many months prior to the mission. The STA hardware consists of a full-scale model of the Spacelab Module, a simulated Orbiter mid-deck and aft flight deck, and a functional simulation of Spacelab's Command and Data Management System (CDMS).

The major part of the Payload and Mission Specialist training for the Sled experiments took place in this DFVLR facility.

Prior to their hands-on training in the STA, the Mission and Payload Specialists had visited the laboratories of the Spacelab experiment Principal Investigators at the University of Mainz (Germany) and at MIT in Cambridge (USA), in early 1984. There, they were familiarised with the scientific objectives of the various experiments and also received instruction in, and practised, biomedical instrumentation and recording. The science training was intensified during the Baseline Data Collection sessions in the second half of 1985 leading up to the flight (see Tables 1 & 2).

The flight
At the end of the Spacelab activation period, which lasted for about 6 h after launch, the D1 crew started to set up and check out the Sled facility for the first set of experiments (Figs. 7 & 8).

W. Ockels, the ESA Payload Specialist, and R. Furrer, DFVLR Payload Specialist, were responsible throughout the mission for the European Sled experiments (blue shift), and E. Messerschmid, DFVLR Payload Specialist, and G. Bluford, NASA Mission Specialist, for the US/Canadian experiments (red shift). The schedule for the Sled-related activities is shown in Figure 7.

Throughout the flight, the workload of the crew was very high, especially during the first shift (Day 0), but the payload operations nevertheless progressed smoothly. The Sled facility's performance was highly satisfactory and the experiment equipment also worked well. Activities scheduled for the second shift on Day 0 and on subsequent mission days were considered, pre-flight, to be less critical than those during the first shift, but the workload proved to be particularly high because of problems with other, non-vestibular, experiment equipment. The crew had to balance their interaction with ground personnel for these troubleshooting activities with the work still to be done for the ongoing Sled experiments.

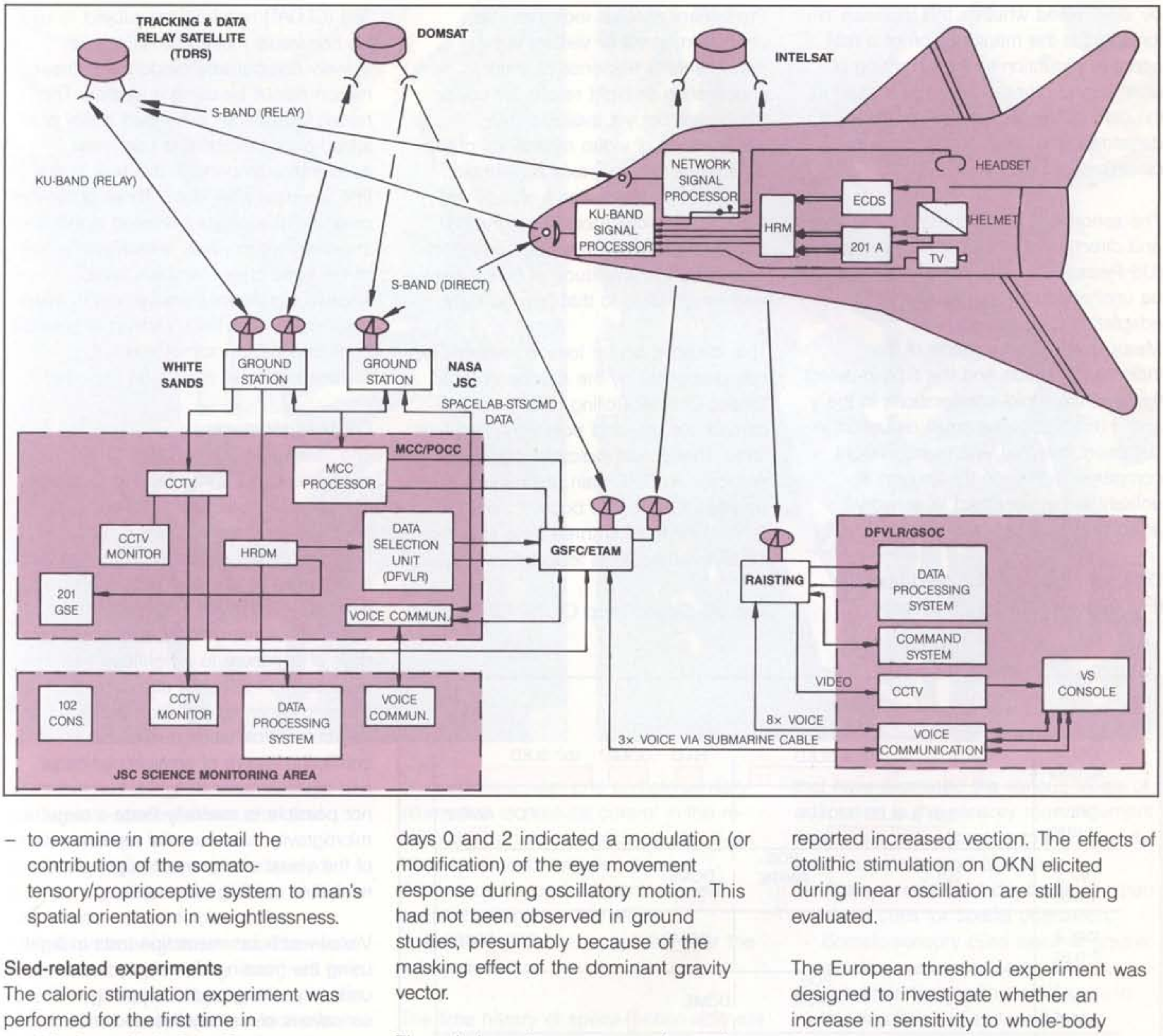
The flight crew compensated for these problems by working roughly 30% more during the seven-day flight than was originally planned. They spent this extra time on mid-mission days not only troubleshooting, but also on some extended Sled tests on their own initiative. These tests, which involved the study of responses to caloric and optokinetic stimuli whilst free of tactile cues (i.e. free-floating), ultimately gave the experimenters very interesting results.

It was feared at one stage that the Sled runs might cause perturbations in Spacelab's microgravity environment which would disturb certain material-science experiments. According to the material scientists' accelerometer measurements, however, the vibrations generated even by the highest Sled accelerations were negligible in this respect.

'Challenger' landed at Edwards Air Force Base in Dryden at 18.00 GMT on 6 November. Some of the test stands for post-flight measurements had been installed there and the Sled teams, having travelled from JSC in Houston, were waiting to test the readaptation of the flight crew to Earth's gravity. Nine hours later, after completion of the first series of post-flight experiments, the flight crew were allowed to sleep for several hours. The ground crew, however, were then transported by a US Air Force plane to Kennedy Space Center to prepare further post-flight tests, which were finally completed 13 days later.

Early scientific results
Although detailed data evaluation and correlation for the numerous pre-, in-, and post-flight Sled experiments has yet to be completed, the available results indicate that the prime objectives of the D1 mission's vestibular studies were fulfilled. These were:
- to confirm the findings of the experiments of the First Spacelab Payload (FSLP) flight on more test subjects and with improved techniques
- to assess the adaptation of human graviceptor responses by applying transient linear accelerations to the human body with the ESA Sled facility

Figure 6 — Data and communications flow for the Vestibular Sled



- to examine in more detail the contribution of the somato-tensory/proprioceptive system to man's spatial orientation in weightlessness.

Sled-related experiments
The caloric stimulation experiment was performed for the first time in combination with in-flight Sled runs. A caloric response with the subject stationary, as first observed in weightlessness during the first Spacelab flight, was verified on three more astronauts. The intensity and direction of nystagmus (i.e. eye movement response) was in accordance with Earth-bound observations (see Table 1). These results have served to demonstrate the inadequacy of the widely accepted thermo-convection theory. Analysis of the data from Sled runs performed on flight days 0 and 2 indicated a modulation (or modification) of the eye movement response during oscillatory motion. This had not been observed in ground studies, presumably because of the masking effect of the dominant gravity vector.

The caloric nystagmus was enhanced when the astronaut was released from the Sled seat and allowed to float freely in the Spacelab Module. This effect is presumably related to the removal of the inhibitory effect of cues from the somato-sensory system.

The gain in Opto-Kinetic Nystagmus (OKN) response (i.e. eye movement response to optokinetic stimuli; see Table 1) was also dramatically increased in the free-float mode, and the subjects reported increased vection. The effects of otolithic stimulation on OKN elicited during linear oscillation are still being evaluated.

The European threshold experiment was designed to investigate whether an increase in sensitivity to whole-body linear acceleration occurs due to the absence of any static cues from the otolith system. In flight, however, no consistent change in the astronaut's ability to detect the direction of discrete linear movements was found.

Comparison of pre- and post-flight measurements showed that the thresholds for the astronaut's detection of movement (along the x, y and z body axes) directions of his were raised for up to 48 h after return to Earth. It remains to

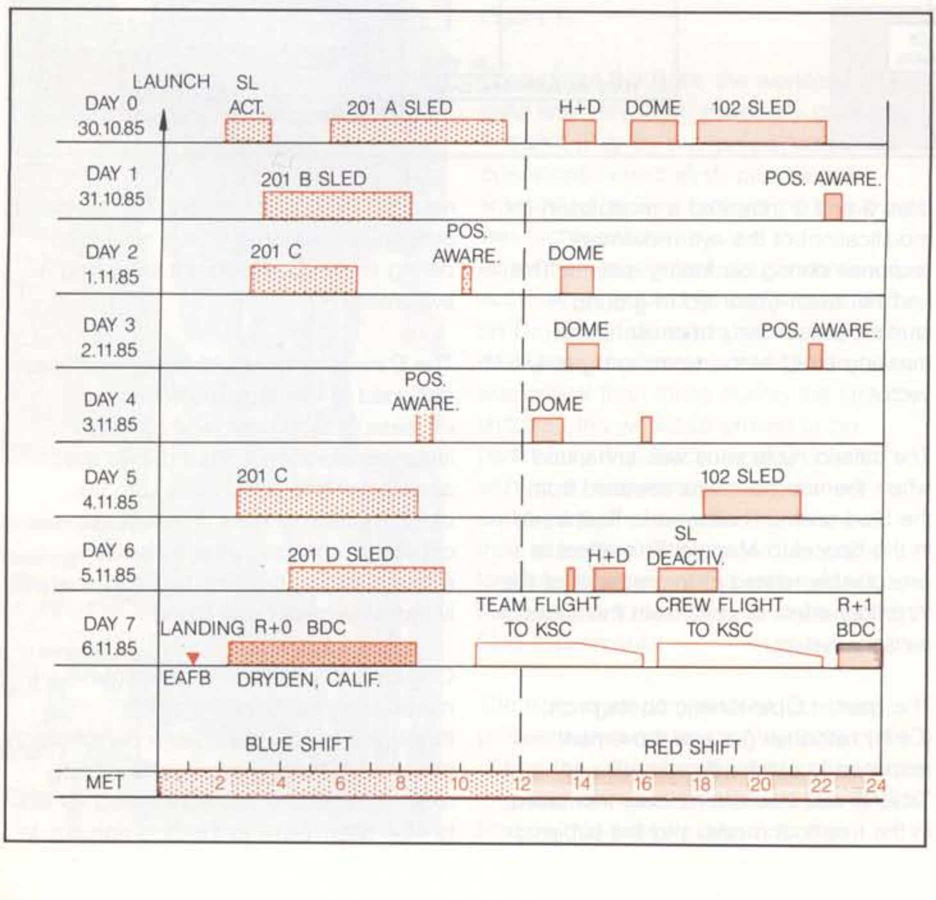


Figure 7 — Mission timeline for the Sled activities during the D1 mission

be determined whether this increase in threshold is the manifestation of a real adaptive reduction in the weighting of otolithic and other graviceptor signals in the central nervous system, or that of a degradation in ability to discriminate otolithic signals.

The astronaut's ability to detect the onset and direction of small acceleration steps (US Perception Experiment) appeared to be unchanged by exposure and adaptation to weightlessness. Measurements were made of the indicated direction and the time-to-detect the near-threshold accelerations in the y and z directions. The small reduction in detection time that was found in-flight compared to that on the ground is unlikely to be significant in sensory adaptation to weightlessness.

Data from the other US Sled tests (Fig. 9) are still being processed.

Preliminary analysis indicates little change in lateral or vertical eye movements in response to linear acceleration. In-flight results for ocular torsion are not yet available, but observations of video recordings of the eyes made during y-axis acceleration suggests that there was a sharp reduction in ocular torsion on the first day after landing. On subsequent post-flight days the amplitude of ocular torsion was comparable to that prior to flight.

This dynamic ocular torsion research was complemented by the European static Ocular Counter-Rolling (OCR) tests carried out pre- and post-flight with a tilt table. These tests indicated significant reduction in OCR gain (defined as degree OCR/degree body tilt; see Table 1) for the first three days after flight for all three subjects tested (Fig. 10).

The US Closed-Loop Otolith Assessment Test (CLOAT) required the subject to use his non-visual motion sensations to actively compensate randomised linear motion stimuli by using a joystick. The results indicate an enhanced ability of all tested crew members to use linear acceleration to perform this task in the first two days after flight. Three of the five crew members tested showed significant improvement in y-axis response and two of the three crew members tested showed significant improvement in z-axis response. In this test, however, a possible contribution from somato-sensory (cutaneous) cues cannot be excluded.

Other experiments

The Vestibular-Ocular Reflex (VOR) experiment was also intended to assess alterations in vestibular function, predominantly semicircular-canal function, during exposure to microgravity. A decrease in yaw and pitch VOR gain was observed at the beginning of the flight, with a return to normal after five days of exposure to weightlessness. The reduction in VOR gain could be due either to a central inhibition of the vestibular information due to the conflicting nature of semicircular-canal and otolithic cues, or to the fact that it is not possible to mentally fixate a target in microgravity, since central representation of the visual environment might also be related to otolithic information.

Visual-vestibular interaction tests in flight using the 'rotating dome' produced uniformly strong and compelling sensations of visually induced motion (vection) in all five crew members (Fig. 11). Measurement of the strength of vection for the two subjects tested repeatedly in flight showed increasing strength with time in orbit, and a carryover of the effect to post-flight tests. All subjects commented that tactile cues effectively reduced the illusion of vection and made it feel more like the experience on the ground. These results, taken in conjunction with those of FSLP, support the hypothesis that during weightlessness the nervous system

Figure 8 — Astronaut Reinhard Furrer preparing the European helmet in orbit for the Sled runs

Figure 9 — US Sled experiments being performed in orbit by the Red Shift crew, with astronauts Guy Blueford and Ernst Messerschmid as operator and test subject, respectively

attaches greater significance to visual and somato-sensory information and ignores otolithic information.
Interesting results were also obtained from an experiment designed to study re-interpretation of somato-sensory information in weightlessness. The neck-receptor test (Table 1) was designed to determine the physiological effects of the neck position receptors (i.e. mechano-receptors in the neck, which indicate the position of the trunk relative to the head; expt. description in Table 1) if decoupled from the otolith system. While no ocular torsion was observed pre-flight in response to neck-receptor stimulation, ocular torsion occurred both in-flight and post-flight.

In all posture experiments, postural instability was again observed post-flight. The 'Tilting Room Experiment' (Table 1) was designed to examine the weighting of visual, vestibular and somato-sensory information in postural control in the re-adaptation phase immediately after flight. The experiments revealed a visual dominance for postural control a few hours after landing, this effect disappearing almost completely over the subsequent days.

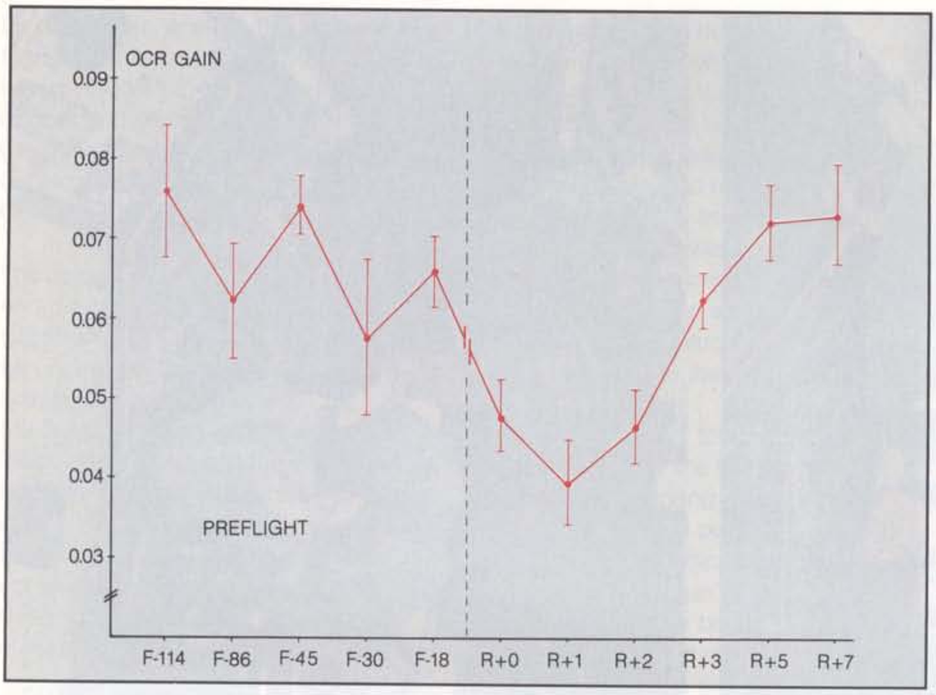
The time history of space-motion-sickness symptoms and the stimuli triggering them were systematically documented by the two crew members who experienced significant symptoms. The course of the condition closely resembled that on previous missions, with volitional head movements being particularly provocative. The linear acceleration of the Sled did not induce symptoms in flight, but it did disturb one test subject during an early post-flight test.

The findings of the several experiments that have examined the various facets of adaptation to the sensory rearrangement associated with exposure to microgravity may be summarised as follows:

- There is increased dependence upon visual cues for spatial orientation.
- Somato-sensory cues assume greater significance and to some extent substitute for gravito-inertial cues in the regulation of eye-movement responses induced by visual and semicircular-canal stimuli and, perhaps, also the detection of whole-body, linear accelerations.
- Considered together, the results of the ocular-torsion tests and the CLOAT experiment support the notion of a reinterpretation of signals from the otolith receptors occurring during sensory adaptation to weightlessness. The ocular-torsion responses (responses that interpret otolith stimulation as tilt with respect to

Figure 10 — Results of the BDC Static Ocular Counter-Rolling Experiment (H. Vogel, Mainz University), showing the averaged OCR gain of three science astronauts measured before and after the D1 flight. The return to pre-flight values occurs six or seven days after the flight

Figure 11 — Rotating Dome experiment in progress in orbit, with astronaut Ernst Messerschmid free-floating but restrained by elastic cords to provide tactile cues to the feet



gravity) are reduced. CLOAT performance (where otolith stimulation is interpreted as linear acceleration) is enhanced. Alternatively, the reduction in ocular torsion might also be indicative of an avoidance of visual/vestibular conflict.

Conclusion

A long time elapsed between the birth of the concept for the Sled facility and its first flight on the Spacelab D1 mission. Nevertheless, it has turned out to be an excellent tool for vestibular research in space and its first flight can only be described as a first-rate success, the scientific returns being judged as substantial by the numerous experimenter teams involved.

ESA and NASA peer reviews have taken place in order to review critically the results obtained so far and to support the Agencies in developing a coordinated programme of future collaborative neurophysiological research which would carry forward to the Space-Station era. Because of the current gap in mission opportunities, it is difficult to achieve a short-term continuation of the programme. Results obtained from FSLP and D1 have, however, triggered substantial ground-based research. At present the scientists are also trying to continue their research by taking advantage of participation in parabolic aircraft flights in preparation for further neuroscience experiments in space.

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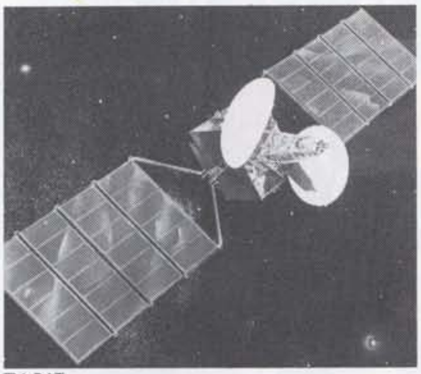
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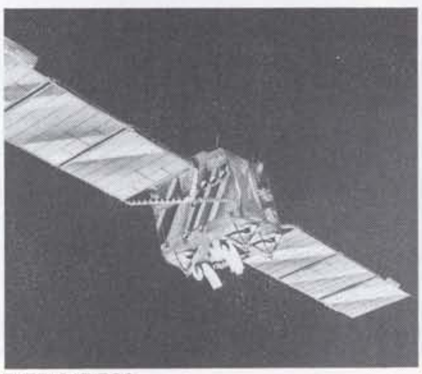
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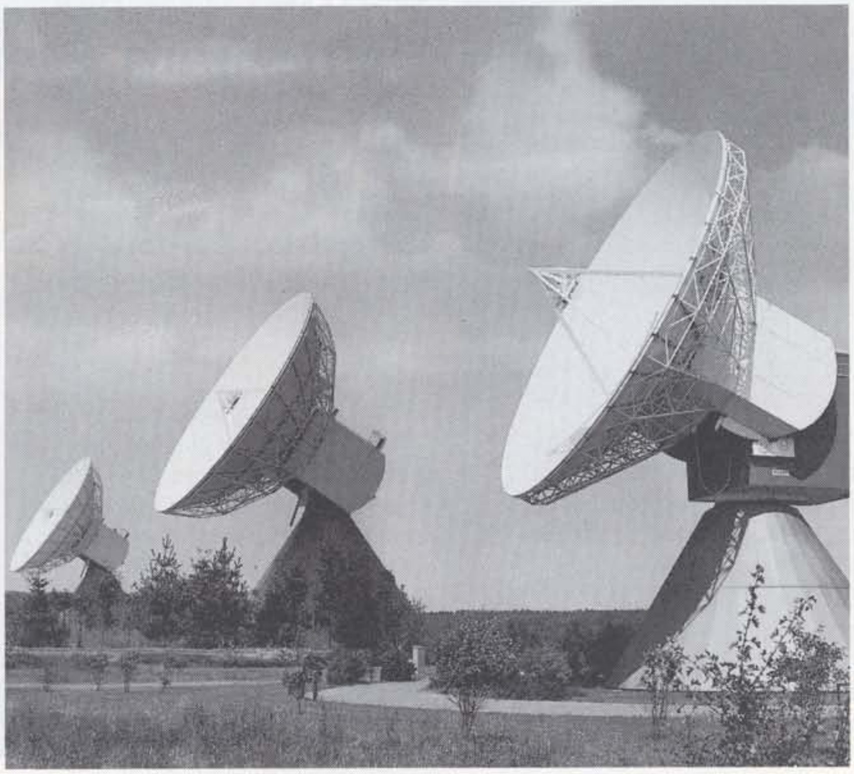
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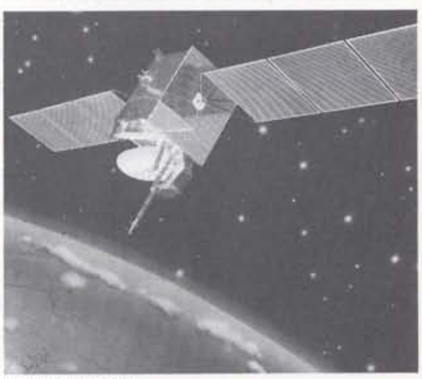
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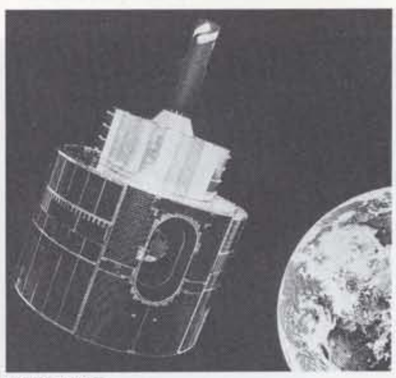
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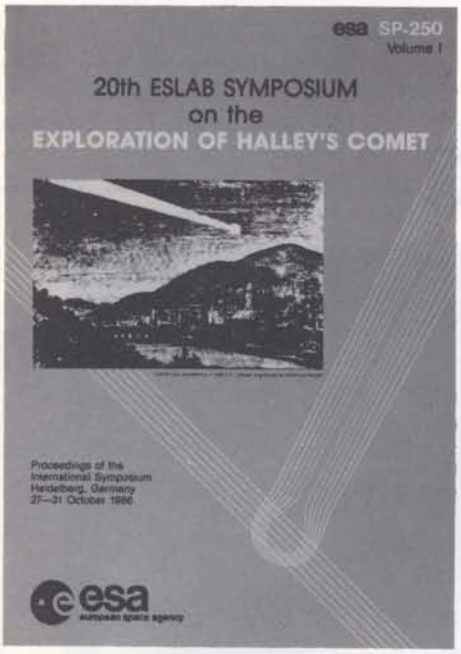


Comet Halley — After the Heidelberg Symposium

R. Reinhard, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

More than 500 scientists from 30 countries gathered in Heidelberg, W. Germany, for the last week of October 1986 to participate in the ESA/ESLAB Symposium on the 'Exploration of Halley Comet'. In 250 oral and 120 poster papers, results were presented from the six space probes that had encountered Halley some seven months earlier, from other Halley observations from space and from the ground, and from theoretical and laboratory work. Some results had been presented on earlier occasions, but this was the first time that scientists from all disciplines had come together to try to arrive at a comprehensive understanding of the nature of Halley's Comet.

The images taken by the cameras onboard ESA's Giotto and the USSR's Vega spacecraft revealed a single solid nucleus of irregular, elongated shape — comparable to that of a potato or a peanut — in the centre of the comet. In mathematical terms, it is best described as an ellipsoid with some deviations. The nucleus is approximately 15×8×8 km, with the largest uncertainties in dimensions on the sunward side. There the nucleus is heated up and releases several tons of gas and fine dust per second. The dust reflects sunlight and regions with a high dust concentration therefore appear bright on the images, masking the nucleus, particularly on the sunward side. Hence, only the night side of the nucleus could be clearly seen against the somewhat brighter background of coma dust. Several shallow craters about 1 km in diameter could be identified near the terminator (the line that marks the transition between the day and night sides). Several possibilities for their origin are being discussed, but no firm conclusion has yet been reached.

It is quite possible that these craters or troughs are of crucial importance for our understanding of the physics of comets. They are the only sign of inhomogeneity on the surface and may be connected with the cometary activity that is known to be inhomogeneous, or they may reflect the inner structure of the nucleus itself. The images also show that almost all of the dust and gas emanates from just a few active regions on the nucleus. While the dust remains confined, forming 'dust jets' which are clearly visible on the sunward side, the gas diffuses very quickly and in principle there should be no 'gas jets' present. CN (cyanogen) and C_2 gas jets were found, however, and the most likely explanation is that most of these molecules originate from the dust particles in the dust jets.

The dust jets form spirals due to the rotation of the nucleus and from their shape the rotation period can be deduced. A period of 2.2 days has been derived from ground-based observations and confirmed by the brightness variations observed in the ultraviolet by Japan's Suisei spacecraft, and by comparing Vega-1 and Vega-2 observations. However, observations of other brightness variations give a rotation period of 7.4 days. The situation is not yet entirely clear, the likely explanation being that the nucleus rotates with a period of 7.4 days around its long axis, while this axis itself precesses with a period of 2.2 days.

The nucleus is covered by a layer of dust. This conclusion was inevitable after Vega's Infrared Spectrometer found that the surface of the nucleus was much warmer (~ 350 K) than expected. If the surface consisted mostly of water-ice mixed with dust, the surface temperature would be controlled by the sublimation temperature of water-ice (<200 K). The thickness of the dust layer is still open to question. Estimates range from ≤ 1 cm, to several tens of metres. In fact, the thickness of the layer may well vary over the surface, since the dust and gas are not blown off homogeneously, and it may also vary with time.

Figure 1 — Some of the Heidelberg Symposium participants, photographed between models of the Halley nucleus (1:10 000) and the Giotto spacecraft (1:1). From left to right: S.M. Gong, E. Grün, J.C. Brandt, K. Hirao, R. Reinhard, R.L. Newburn, H.U. Keller, R.M. Bonnet, K.I. Gringauz, K. Szego, W.I. Axford, E.A. Trendelenburg, F.L. Whipple, A.A. Galeev, D. Dale, R. Lüst, H. Fechtig, M. Belton, W. Schmidt and J. Geiss

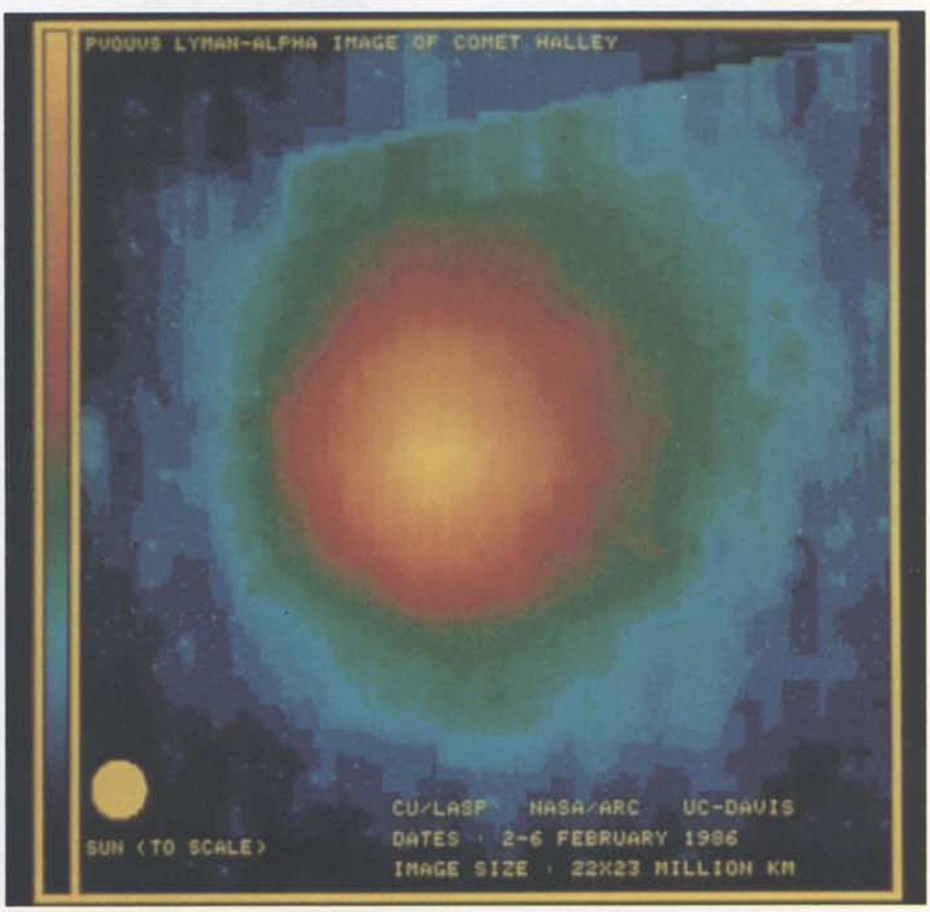
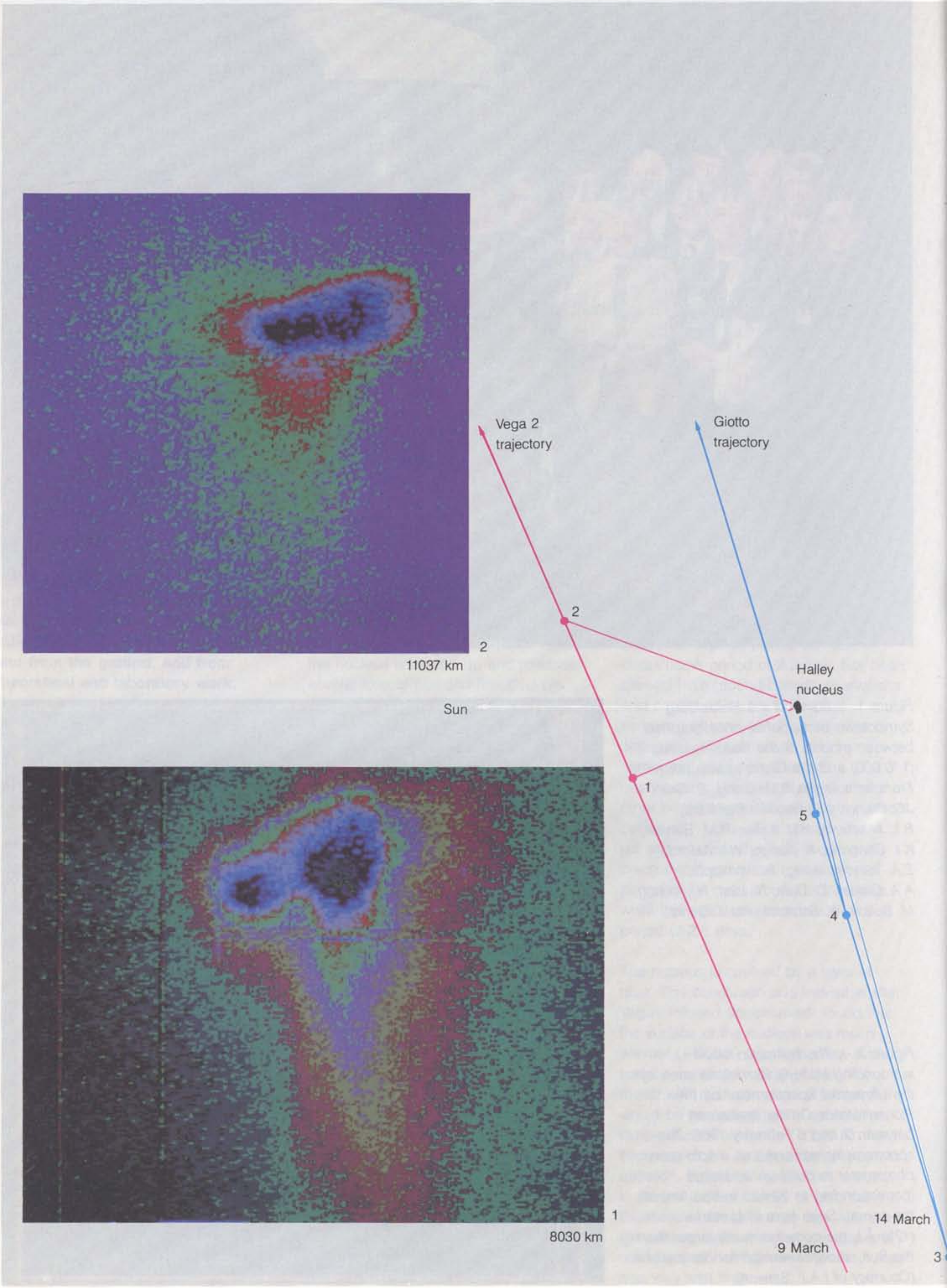


Figure 2 — The hydrogen cloud surrounding Halley's Comet, as seen by the Ultraviolet Spectrometer on the Pioneer Venus Orbiter spacecraft between 2 and 6 February 1986. The spectrometer was used as a spin-scan photometer to build up an image (corresponding to 22×23 million km) of the comet. Seen here in Lyman-α (1216 Å), the comet is much larger than the Sun, shown lower left for comparison. (Courtesy of I.A.F. Stewart)


Vega 2
trajectory
Giotto
trajectory
2
2
11037 km
Halley
nucleus
Sun
1
5
4
1
8030 km
14 March
9 March
3

5

5000 km

4

9500 km

3

25700 km

Figure 3 — False-colour Vega-2 images (left) and black-and-white Giotto images (right) taken at various distances from the cometary nucleus. On image 1 a near-infrared filter (700—900 nm) was used, the Sun is towards the lower left, 113° from the vertical, and the resolution is 120 m per pixel. For image 2, a clear filter (400—650 nm) was used, the Sun is towards the lower right, 125° from the vertical, and the resolution is 160 m per pixel. The comet nucleus appears as an aspherical peanut-shaped object with overall dimensions of 15×8×8 km. The region surrounding the nucleus appears bright due to sunlight reflected by dust particles. Prominent dust jets — regions in the cometary coma with a high dust concentration — are directed from the nucleus essentially towards the Sun, i.e. towards the observer because they are seen in projection.

Images 3—5 were taken by the Halley Multicolour Camera (HMC) onboard Giotto using a clear filter (300—1000 nm). The Sun is to the left. In image 3 it is 26° above the horizontal and 17° behind the image plane; in image 4, 27° above the horizontal and 15° behind; and in image 5, 30° above horizontal and 11° behind. In image 3 the night side of the nucleus can be clearly seen against the somewhat brighter background. Also, several jets can be identified, the most prominent ones being directed towards the Sun. Images 4 and 5 show details such as craters at the upper end of the nucleus. Resolution is 200 m per pixel in image 4, and 100 m per pixel in image 5. (Courtesy of K. Szego & H.U. Keller)

There is considerable evidence that the larger dust particles are aggregates of submicron-sized dust particles with ice in between or, after the ice has evaporated as in the case of the dust layer, with voids between. The dust crust would then be porous, allowing the gas to diffuse through it from underneath. Also, solar photons could be easily trapped in this lattice of small dust particles, which might explain why the nucleus appears so dark. It has an albedo of only 2—4%, which makes it one of the darkest objects in the solar system. Another consequence of the low packing density would be a low heat conductivity between the outer dust layer and the ice—dust mixture beneath, so that the layer would not have to be very thick to maintain a temperature difference of 150°.

The mass of the nucleus is inferred from non-gravitational effects on its orbit to be $\sim 10^{17}$ g, which implies a mean density of only a few tenths of a g/cm^3 — considerably less than if the nucleus were a solid mixture of water-ice and dust (~ 1 g/cm^3).

The density of the dust particles in the dust layer is likely to be even lower (~ 0.1 g/cm^3) and probably similar to that in the coma, which was found to be very low. The gravitational attraction on the comet nucleus is very small (one billionth of that of the Earth) and fragile low-density structures can easily be preserved.

The chemical composition of the dust varies from grain to grain. Nevertheless, three broad classes of grains could be identified: one class composed mainly of the elements H, C, N, and O; a second class similar to C1 chondrites (a carbon-rich stony meteorite); and a third class, similar to the second, but more enriched in hydrogen. The H, C, N and O could be the building blocks of simple organic molecules. They may form tar-like substances, which could be another reason why the nucleus appears dark. Perhaps the dust particles are more

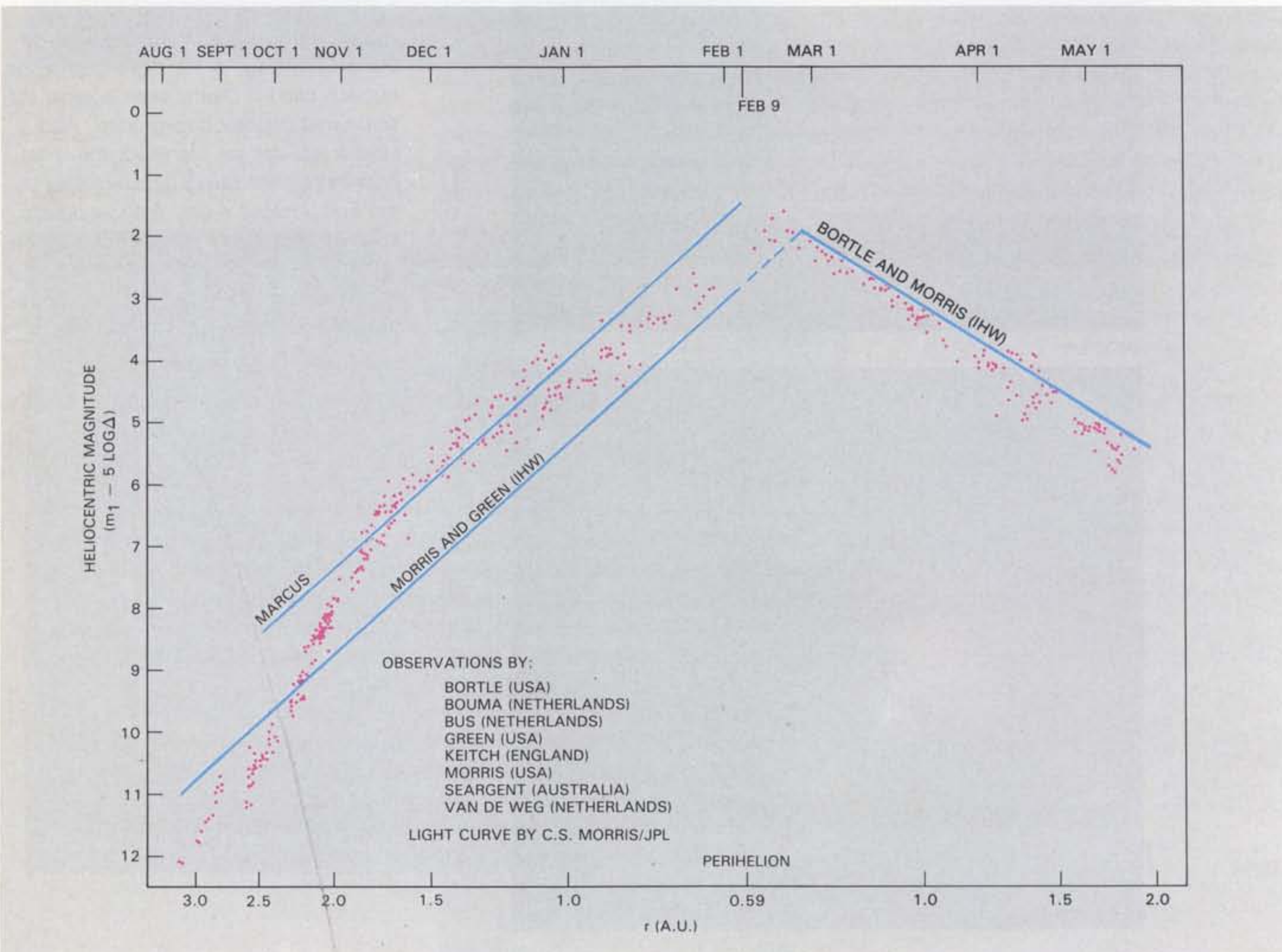


Figure 4 — Light curve for Halley's Comet during the 1985/86 apparition, showing the variation in brightness or magnitude with time (top) or heliocentric distance (bottom scale). The effect of the magnitude variation due to a varying geocentric distance has been removed and all observations are normalised to a distance of 1 AU. If the comet were inactive, its brightness would increase quadratically towards the Sun. However, as the cometary atmosphere grows in size and density during the approach to the Sun, the increase is much steeper. The pre-perihelion solid lines correspond to an increase with exponent 4.5. The increase between 3 and 1.8 AU is even steeper, indicating the onset of major activity, presumably caused by the sublimation of water ice which starts at 2.8 AU. The scatter in the data points reflects both uncertainties in the magnitude determination and real short-term variations in activity. (Courtesy of C.S. Morris)

Figure 5 — Pseudo-colour image of Halley's nucleus from a composite of four images taken by the Halley Multicolour Camera (HMC) on board Giotto from distances of 19 947, 9847, 4947 and 2490 km. In the final-approach phase, the nucleus was resolved and images with higher and higher spatial resolutions (50 m per pixel in the innermost frame) were taken as the distance to the nucleus decreased. At the same time, the size of the frame decreased due to the fixed field of view of the camera (0.1°). The innermost frame corresponds to four kilometres. The images were exposed through the clear filter (wavelength range 300—1000 nm) and the Sun is to the left, 27° above the horizontal, and 15° behind the image plane. The composite image shows the dark night side of the nucleus (right), the bright dust jets on the day side (left), and the faint background light of the dust coma. On the daylight side of the nucleus, several crater-like features can be identified.
(Courtesy of H.U. Keller)

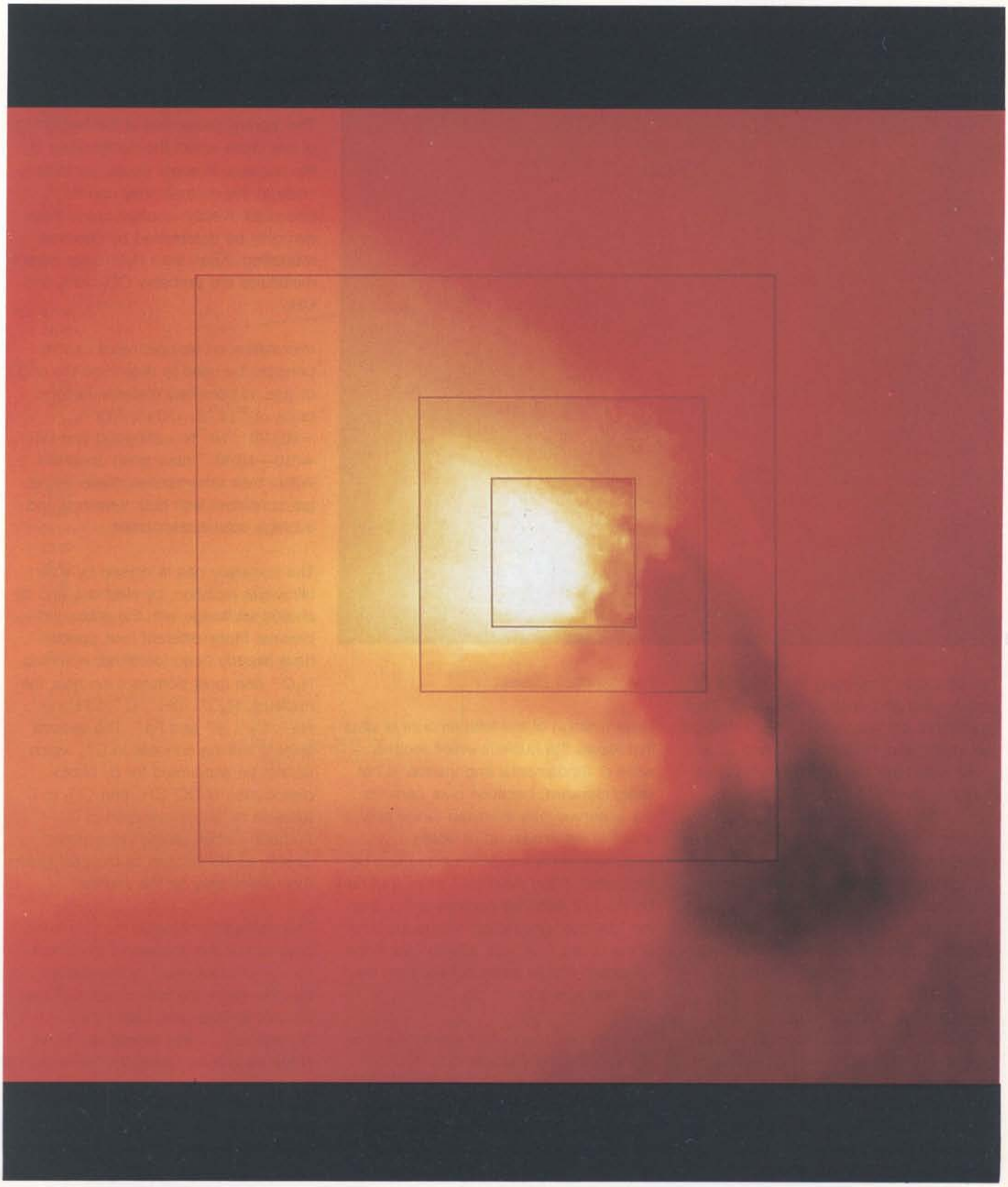
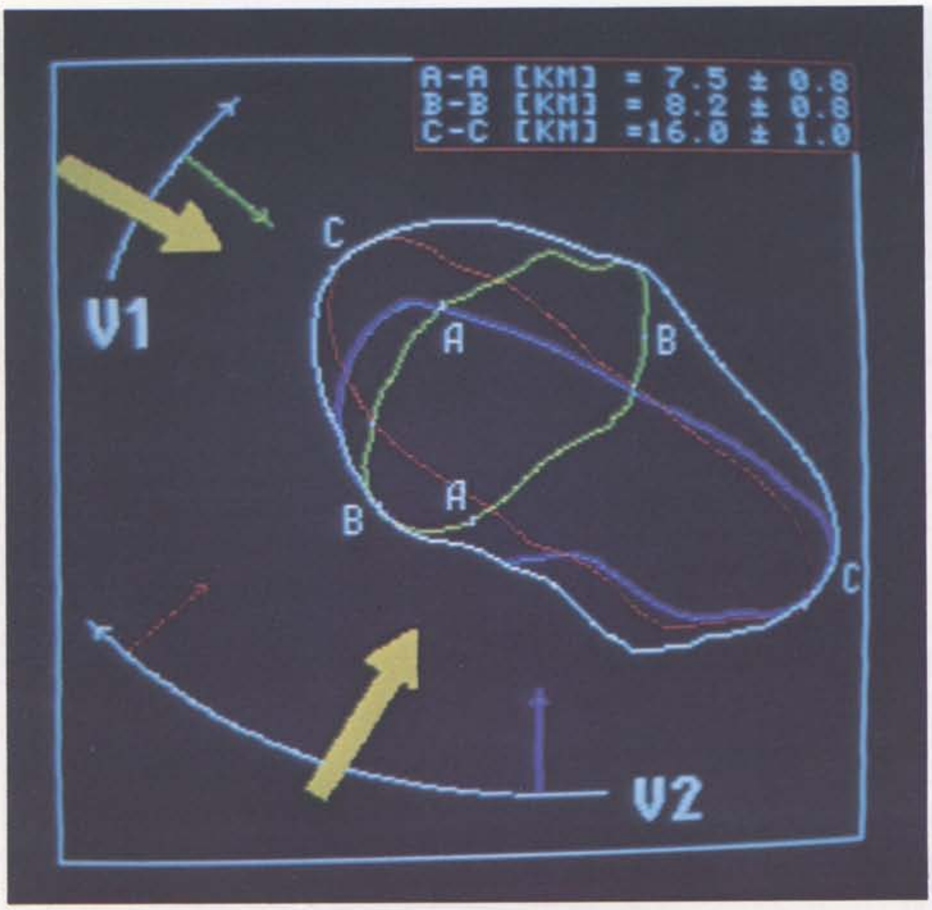


Figure 6 — Sketch of the Halley nucleus as derived from Vega-1 and -2 images. (Courtesy of R.Z. Sagdeev)

Figure 7 — Activity peaks (red triangles) in the hydrogen coma of Halley's Comet, observed with the Lyman-α Imager onboard the Suisei spacecraft. In this plot, time runs like the lines on a page. The Lyman-α brightness reaches a peak every 52.9 h, which is interpreted as being the signature of an inhomogeneously active nucleus with a rotation period of 52.9 h. The blue curve connecting the red triangles turns appreciably in the centre of the figure due to the effect of the true anomaly, but is almost vertical in the uppermost and lowermost portions. No observations were made from mid-December to early February. V1, V2, Su, Sa, G denote the times of the Vega-1, Vega-2, Suisei,



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complex than previously thought, with a silicate core and an organic mantle. The grains that are rich in H, C, N, O may be the 'parents' of the spiral CN and C_2 jets observed in the coma of Halley's Comet from the ground.

Neither the optical nor the infrared data provide any reliable information about particles smaller than 0.1 μm. Before the encounters it was unclear whether such small dust particles existed at all in the cometary coma. It was therefore a major surprise when the impact detectors onboard the flyby spacecraft found a large number of these small particles. Moreover, they were found outside their bounding paraboloids defined by the classical theory based on radiation-pressure deceleration. One possibility might be that these grains are electrically charged and are accelerated by the electric fields in the magnetised interplanetary plasma.

Determination of the total amount of dust that leaves the nucleus every second, while of fundamental importance, is not straightforward, because dust particles are observed over a limited range only and it is not known up to which maximum mass the distribution must be integrated. If the maximum mass that can be lifted off from the nucleus is 1 g, then the total dust production rate at the time of the Giotto flyby was 3.3×10^6 g/s; if the maximum liftable mass is 1 kg, then the total rate was 3.3×10^7 g/s.

The total gas production rate at the time of the Giotto flyby was 6.9×10^{29} molecules/s, of which 5.5×10^{29} molecules/s or 1.5×10^7 g/s were water molecules. This means that 80 to 90% of the nucleus consists of water ice and dust. The composition of the remaining 10 to 20% is not yet completely clear. The problem is that, unlike the dust grains, the composition of the gas changes with distance from the nucleus in a chain of complex chemical reactions. The 'parent' molecules at the beginning of this chain reflect the composition of the nucleus. In some cases, particularly close to the nucleus, they can be observed directly; in other cases they can only be determined by chemical modelling. Apart from H_2O, other parent molecules are probably CO_2, NH_3 and CH_4.

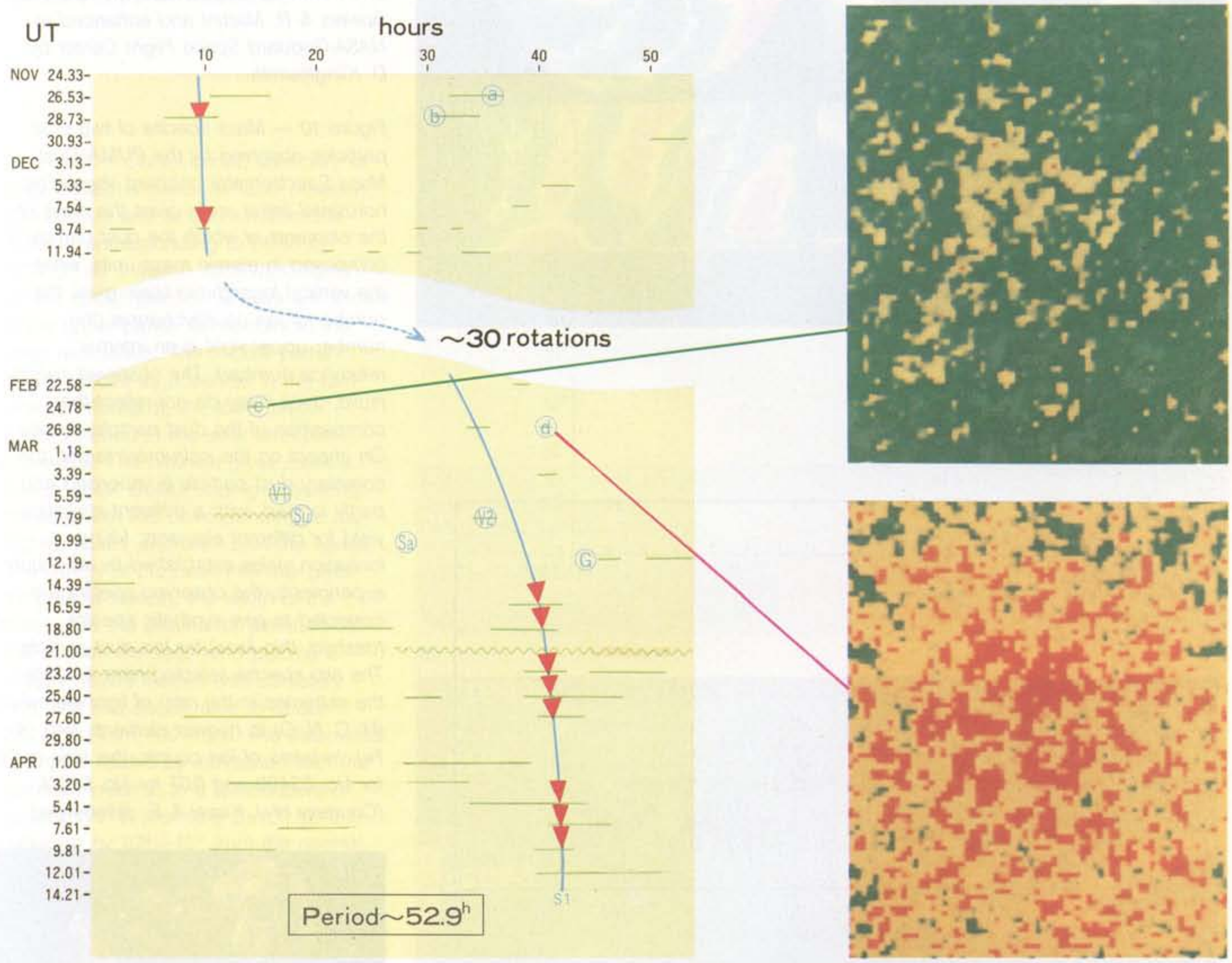
Information on isotopic ratios can in principle be used to determine the origin, or age, of cometary material. Isotopic ratios of $^{32}S/^{34}S = 23\pm5$, $^{12}C/^{13}C = 80\pm20$, $^{14}N/^{15}N = 250\pm100$ and $D/H = (0.6—4.8)10^{-4}$ have been observed. Within their uncertainties, these values are consistent with both terrestrial and average solar-system ratios.

The cometary gas is ionised by solar ultraviolet radiation, by electrons and by charge exchange with the solar-wind plasma. Many different ionic species have already been identified, including H_3O^+ (the most dominant ion near the nucleus), H_2O^+, OH^+, C^+, CH^+, O^+, Na^+, C_2^+, S^+ and Fe^+. The spectra show a striking richness in C^+, which cannot be accounted for by photo-dissociation of CO, CH_4 and CO_2 to C followed by photo-ionisation of C. Perhaps carbon atoms are released directly at the surface, or the dust grains themselves may be the source.

The interaction between the solar-wind plasma and the cometary ionosphere can be characterised by two distinct boundaries — the bow shock and the contact surface (also called the 'ionopause') — and several additional sharp transitions, giving the impression of a multilayered interaction region. The bow shock was detected 1.1×10^6 km from the nucleus, which was in very good agreement with the theoretical predictions and the scaling of the

Sakigake and Giotto encounters, respectively. Thin green lines represent times when UV observations were made; (c) and (d) mark the times of the two observations shown on the right displaying examples of the brightness variation.
(Courtesy of E. Kaneda)

Figure 8 — Variation in C_2 production rate as a function of time in March (upper panel) and April 1986 (middle panel). Arrows mark the times of the various spacecraft encounters. Dashed lines identify corresponding minima in March/April. A search for periodicity in the observations was performed (applying the method of phase-dispersion minimisation). A minimum was found in the April data for 7.4 days, which is interpreted as the rotation period of the Halley nucleus.
(Courtesy of R.L. Millis & D.G. Schleicher)



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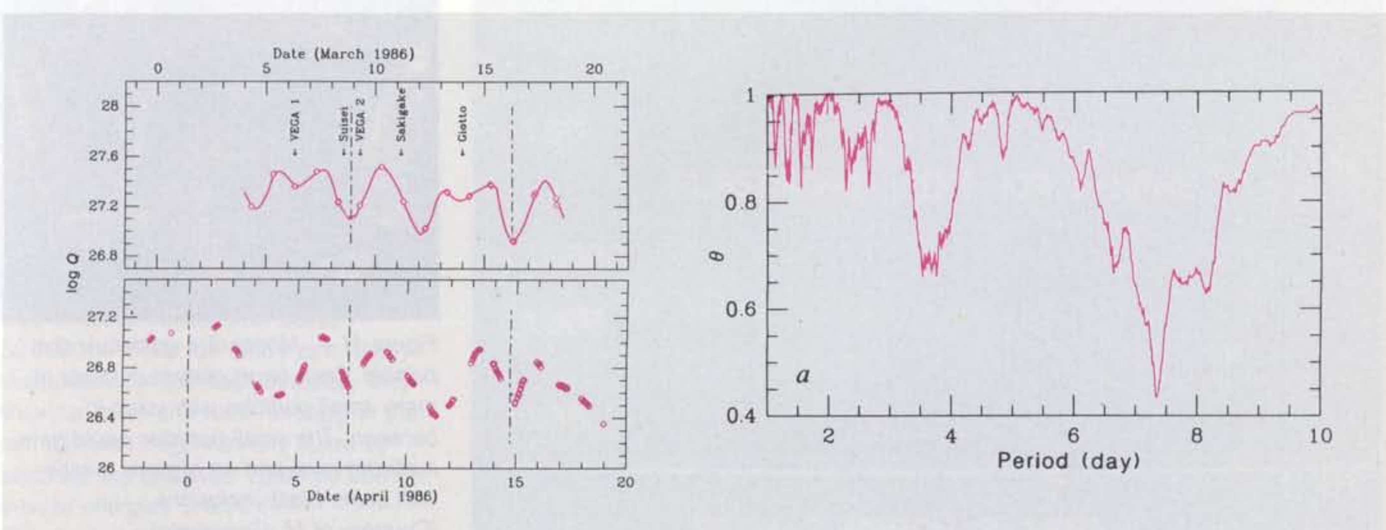

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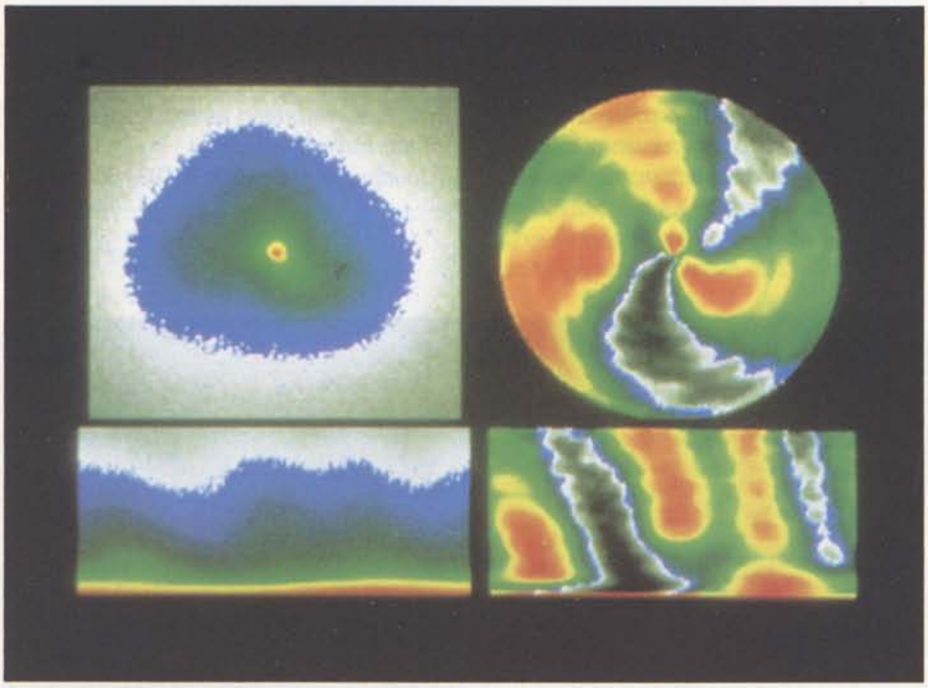

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Figure 9 — Image of Comet Halley taken in the light of the CN radical on 23 April 1986. On the right, this image has been enhanced to show three prominent gas jets (in red) emanating from the nucleus. The photograph was taken at Perth Observatory, Western Australia by a team of astronomers from the University of Maryland (M. A'Hearn and S. Hoban) and from Perth Observatory (P. Birch, C. Bowers & R. Martin) and enhanced at NASA-Goddard Space Flight Center by D. Klinglesmith.

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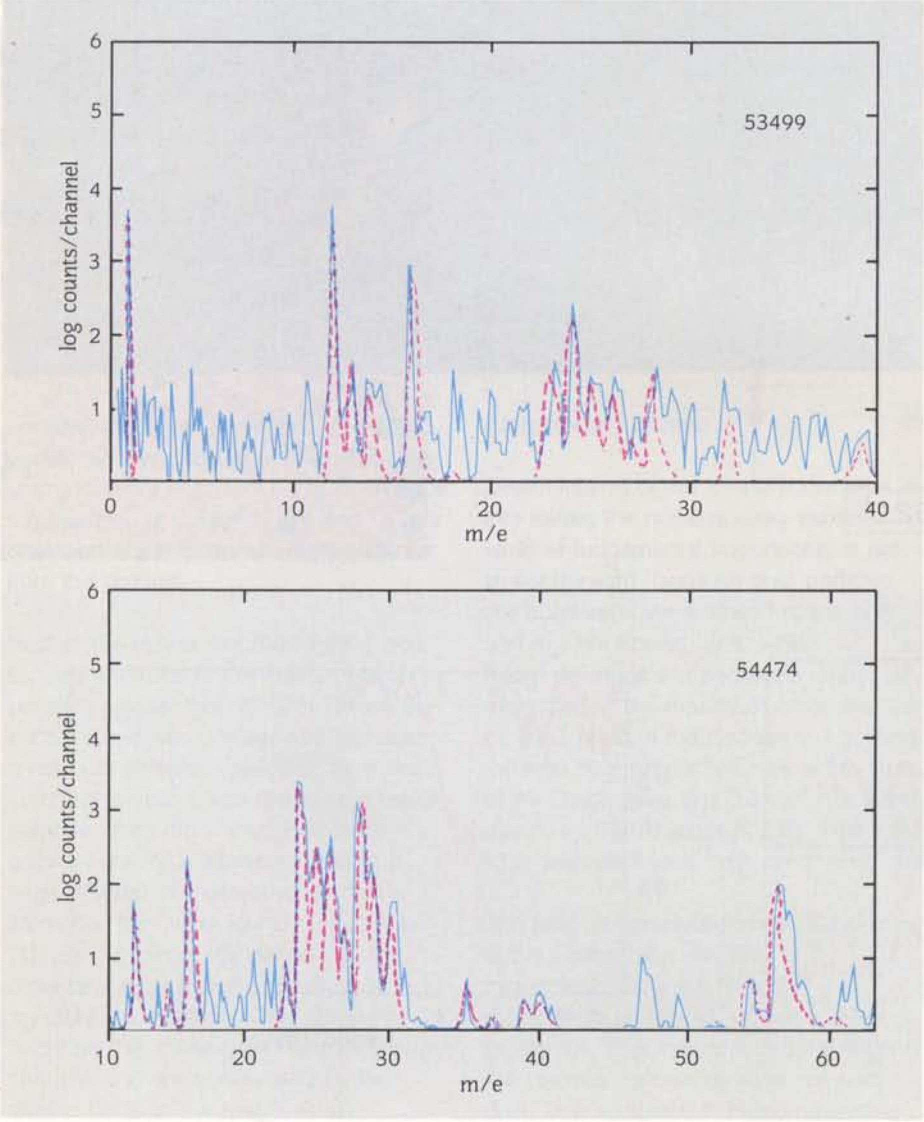
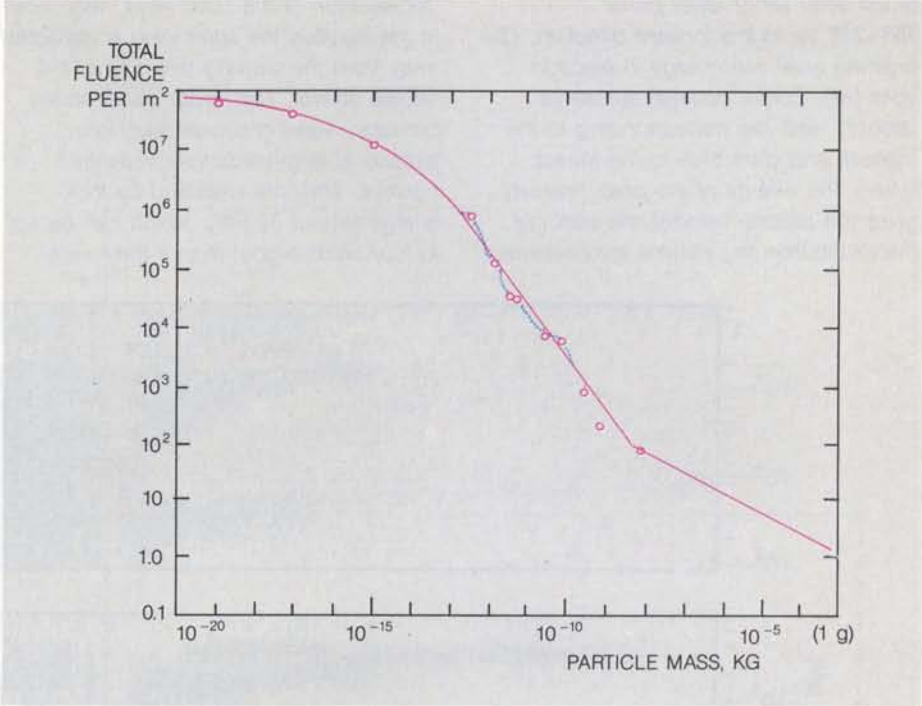


Figure 10 — Mass spectra of two dust particles observed by the PUMA Dust Mass Spectrometer onboard Vega. The horizontal linear scale gives the mass of the elements of which the dust particle is composed in atomic mass units, while the vertical logarithmic scale gives the number of ion counts/channel (the number upper right is an internal reference number). The observed spectra (solid, thick lines) do not reflect the composition of the dust particle directly. On impact on the instrument target, the cometary dust particle is vaporised and partly ionised, with a different ionisation yield for different elements. Using ionisation yields established by laboratory experiments, the observed spectra are corrected to give synthetic spectra (dashed, thin lines) for the dust particle. The two spectra selected here illustrate the extremes in the ratio of light elements (H, C, N, O) to heavier elements (Mg, Si, Fe). In terms of ion counts, this ratio is 24 for No. 53499 and 0.07 for No. 54474. (Courtesy of J. Kissel & E. Jessberger)

Figure 11 — Model of a cometary dust particle. Each large particle consists of many small particles with voids in between. The small particles could have a silicate core and an organic mantle with some black inclusions. (Courtesy of M. Greenberg)

Figure 12 — Fluence as a function of particle mass derived from Giotto's dust-impact sensors 'PIA' (particles $<10^{-15}$ kg) and 'DIDSY' (particles 10^{-8} to 10^{-15} kg) from 5 min before until 5 min after closest approach. For the large masses ($>10^{-8}$ kg), statistics are poor and the deceleration of the spacecraft was used to determine the fluence. (Courtesy of J.A.M. McDonnell)

Figure 13 — Colour-coded summary of Vega-2 plasma measurements between 230 000 km and 14 000 km from the nucleus, corresponding to 06.30 to 07.17 UT on 9 March 1986 (tick-marks 10 min apart). Electron spectra are shown in the upper panel, ion spectra in the lower two panels. The middle panel shows spectra as observed in the ram direction (forward), the lower panel spectra viewed in the solar direction (sideways). The ordinate gives particle energy in eV. Colour coding represents intensity, with red corresponding to the highest fluxes, and dark blue the lowest. The energy of the peak intensity gives the plasma velocity, the width of the distribution the plasma temperature. At 230 000 km the solar-wind plasma is already heavily loaded with cometary ions, and has decelerated to about 230 km/s (from 400 km/s). The solar-wind plasma is heated by interaction with the cometary plasma, to a temperature of about 5×10^5 K (normally 5×10^4 K). It is deflected by 10° —15° from the normal radial direction to the Sun, as it has to flow around the cometary ionosphere. Between 06.43 and 06.45 UT (16 000 km), Vega-2 crosses a sharp boundary (cometopause) separating two plasma regions of different chemical composition, and enters the cometary plasma region. Significant fluxes of protons (peak at a few hundred eV) are detected by the solar-direction sensor only outside the cometary plasma region, and by the ram sensor only within 50 000 km (07.10 UT). Heavy ions (peak at about 1000 eV) are detected by the solar-direction sensor until about 50 000 km. While the heavy ions slowly disappear from the solar direction, they show up more and more strongly in the ram direction. High-intensity fluxes of electrons are observed inside 50 000 km, even at energies >1000 eV. (Courtesy of K.I. Gringauz)



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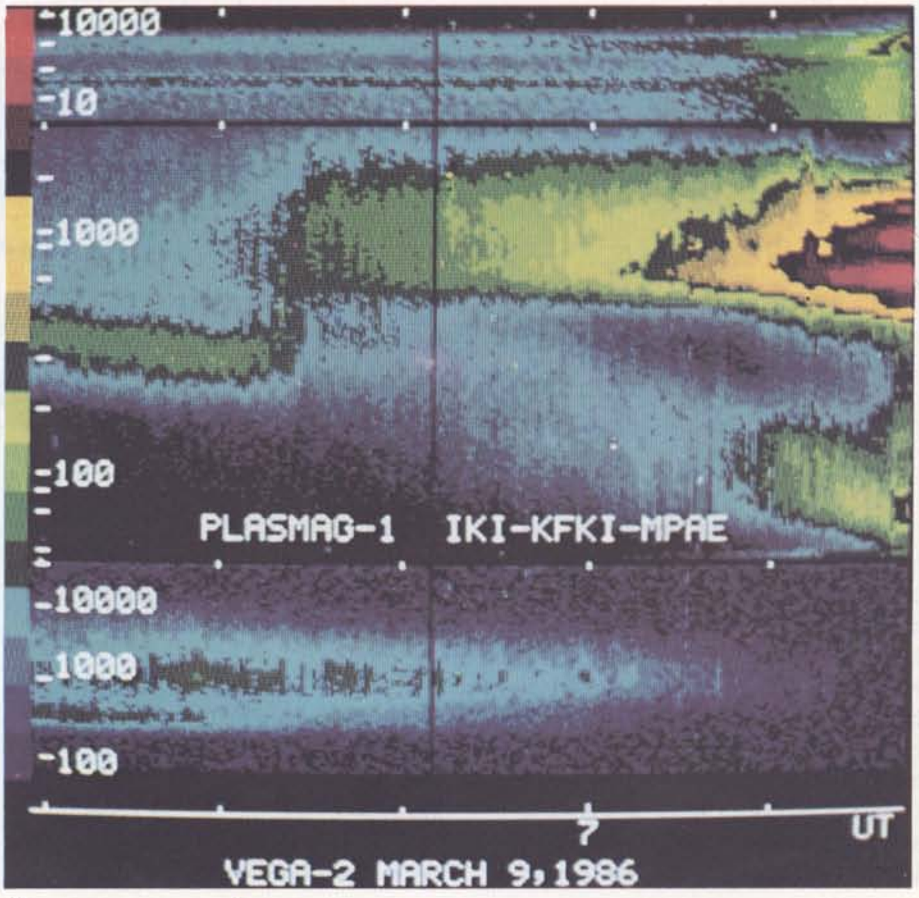

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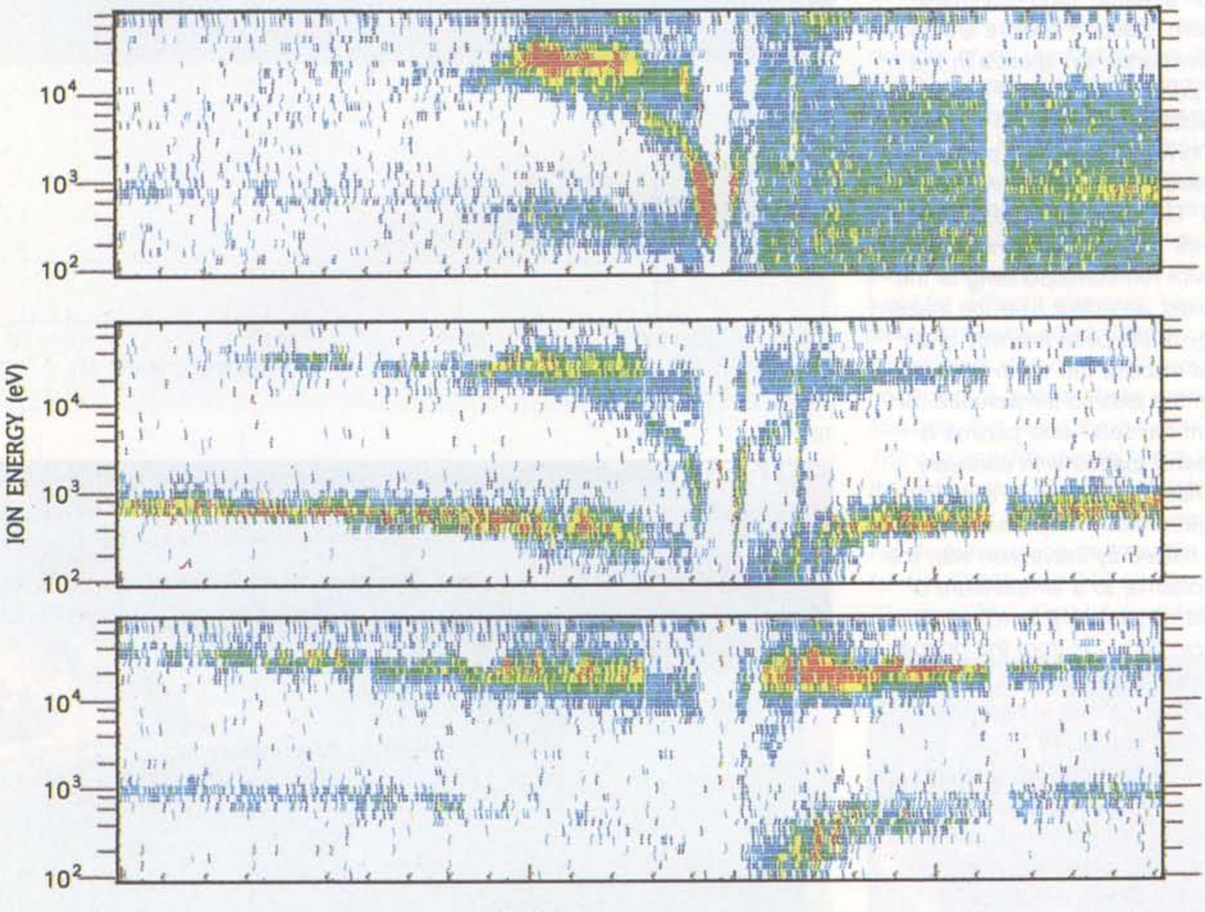
Figure 14 — Cometary ions observed in three different directions by the Implanted Ion Sensor of the JPA experiment onboard Giotto. Observations are shown from 12.34 UT on 13 March (2.8 million km before closest approach) to 12.00 UT on 14 March (2.9 million km after closest approach): upper panel 85°–95°, i.e. perpendicular to the spacecraft spin axis; centre panel 50°–60°, i.e. in the direction of the solar wind; lower panel 15°–25°, i.e. in the forward direction. The ordinate gives ion energy in electron Volts (eV). Colour coding represents intensity, with red corresponding to the highest, and dark blue to the lowest fluxes. The energy of the peak intensity gives the plasma velocity, the width of the distribution the plasma temperature. In each panel the lower band refers to protons, the upper panel to ions in the mass range 12—22 atomic mass units (predominantly O^+, OH^+, H_2O^+). Far from the nucleus, the undisturbed solar wind is clearly seen in the middle panel at about 700 eV, corresponding to 350 km/s. Closer to the nucleus, the distribution broadens (plasma heating) and shifts to lower energies, indicating deceleration of the solar wind. Very close to the nucleus the solar wind is deflected away from the viewing direction of the middle sensor. The upper panel shows cometary water-group pick-up ions already at large distances from the nucleus. They are identified by their energy (about 30 keV), which can be up to four times higher than if they were solar-wind ions. Their distribution widens significantly between 19.30 and 20.00 UT, indicating Giotto's crossing of the bow shock. At large distances from the nucleus, pick-up ions were mostly observed perpendicular to the spacecraft spin axis, which at that time was roughly perpendicular to the magnetic field. Closer to the nucleus, most pick-up ions come from the forward direction (lower panel), indicating the draping of magnetic field lines around the comet. The blank spaces in the centre of each panel are data gaps due to the loss of the Giotto telemetry link after dust impact at the time of closest approach. (Courtesy of A.D. Johnstone)



Giacobini-Zinner observations with the higher gas production rate of Halley. The contact surface, which is a paraboloid-shaped tangential discontinuity, was found 4700 km from the nucleus, where it was identified by a sharp transition between strong fields outside (in the so-called 'magnetic pile-up region') and zero fields inside (in the so-called 'cavity'). Outside the contact surface, a layer of stagnant cometary plasma was found. Inside, the cold, cometary ions flowed smoothly outward at a velocity of ~1 km/s. The ion temperature dropped from 2600 K to as low as 340 K across the contact surface.

The location of the contact surface should be determined by a pressure equilibrium between the magnetic pressure or solar-wind ram pressure on the outside, and the thermal pressure of the cometary ionosphere on the inside. Using the observed parameters in the equations, however, gives a distance much smaller than observed. Including in the pressure balance the frictional force between the stagnating cometary ions in the region outside the contact surface and the neutrals flowing out at a speed of ~1 km/s, leads to satisfactory agreement with the observations.

The solar-wind/comet interaction is not only characterised by these two main boundaries and a few others that are not yet well understood, but also by large variations in magnetic field strength and other plasma parameters acting on shorter time scales and a high level of micro-turbulence, much of which is caused by the pick-up of heavy cometary ions by the solar wind. Pick-up ions were observed out to several million kilometres from the nucleus, and possibly even out to 3×10^7 km. These ions are cometary particles that travel out to large distances from the nucleus as neutral atoms or molecules, before being ionised and 'picked-up' by the solar wind. They can be distinguished from solar-wind ions by their higher energy.

Conclusion

While much has already been learnt from the missions to Halley's Comet the picture is still necessarily incomplete, and more analysis of the data and improvement of the theory is expected in the coming years.

The flight projects and the many ground-based observations have brought together the largest number of scientists ever to combine their efforts in a single astronomical project or study. All space missions to Halley's Comet and all remote observations from space were coordinated by the Inter-Agency Consultative Group (IACG), while all ground-based observations were coordinated by the International Halley Watch (IHW). Having completed the space missions to Halley's Comet, the IACG continues to exist, having subsequently been charged with coordinating several space missions in 'Solar Terrestrial Science'.

Giotto, which played such a key role in the exploration of Halley's Comet, has in the meantime been redirected back towards the Earth, where it will arrive on 2 July 1990. If the spacecraft and the onboard camera are still working, it could be decided at a later date to redirect Giotto, using an Earth's-gravity assist manoeuvre, to encounter Comet Grigg-Skjellerup on 14 July 1992. →

Figure 15 — On the left, magnetic field strength (bottom panel), ion temperature (middle panel) and velocity (top panel) within 25 000 km of the nucleus. The right-hand side of the figure shows two representative ion mass spectra at 6000 km (outside the contact surface) and at 1500 km (inside the contact surface) from the nucleus. Comparison of the two mass spectra indicates substantial changes in ion composition with distance from the nucleus. (Courtesy of H. Balsiger & F.M. Neubauer)

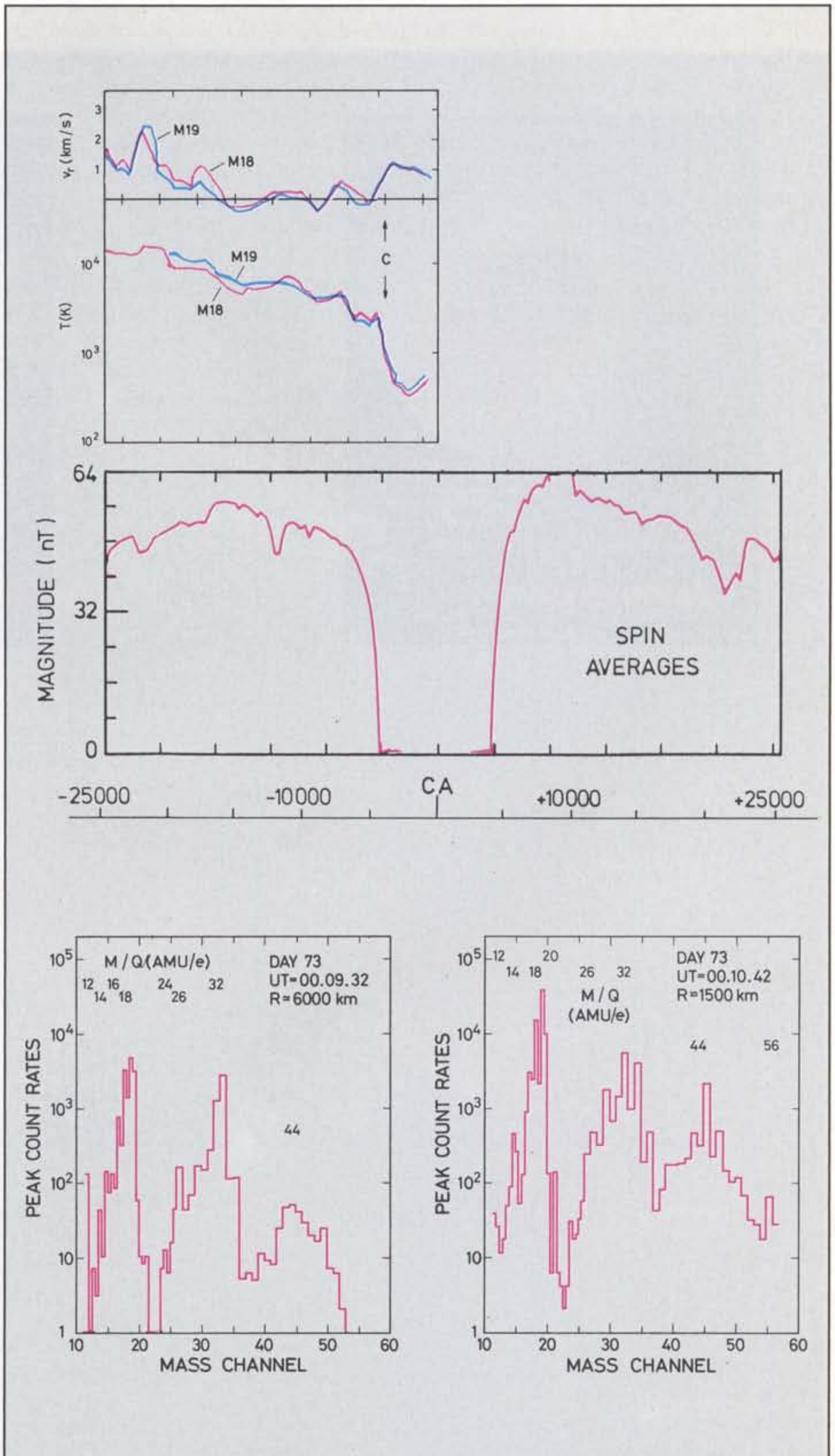


Figure 16 — Suisei observations of the solar-wind interaction with Halley's Comet. The spacecraft's trajectory is shown in the lower panel, passing within 151 000 km of the nucleus on the sunward side at 13.06 UT on 8 March 1986. Suisei traverses the cometary coma from left to right, crossing the bow shock at about 11.00 and 14.45 h. The length and direction of the arrows indicate the speed and direction of the solar-wind plasma. Outside the bow shock, the solar wind is undisturbed and flows from the direction of the Sun at a speed of 400—500 km/s. Inside the bow shock, the solar wind is decelerated (minimum 54 km/s at closest approach) and deflected around the obstacle 'comet'. The upper two panels show examples of the phase space density of ions inside and outside the bow shock. Different colours represent different intensities, red being the highest. Ring-like structures seen in both examples are interpreted as the ecliptic cross-section of the pick-up shell for water-group ions (left) and H^+ (right, small circle) and O^+ (right, large circle) ions.
(Courtesy of T. Mukai)

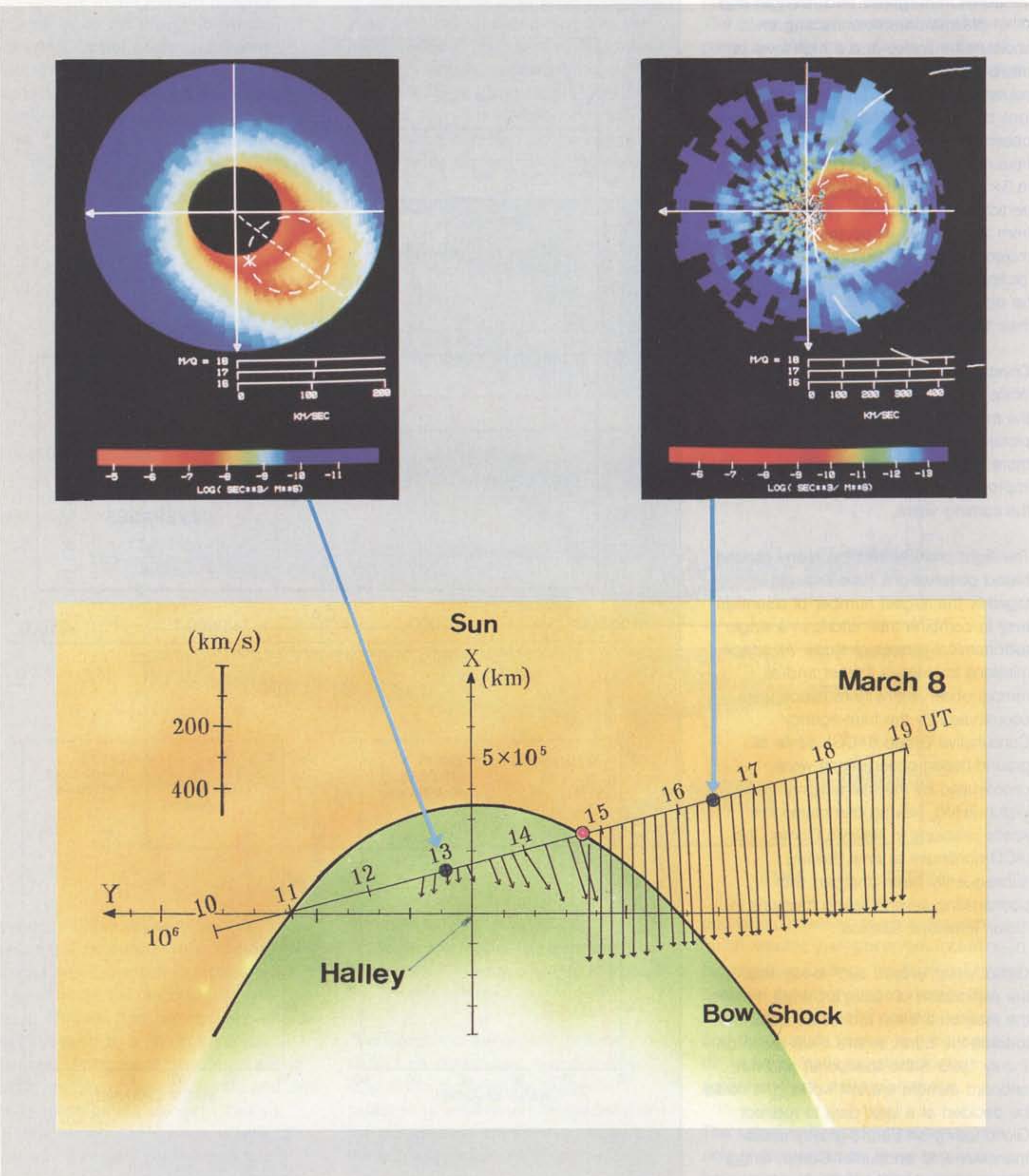


Figure 17 — Halley's Comet photographed on 21 March 1986 when near the Milky Way in the constellation Sagittarius. The comet's long straight ion tail is clearly visible, but the faint light from its outermost parts is lost in the glow of the Milky Way's bright clouds. (Courtesy of R. Häfner)

In Brief

Hermes Space Plane Preparatory Programme Underway

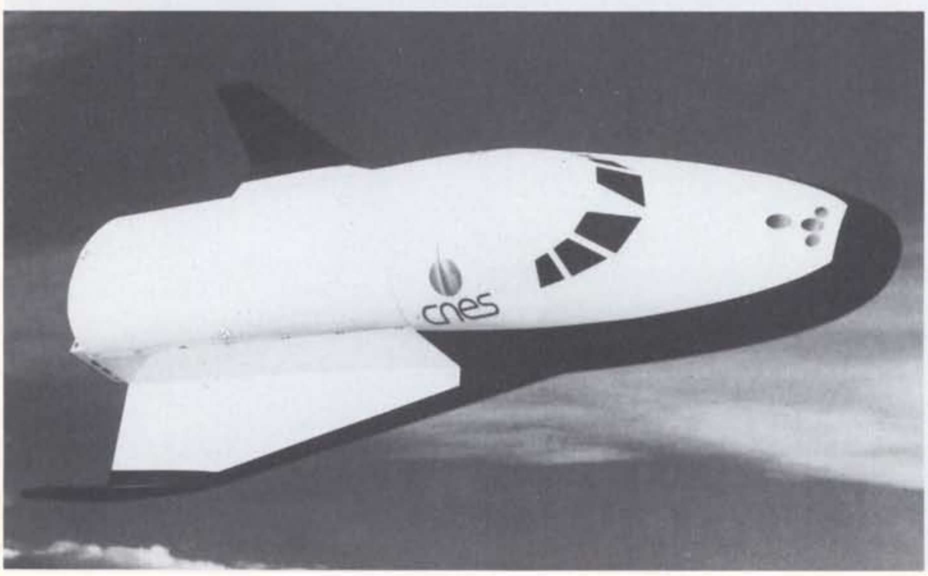
When it met on 22—23 October 1986, the Agency's Council gave the go-ahead for commencement of the Hermes Preparatory Programme as an optional ESA programme.

Hermes is a crewed, delta-wing space plane to be lifted into low Earth orbit by Ariane-5. When each mission is completed, it will land on a runway like a normal aircraft. The main missions planned for Hermes include servicing of all the elements of Columbus — unmanned Platforms, an autonomous Man-Tended Module and the Pressurised Module attached to the international Space Station — as well as the future independent European Space Station.

The Council decision made it possible, from the end of November, to embark on a Preparatory Programme which should lead, during 1987, to a final decision to develop the space plane to be taken at Ministerial Level.

The goals of the industrial work within the Preparatory Programme are twofold: to arrive at a detailed definition of the space plane and the associated ground-segment requirements; and to continue the Hermes mission and utilisation studies and sketch out a first definition of the technology for Extra-Vehicular Activity (EVA).

An ESA team to take charge of the Hermes Programme is currently being set up. Some of the staff will work in Toulouse, in close collaboration with CNES, to whom the Agency will be delegating a number of tasks.



The industrial framework chosen by ESA for the undertaking of the preparatory programme is the following:

Aérospatiale has been appointed industrial Prime Contractor. Avions Marcel Dassault (AMD-BA) has been delegated responsibility for the aeronautics, and other European firms will be cooperating in the prime contractorship work.

The various Hermes subsystem contracts have been awarded to the following firms:

Propulsion	MBB (D)
Functional electronics	Matra (F)
On-board power supply	ETCA (B)
Fuel cells	Dornier (D)
Thermal re-entry protection	AMD-BA (F)
Atmospheric-stage flight guidance and control	AMD-BA (F)
Manipulator arm	Fokker (NL)
Thermal control	Aeritalia (I)
Environmental control and life support	Dornier (D)
Data acquisition and communications	ANT (D)
Onboard software	Aerospatiale (F)
Airlock	CASA and Sener (S)

The firms listed above will secure the support of others, including: AEG (D), Alcatel-Espace (F), BTMC (B), Selenia (I), SEP (F) and SPAR (Can).

The involvement of British industry will be finalised shortly.

Lastly, the structures and equipment will be put out to competitive tender during the Preparatory Programme in order to finalise the industrial organisation, which will involve firms from the 13 European member countries of ESA and Canada who have declared their interest in participating in Hermes.

Technical Features of Hermes

Length	18 m
Wing span	10 m
Dry mass in orbit	12 t

Load capacity: 4—6 crew members (including two pilots); 4½ t carried in the cargo bay (for a 28° -inclination orbit); 35 m^3 cargo-bay volume (diameter 3 m).

Decision on the New Ignition System for Ariane's Third Stage

The configuration for the new ignition system for the Ariane third stage was approved by ESA and Arianespace on 28 November 1986. It was proposed by Société Européenne de Propulsion (SEP) following the series of studies and tests carried out since July 1986. This test programme included 23 altitude-simulation tests on the PF 41 test stand at Vernon near Paris. The Enquiry Board set up in June 1986 has expressed a favourable opinion.

The main changes made to the third-stage engine involve:
- tripling the energy of the igniter
- better distribution of this energy in the combustion chamber by employing two jets angled at 45° to the ignition axis, and
- re-timing the moment of ignition.

A detailed programme of qualification and acceptance tests is now being carried out on several engines before giving authorisation for the resumption of launch services.

ESA at Technospace in Bordeaux

In the company of the President of the French National Assembly and Deputy Mayor of Bordeaux Mr. J. Chaban-Delmas, the Managing Director of Technospace, Mr. G. Dedieu and the French Minister of Economic Affairs, Finance and Privatisation, Mr. E. Baladur, ESA's Director General, Prof. Reimar Lüst, Chairman of the Technospace Exhibition, inaugurated the International Space Industry and Technology Exhibition in Bordeaux on 2 December 1986.

This exhibition, which lasted from 2 to 5 December 1986, brought together the majority of Europe's partners in the space sector, including the many firms and agencies concerned with the spin-off from space activities, and space users.

On its own stand, ESA presented the complete range of Agency programmes, with particular emphasis on microgravity, with a full-size model of Biorack, and scale models of the international Space Station, of which the European Columbus Programme is a part, and of Eureca.

Various events were arranged in parallel with this major exhibition, including:
- A Round Table on 'Government Policy Towards Access to Space', which was chaired by Mr G. Van Reeth, ESA's Director of Administration.
- The Sixth Symposium on 'Materials Sciences in Microgravity' (2—5 December 1986) organised by ESA and CNES under the patronage of the French Ministry of Research and Higher Education. Here, Mr P. Goldsmith, ESA's Director of Earth Observation and Microgravity Programmes, represented the Agency's interests.
- A Round Table on the 'Future of Communication and Broadcasting Satellites in Europe', chaired by Mr P. Bartholomé, Head of ESA's Telecommunications Systems Division at ESTEC in Noordwijk.

ESA's Director General Nominated 'Science Personality of the Year'

At the end of 1986, Reimar Lüst was named 'Science Personality of the Year' by an international jury of leading scientists. Former winners of the award nominated Prof. Lüst for his special contribution to the space programme, which now includes Ariane-5, the Hermes space plane, and the European component, 'Columbus', of the international Space Station planned for the late 1990s.

The jury, composed of former laureats, selects outstanding men and women in 12 fields. Some 700 personalities have been honoured in the sixteen years of the contest.

Italy's First Telecommunications Satellite to be Launched by Ariane

On 5 January 1987, Mr. Luigi Rossi-Bernadi, Chairman of CNR, the Italian National Research Council, and Mr. Charles Bigot, Director General of Arianespace, signed a launch contract for Italsat, the national telecommunications satellite.

Italsat will be placed into geostationary transfer orbit on a dual launch in mid-1990 by an Ariane-4 vehicle. The launch will take place from the Guiana Space Centre in Kourou (French Guiana).

During 1986, Arianespace logged 17 satellite launch contracts worth approximately 5.7 billion French Francs (about 871 million US Dollars). Nine of the contracts involved first-time customers: Italsat, UK Ministry of Defence, Hughes Communications for JC-SAT (USA), RCA (USA), ISRO (India) and Space Communications Corp. (Japan).

IIW—ISO Meeting at ESTEC

ESA has been participating with the International Institute of Welding (IIW) in the drafting of specifications concerning solder alloys, soldering fluxes and solder pastes. A meeting was held at ESTEC on 13/14 November 1986 to finalise a Solder Paste Specification which will be forwarded to the International Standards Organisation ISO for inclusion into their series of ISO Materials Specifications.

Twenty three people, representing most European and North American countries, attended the meeting. The Solder Paste Specification will enable spacecraft contractors to purchase a standardised formulation with well defined properties such as viscosity, wettability, corrosivity and composition.

The use of miniature hybrid circuits and the assembly of surface-mounted components onto a variety of new printed circuit board laminates have led to considerable advances in our understanding of the behaviour and application of solder pastes. In mounting the modern surface devices, solder is the only load-bearing member; i.e. it must provide the mechanical connection to the board, and it must absorb stresses resulting from vibration and mismatches in thermal expansion coefficients during thermal cycling, as well as provide reliable electrical contact.

A number of solder alloys are used to interconnect the new generation of small surface-mounted components. The solder is applied in paste form to the board by screen printing. The solder paste consists of a fine powder of metal alloy mixed with flux and solvents to obtain the correct viscosity. The solder paste slurry will hold components in place before and during reflow when soldering is either performed in the vapour phase of an organic fluid with a boiling point in the region of 215°C or, alternatively, by infrared heating.

B.D. Dunn, ESTEC

The IIW—ISO Meeting participants

Second International Symposium on Spacecraft Flight Dynamics

An International Symposium on Flight Dynamics was held in Darmstadt from 20 to 23 October 1986. It was the second symposium of this type organised by ESOC. The first took place in Darmstadt in 1981.

The initiative for arranging this Symposium came from ESOC's Orbit Attitude Division. It was the intention of the organisers to convene an international meeting of experts in spacecraft flight dynamics and related fields, and thus to provide a forum for the exchange of information and experience in this relatively young discipline.

Like the first symposium five years earlier, this Second Symposium attracted a large number of experts from around the World. Participants from 17 countries were registered, underlining the meeting's international character. NASA, INTERCOSMOS, NASDA, CNES, DFVLR, ISAS and ISRO were among the well-known space research institutes and agencies represented.

The programme of the Symposium was split-up into sessions centred around specific themes, one of which was interplanetary missions. After the interplanetary missions to Halley's comet in 1985/86, it was obvious that the Symposium would provide a welcome opportunity for all those involved in these missions to discuss the different aspects of interplanetary spacecraft navigation in the light of the experience acquired during the past two years. Most of the flight-dynamics experts who had supported the Pathfinder collaboration for the Halley encounter were present at the Symposium.

Not all presentations within this theme were concerned with the missions to Halley's comet. Several papers were devoted to the analysis of future mission requirements, e.g. comet-nucleus sample return missions. Clearly, for a long time to come, interplanetary missions will remain one of the most favoured topics for flight dynamicists.

Another interesting theme of the Symposium was concerned with precise orbit determination, an area in which the European satellite control centres have no operational experience as yet. ESOC is currently deeply involved in building-up its capabilities in this field. Close cooperation exists with some universities and research institutes in Europe and in the United States, which were represented at the Symposium by a number of lecturers. ESOC hopes through this cooperation to arrive at the appropriate Earth-gravity models for the operational support of future near-Earth observation missions.

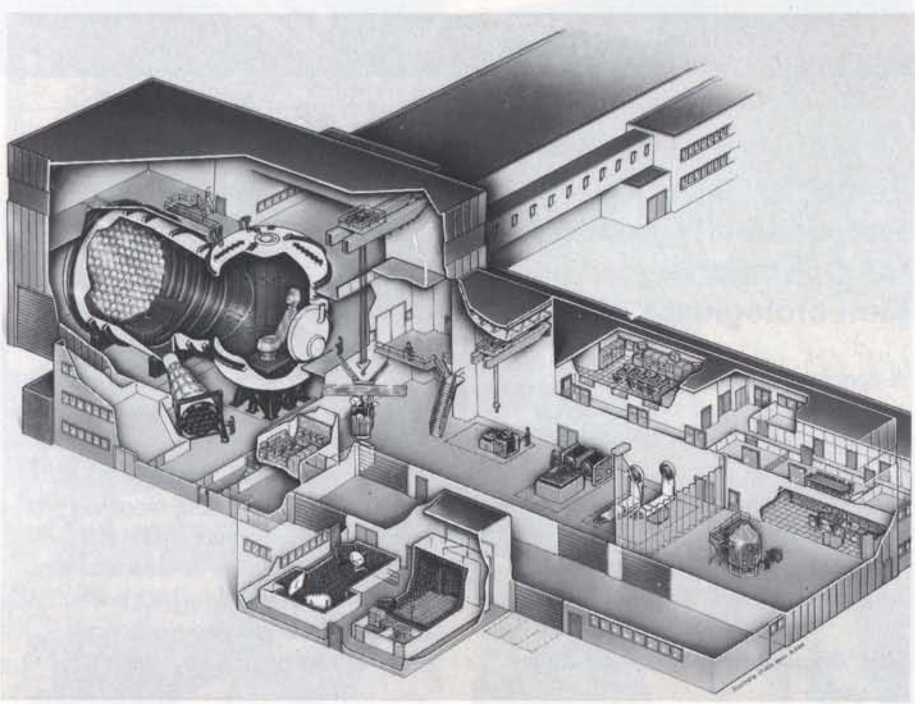
Among the remaining themes, both the dynamics of spacecraft with flexible structures and precise attitude determination constituted major topics for presentation and discussion.

It was considered important that the Symposium should not only deal with theoretical problems, but that the more practical aspects of flight-dynamics ground support should also be adequately covered. Accordingly, specific questions of software implementation and testing, and operational constraints, were thoroughly dealt with.

Summing up, it may be said that the Symposium's four-day programme was densely packed with presentations and lively discussion, and both theoretical and practical aspects were equally covered.

The wish was expressed by many that the by now well-established 'tradition' of this International Symposium in Darmstadt be continued. The Third International Symposium on Spacecraft Flight Dynamics is therefore already being planned, and will be held at ESOC, at the latest in five years time.

K. Debatin, ESOC



Inauguration of the Large Space Simulator at ESTEC

One of the most spectacular facilities in Europe for the testing of large spacecraft, the Large Space Simulator (LSS), was formally inaugurated on Wednesday 14 January 1987 at ESA's European Space Research and Technology Centre at Noordwijk, The Netherlands.

The inauguration was performed by Dr. Rudolf W. de Korte, Holland's Deputy Prime Minister and Minister of Economic Affairs, who switched on the high-power solar simulator of the LSS for the first time. In the simulator was the structure of IRIS (Italian Research Interim Stage), an Italian spacecraft-deployment cradle and perigee stage to be used on Shuttle missions. Its extensive testing in the LSS will last several months.

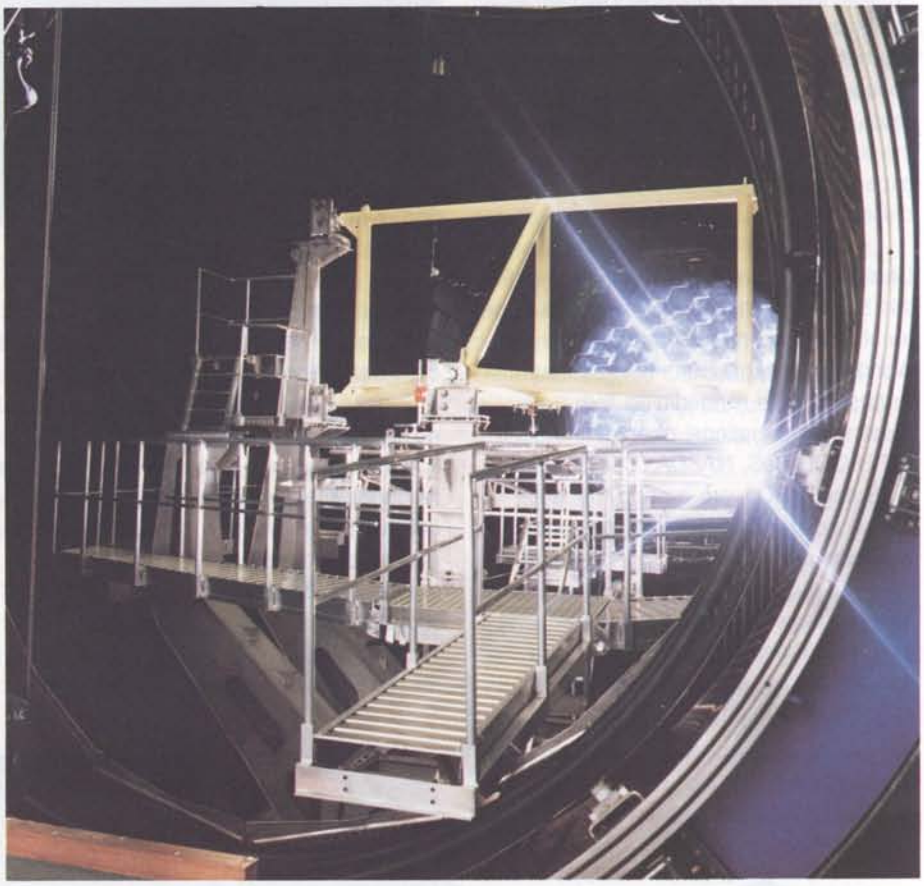
The Large Space Simulator, which provides accurate simulation of in-orbit environmental conditions for large payloads, is unique, combining high performance and state-of-the-art technology with economical operating costs.

The chamber, with a volume of 2100 m^3 is the largest in Europe and provides a high vacuum (approx. 10^{-6} mbar). The solar simulator provides a horizontal beam 6 m in diameter, the lamp house containing 19 xenon lamp modules with a nominal power of 20 kilowatts per lamp, directed at a large collimation mirror 7.2 m in diameter, consisting of 121 hexagonal mirror segments. The inside of the chamber is covered with shrouds, operating at temperatures between −196°C and +100°C.

Other LSS tests scheduled in 1987 include the structural/thermal model of IRIS; the thermal model of Eureca, the European Retrievable Carrier; the large solar arrays of the American Intelsat spacecraft; and the proto-flight model of the ESA scientific spacecraft Hipparcos.

The celebration on 14 January marked the completion of the first phase in upgrading ESTEC's Test Centre to meet the demands of Europe's ambitious space projects for the next decades.

Dr. Rudolf W. de Korte switching on the high-power simulator for the first time



View of the inside of the new Solar Simulator

Eumetsat Takes Over Responsibility from ESA for Operational Meteorological Satellites

A cooperative agreement between ESA and Eumetsat, signed on 12 January 1987 by Prof. Reimar Lüst, Director General of ESA, and Mr John Morgan, Director of Eumetsat, which represents the national meteorological services of 16 European States, makes Eumetsat responsible for the Meteosat Operational Satellites Programme. This programme, developed by ESA, is due to operate until the end of 1995, with the launching of three new satellites over the next four years. These satellites will replace the two pre-operational Meteosat satellites currently in orbit, which were launched in 1977 and 1981, respectively.

Prof. Reimar Lüst (left) and Mr John Morgan

Whilst the satellites' construction, launch, control in orbit and data processing will continue to be carried out by ESA, Eumetsat, which has its Headquarters in Darmstadt, Germany, will look after the funding of the programme and all external relations.

Balloon Crew Use Satellite Communication for Atlantic Crossing

In September 1986 the 'Dutch Viking' trans-Atlantic Balloon Expedition successfully crossed the Atlantic from Canada to The Netherlands in less than 52 h, breaking the former American record by more than 28 h. The crew of three, Henk and Evelien Brink and Willem Hageman became the first Europeans, and Evelien the first woman, to complete the crossing by balloon.

In the accompanying photograph showing the balloon ready for take-off from New Foundland on 31 August, an ESA antenna is visible. The Agency's PROSAT (an ESA mobile-satellite-communication programme) team became involved in the Expedition in early 1984, when ESTEC was approached by the Dutch team about the possibility of a satellite communication link.

With the help of the RF System Division and the Engineering Workshop at ESTEC, a lightweight terminal with a small compass-driven helical antenna was quickly designed and constructed to provide voice communication. At ESA's request, Inmarsat then granted a dedicated channel via the Marecs-B satellite, working in a double-hop configuration through ESA's Villafranca tracking station, which linked the balloon crew with their flight centre at Amsterdam's Schiphol airport.

The hot air/helium balloon used for this crossing makes altitude changes (necessary for 'steering') by varying the air temperature rather than reducing ballast or helium content. The satellite voice link was of particular importance as it allowed communication between the crew and Dutch meteorologists on the ground for optimisation of a track precise enough to bring them from Canada to Amsterdam by selection of altitude (and hence wind current) alone.

The satellite link was also used for position finding, air-traffic control messages, and gave the crew a comforting link with the ground. In an earlier attempt to make the crossing (see ESA Bulletin no. 44, p. 94) a valve malfunction forced the balloon to ditch in the sea, but the crew were able to communicate the nature of the problem via the link and were quickly rescued.

The mobile terminals developed within the framework of the PROSAT programme will provide similar satellite communication facilities to airliners for a pre-operational evaluation as from summer 1987.

The 'Dutch Viking' balloon gondola and its crew

ESA Astronomer Wins Bruno Rossi Prize

At its January Meeting in Pasadena (California), the American Astronomical Society (AAS) announced the awarding of its Bruno Rossi Prize for High-Energy Astrophysics to the Agency's scientist Michiel van der Klis. Michiel, who is presently a member of the Exosat Observatory Team in the Astrophysics Division of ESA's Space Science Department, received the prize for his work on observing compact X-ray sources, particularly the discovery of QPOs (quasi-periodic oscillations) with ESA's X-ray Observatory satellite (Exosat).

Compact X-ray sources are collapsed stars, heavier than our Sun, but less than 20 km across. Some of them are neutron stars, others black holes. QPO is the nickname astrophysicists have given to the mysterious new type of oscillations discovered in early 1985 by van der Klis and his colleagues from the Space Research Laboratory Leiden (Netherlands), the University of Amsterdam, the Massachussetts Institute of Technology (USA) and the Max Planck Institute in Munich.

The oscillations were found in one of the most energetic of the compact X-ray sources, the star GX 5-1, which is hundreds of thousands of times more energetic than our Sun and — fortunately — about thirty-thousand light-years away, near the centre of our Galaxy. Similar oscillations have since been found in several other X-ray stars. The stars oscillate very rapidly (thousands of times per minute), not with the single oscillation period characteristic of numerous other compact X-ray sources, but rather with a whole range of periods. Although most astrophysicists agree that the oscillations must be related to the compactness and the extreme gravitational pull of these stars, precise explanation has so far defied scientific endeavour.

Space Physics Application Network (SPAN) Comes to Europe

The beginning of 1987 saw the inauguration of a line across the Atlantic connecting the Space Physics Application Network (SPAN) in the US with their European counterparts. Although inaugurated without ceremony, this event marks the beginning of a new era in scientific networking, heralding considerable improvements in the international exchange of scientific data (see ESA Bulletin No. 45, pp. 21—23).

Prior to 1987, trans-Atlantic networking was possible, but on an ad hoc basis using connections scheduled at fixed times during the day to overlap the working day in the US and Europe, or using special connections made only for the duration of the data transfer. Now that the trans-Atlantic connection is open 24 hours per day, these difficulties should be a thing of the past.

Currently, computers at ESOC, at ESTEC, at the European Space Telescope Coordination Facility in Garching, and at ESA's Villafranca Ground Station in Spain, are among the 20 nodes already active, in Europe.

SPAN Users Group

Dr. Chris C. Harvey	Observatoire de Paris (Chairman)	
Dr. Wolfgang Baumjohann	MPI, Garching, Germany	
Dr. Günter Green	University of Kiel, Germany	
Dr. Mike Hapgood	RAL, Chilton, UK	
Dr. Per-Arne Lindquist	RIT, Stockholm, Sweden	
Dr. Vivien Moore	Imperial College, London	
Dr. James L. Green	NASA/NSSDC	SPAN Project Scientist
Jenny Franks	ESOC, Darmstadt, Germany	Network Manager
Nick van der Heijden	ESA HQ, Paris	Project Manager
Dr. Daniel de Pablo	ESA, Villafranca, Spain	Vilspa Systems Manager
Dr. Miguel Albrecht	ESRIN, Frascati, Italy	ESIS Study Scientist
Dr. Piero Benvenuti	ESO, Garching, Germany	ST/ECF Assist. Project Scientist
Dr. Trevor Sanderson	ESA Space Science Dept., Noordwijk, Netherlands	ESA Project Scientist

Other networks such as the Joint Academic Network in the UK, the Canadian Scientific Network, DAN, are able to transfer data to SPAN, and gateways exist to Earn, Arpanet and Bitnet, etc. In addition, the High-Energy Physics Network, with many nodes in Europe, is fully integrated with SPAN, whilst connections to Japanese computers are also possible.

In the US, the network is managed by the National Space Science Data Center at Goddard Space Flight Center in Washington.

In the European node management structure, a Users Group represents the participating members. So far, several meetings have been held, including a presentation to the scientific community in Darmstadt in September 1986, a presentation to the JANET community in the UK in December, and the first Users Meeting in Paris in January of this year.

Further information about the network can be obtained from the ESA Project Scientist, or from any member of the SPAN Users Group listed in the above table.

New Large Antenna Test Facility for ESA

In Gothenburg, Sweden, at Ericsson Radio Systems, a large antenna test facility has recently been constructed for ESA. The facility is to be used for testing of the large Synthetic Aperture Radar (SAR) antenna on ESA's Earth-observation satellite, ERS-1.

The SAR antenna measures $10\times1\ m^2$ when deployed in orbit and it operates in the microwave band at a frequency of 5.3 GHz. The determination of the radiation characteristics of such a large antenna is very difficult and requires the use of either a very long (2—5 km) outdoor test facility, or a test facility of the 'near-field' type such as the one at Ericsson. In the near-field facilities, the radiation close to the antenna is accurately measured, and via mathematical transformation techniques, the expected behaviour of the antenna when in orbit is calculated. A near-field type of facility has been selected over outdoor ranges in view of the high accuracy that can be obtained, and considering all the advantages of an indoor facility in terms of handling, cleanliness, and availability (no weather problems).

The development of the antenna is carried out by Dornier Systems and Ericsson Radio Systems, with Ericsson being responsible for electrical design and testing. The test facility has been developed for ESA by Ericsson in co-operation with Sener, Bilbao, who designed and manufactured the key part of the facility, a high-accuracy planar positioning system. This system permits a probe in front of the antenna to be moved over a surface of $12\times5\ m^2$ with a precision of better than 1/10 mm. The full electrical validation of the test facility is expected to be completed by April 1987, with first operational tests on the engineering model of the ERS-1 SAR antenna being scheduled for June 1987.

The completion of this antenna test facility represents a significant milestone in the continuing efforts in Europe on satellite antenna testing. It will permit high-accuracy testing of the ERS-1 SAR antenna and can be used for the future testing of large antennas for other European space programmes.

Publications

Special Publications

ESA SP-249 // 239 PP
COMET NUCLEUS SAMPLE RETURN, PROC. ESA WORKSHOP, UNIV. KENT, CANTERBURY, UK, 15–17 JULY 1986 (DECEMBER 1986)
MELITA O (ED)

ESA SP-250 (3 VOLUMES) // 618 PP / 466 PP / 528 PP
20TH ESLAB SYMPOSIUM ON THE EXPLORATION OF HALLEY'S COMET, PROC. INTERNATIONAL SYMPOSIUM, HEIDELBERG, GERMANY, 27–31 OCTOBER 1986 (DECEMBER 1986)
BATTRICK B, ROLFE E J & REINHARD R (EDS)

ESA SP-253 // 450 PP
COSMOS – AN EDUCATIONAL CHALLENGE, PROC. GIREP CONFERENCE 1986, COPENHAGEN, DENMARK, 18–23 AUGUST 1986 (NOVEMBER 1986)
HUNT J J (ED)

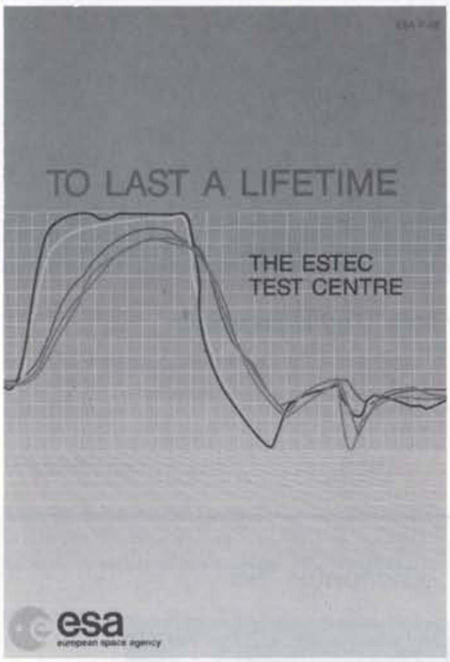
ESA SP-266 // 122 PP
ESPOIR – PROC. EUROPEAN SYMPOSIUM ON POLAR PLATFORM OPPORTUNITIES AND INSTRUMENTATION FOR REMOTE-SENSING, AVIGNON, FRANCE, 16–18 JUNE 1986 (NOVEMBER 1986)
ROLFE E J & BATTRICK B (EDS)

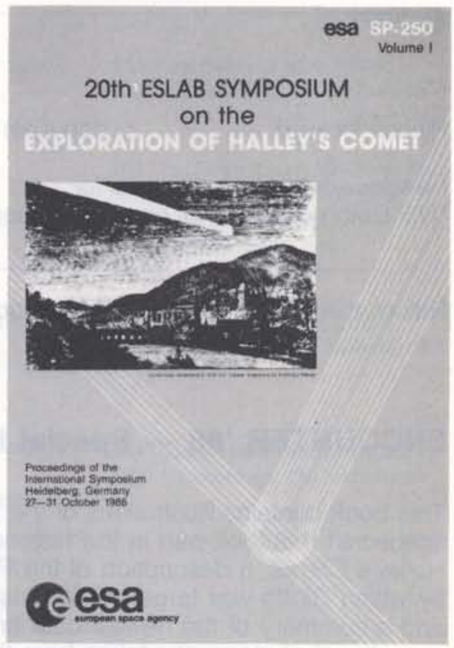
Brochures

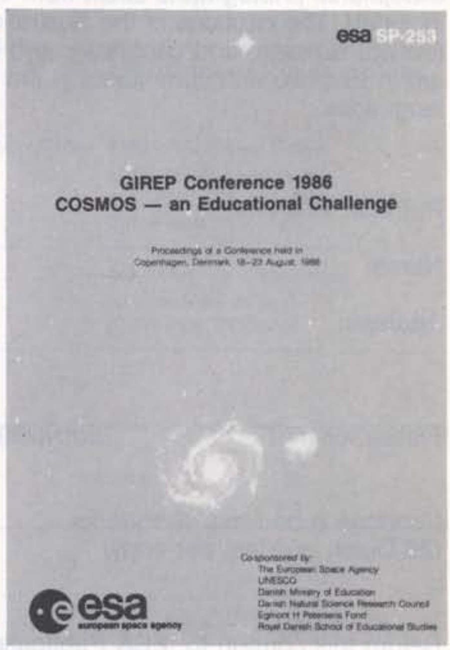
ESA BR-33 // 19 PP
ECS THIRD YEAR IN ORBIT (DECEMBER 1986)
BURKE W R (ED)

Folders

ESA F-02 TO LAST A LIFETIME – THE ESTEC TEST CENTRE
LONGDON N & DAVID V (EDS)





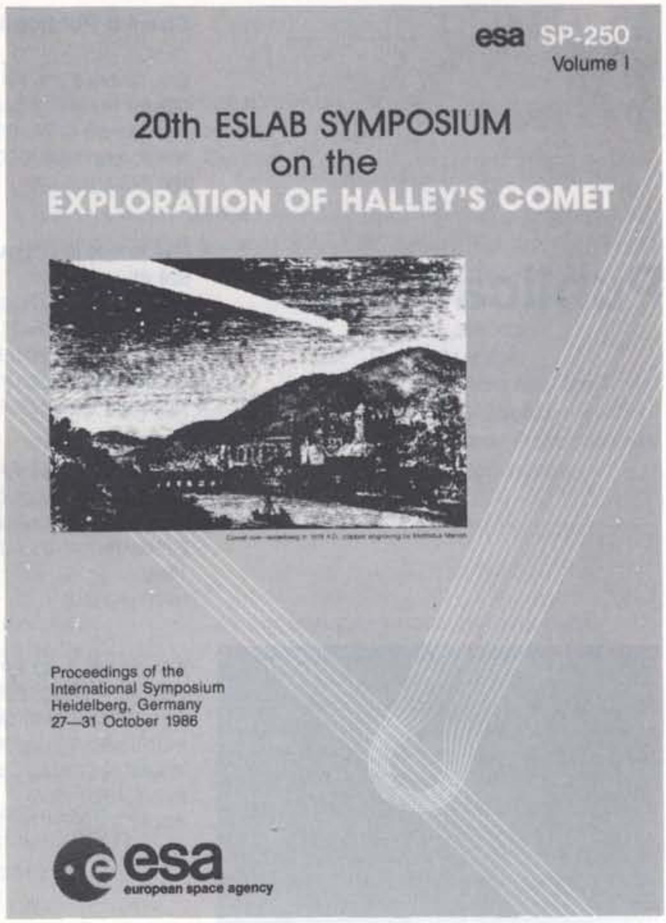


'EXPLORATION OF HALLEY'S COMET'

Proceedings of 20th ESLAB Symposium, Heidelberg, Germany, 27—31 October 1986

(Eds. B. Battrick, E. Rolfe & R. Reinhard)

These camera-ready Proceedings (three volumes with numerous colour images) contain 300 papers — invited papers, contributed papers and posters — presented at *the* major international Symposium of 1986 devoted to the results of *all* of the major international (European, Russian, Japanese and American) space missions to Halley's Comet, as well as those of the concurrent ground-based, airborne and near-Earth observing programmes.



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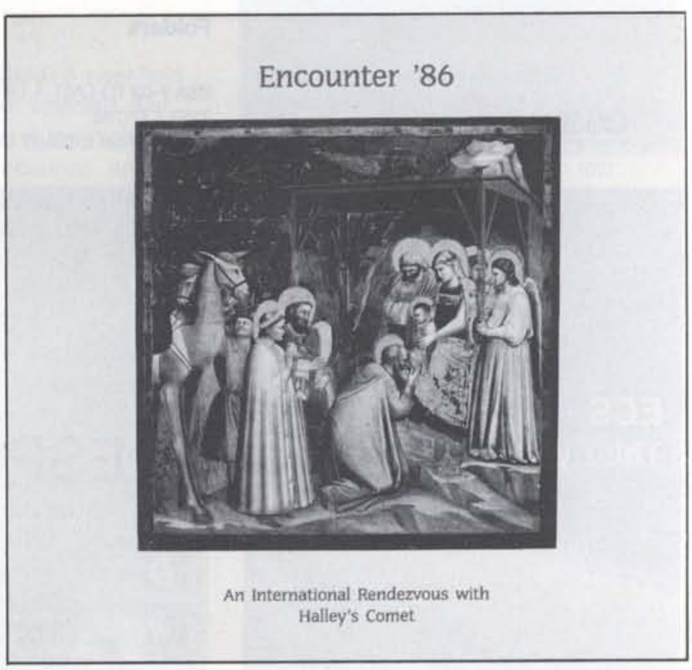
This book contains illustrations of the results from the six spacecraft that took part in the historic encounters with Halley's Comet, a description of the Pathfinder concept by which *Giotto* was targetted so close to the nucleus, and a summary of the newest data on the comet. Some exceptional photographs taken from the ground are also included. The captions of the illustrations are in English, French, Russian, and Japanese, and the main articles are in English, with summaries in the other three languages.



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ESA Journal	4	ESA's learned journal	,,	2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly (English or French)	4	Remote sensing newspaper	,,	,,
Columbus Logbook	4	Space Station/Columbus newspaper	,,	GTS Ltd., Forge House, 20 Market Place, Brentford Road, Middx. TW8 8EQ, UK
News & Views	6	ESA Information Retrieval Service's newspaper	,,	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy
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ESA Folders	(F-xxx)	'Folders' giving short description of a subject for the space-interested layman	Free of charge	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
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