esa bulletin

number 32 november 1982

european space agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European Space Organisations: the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Austria and Norway are Associate Members of the Agency. Canada has Observer status.

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of Space Transportation Systems, the Technical Director, the Director of ESOC, 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: Prof. H. Curien (France).

Director General: Mr. E. Quistgaard.

agence spatiale européenne

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

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 satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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.

Le Directoire de l'Agence est composé du Directeur général, du Directeur des Programmes scientifiques, du Directeur des Programmes d'Applications, du Directeur des Systèmes de Transport spatial, du Directeur technique, du Directeur de l'ESOC et du Directeur de l'Administration.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

LE CENTRE EUROPEEN DE RECHERCHE ET DE TECHNOLOGIE SPATIALES (ESTEC), Noordwijk, Pays-Bas.

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

ESRIN, Frascati, Italie.

Président du Conseil: Prof. H. Curien (France).

Directeur général: M. E. Quistgaard.

esa bulletin

no. 32 november 1982

contents/sommaire

Front cover: European Payload Specialist for the Spacelab-1 mission, Dr. Ulf Merbold, photographed during training at ESA/SPICE, Porz-Wahn, Germany (see page 83).

Back cover: The first Multispectral Scanner (MSS) scene generated by ESA/Earthnet (Rome) from Landsat-4 data. Area shown is Trieste, Northern Italy (see page 6).

Editorial/Circulation Office
ESA Scientific and Technical Publications Branch
c/o ESTEC, Noordwijk, The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Editorial Assistants
Erica Rolfe, Gabrielle Lévy

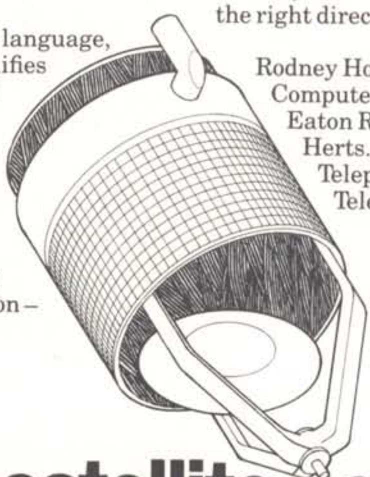
Layout
Carel Haakman

Advertising Agent
La Presse Technique SA
3 rue du Vieux-Billard
CH-1211 Geneva 4

Printed in The Netherlands by ESTEC Reproduction Services 822134
ISSN 0376-4265

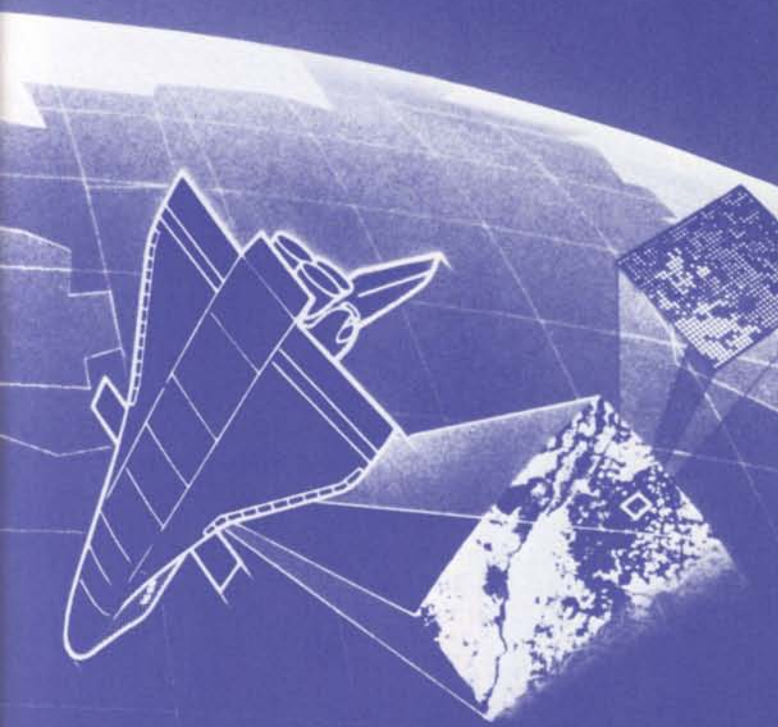
european space agency
agence spatiale européenne

8-10, rue Mario-Nikis
75738 Paris 15, France



Dornier Remote Sensing

Microwave Remote Sensing Experiment for FSLP



Study on 2nd Generation SAR-Experiment with 2 Frequencies.

Computer-based Meteorological Satellite Ground Station.

DORNIER's continuous engagement led to a broad variety of remote sensing projects carried out in national, european, and international programmes.

DORNIER's present capabilities and experience are the basis for further remote sensing tasks.

DORNIER – The reliable partner for:

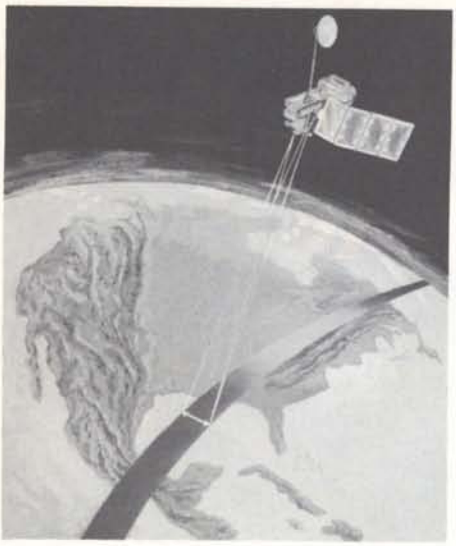
- Design and Development of Overall Systems
- Design and Development of Airborne and Spaceborne Instruments
- Technology Development
- Ground Systems

Programs. Products. Perspectives.

DORNIER

Dornier System GmbH, Dept. VRK, P.O.Box 1360, D-7990 Friedrichshafen 1, Federal Republic of Germany, Tel. 07545/81, Telex: 0734209-0


ARIANE :
VOTRE PLACE
DANS
L'ESPACE
Avec un lanceur opérationnel
De nombreux clients à travers le monde ont déjà fait confiance à ARIANE
• ESA (meteosat, sirio 2, exosat, giotto, L. sat, hipparcos) — ESA/INMARSAT (marecs a, b)
• ISRO-INDE (apple)
• ESA/EUTELSAT (ecs 1, 2, 3, 4)
• INTELSAT (intelsat V F6, F7, F8 - intelsat VA F14, F15)
• DIRECTION GENERALE DES TELECOMMUNICATIONS-FRANCE (telecom 1a, 1b)
• WESTERN UNION -ETATS-UNIS (westar 6)
• SOUTHERN PACIFIC COMMUNICATIONS - ETATS-UNIS (spacenet 1, 2)
• ARABSAT -PAYS ARABES (arabsat 1)
• GENERAL TELEPHONE ELECTRONICS - ETATS-UNIS (gstar 1, 2)
• CENTRE NATIONAL D'ETUDES SPATIALES-FRANCE (spot 1, 2)
• SWEDISH SPACE CORPORATION -SUEDE (viking)
• BUNDESMINISTERIUM FUR FORSCHUNG UND TECHNOLOGIE - ALLEMAGNE (tv sat)
• TELEDIFFUSION DE FRANCE (tdf 1)
Cette liste, déterminée par la date de lancement du 1er satellite, ne mentionne que les commandes fermes sans tenir compte des nombreuses réservations supplémentaires.
Notre spécialité : un service de lancement sur mesure pour l'orbite géostationnaire
arianespace
La première société commerciale de transport spatial
1, RUE SOLJENITSYNE 91000 EVRY-FRANCE
TEL. (33) (6) 077.92.72 + - TELEX ARESP 692392



Earthnet prepares for Landsat-D

L. Marelli, Earthnet Programme Office, ESRIN, Frascati, Italy

Landsat-D, launched successfully on 16 July 1982, carries the traditional Multispectral Scanner (MSS) already flown on Landsat-1, 2 and 3, but also a Thematic Mapper (TM), the new, enhanced capabilities of which are particularly well-suited to European requirements. Work is in progress to upgrade the Earthnet Landsat stations at Fucino and Kiruna for Landsat-D and D′, so that by mid-1983, when the complete Landsat-D payload becomes routinely available to the Earthnet stations, the European remote-sensing user community will have at its disposal a new and powerful tool for resource management. Four passes of Landsat-D MSS data have so far been acquired and are being evaluated, and it is planned to acquire the first TM images before the end of the year.

The Landsat programme

NASA's Landsat programme has been the most successful space-based remote-sensing mission to date, with a first satellite launched in 1972, a second in 1975 and a third in 1978, all carrying the same basic payload, namely the Multi-Spectral Scanner, or 'MSS'. It has already yielded in excess of 700 000 scenes (each 185 km × 185 km) in four spectral bands and with a ground resolution of approximately 60 m × 80 m.

Thirteen regional stations are now in operation worldwide, and they cover the bulk of the Earth's land masses, with the exception of parts of Africa, Central Asia and China, and Antarctica. A further six Landsat stations are planned and are in various stages of development.

Earthnet, which is the European network for the acquisition, preprocessing, archival and distribution of remote-sensing data established by ESA, has operated the Fucino (Italy) Landsat station since 1976 and that at Kiruna (Sweden) since 1978.

The worldwide interest in MSS data has led the US authorities to transform the Landsat programme, which was initially formulated as a research and development activity, into an operational service. Consequently, responsibility for the mission will be transferred from NASA to NOAA, the National Oceanographic & Atmospheric Administration, from 1 October 1982 for Landsat Multi-Spectral Scanner (MSS) data, and from 1 January 1985 for Thematic Mapper (TM) data.

Landsat-D and D′

Compared with its predecessors, Landsat-D (Fig. 1), formally known as Landsat-4 since its launch on 16 July, has several interesting innovations:

- a new set of sensors, including both MSS and Thematic Mapper (Table 1)
- a new orbit with a mean altitude of

Table 1 – Comparison of Landsat-4 TM and MSS sensor characteristics

	TM spectral data		MSS (Multi-Spectral Scanner) data	
Band	Spectral range, μm	Radiometric resolution, NE_p	Spectral range, μm	Radiometric resolution, NE_p
1	0.45 – 0.52	0.8%	0.5 – 0.6	0.57%
2	0.52 – 0.60	0.5%	0.6 – 0.7	0.57%
3	0.63 – 0.69	0.5%	0.7 – 0.8	0.65%
4	0.76 – 0.90	0.5%	0.8 – 1.1	0.70%
5	1.55 – 1.75	1.0%		
6	10.4 – 12.5	0.5 K NETD		
7	2.08 – 2.35	2.4%		

NE_p = Noise equivalent reflectance
NETD = Noise Equivalent Temperature Difference

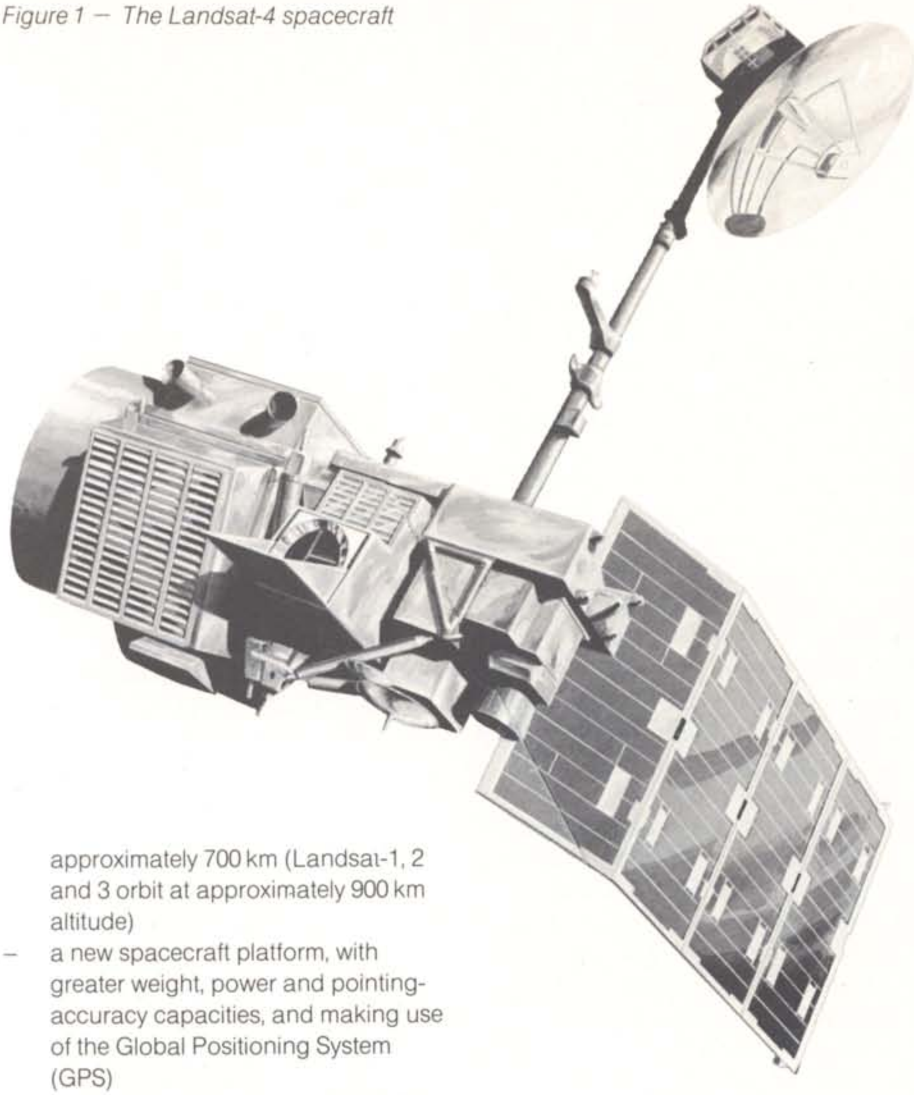


Figure 1 – The Landsat-4 spacecraft

Figure 2a – The Landsat antenna at the Fucino (Italy) Earthnet station

Figure 2b – The Fucino Earthnet ground station

approximately 700 km (Landsat-1, 2 and 3 orbit at approximately 900 km altitude)

- a new spacecraft platform, with greater weight, power and pointing-accuracy capacities, and making use of the Global Positioning System (GPS)
- a faster communications downlink, which can operate at up to 100 Mbit/s
- the ability to transmit data to the Tracking and Data Relay Satellite System (TDRSS), which allows nearly global coverage without the need for on-board recording.

In particular, the TM sensor offers improved ground resolution, which is of the order of 30 m × 30 m for the visible and infrared channels and 120 m × 120 m for the thermal IR channel. There is also an improved radiometric resolution, due to the inclusion, in addition to the four spectral channels in the visible and IR already present in the MSS, of two IR channels in the 1.5–2.3 μm and 10–12 μm thermal wavelength bands.

Upgrading Earthnet for Landsat-D and D′

Earthnet has been responsible for Landsat operations at Fucino and Kiruna since 1976 and 1978, respectively. Both stations acquire, archive and preprocess MSS data, while Fucino is also equipped to handle data from Landsat-3's Return Beam Vidicon sensor (Figs. 2 & 3).

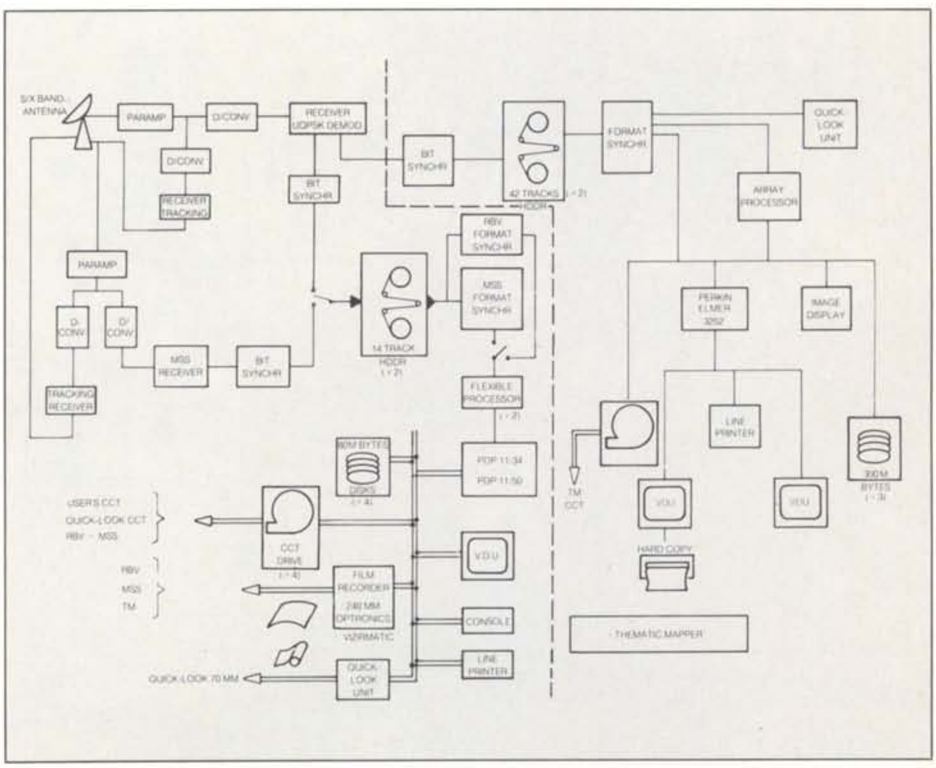


Figure 3a – The Landsat antenna at the Kiruna (Sweden) Earthnet station

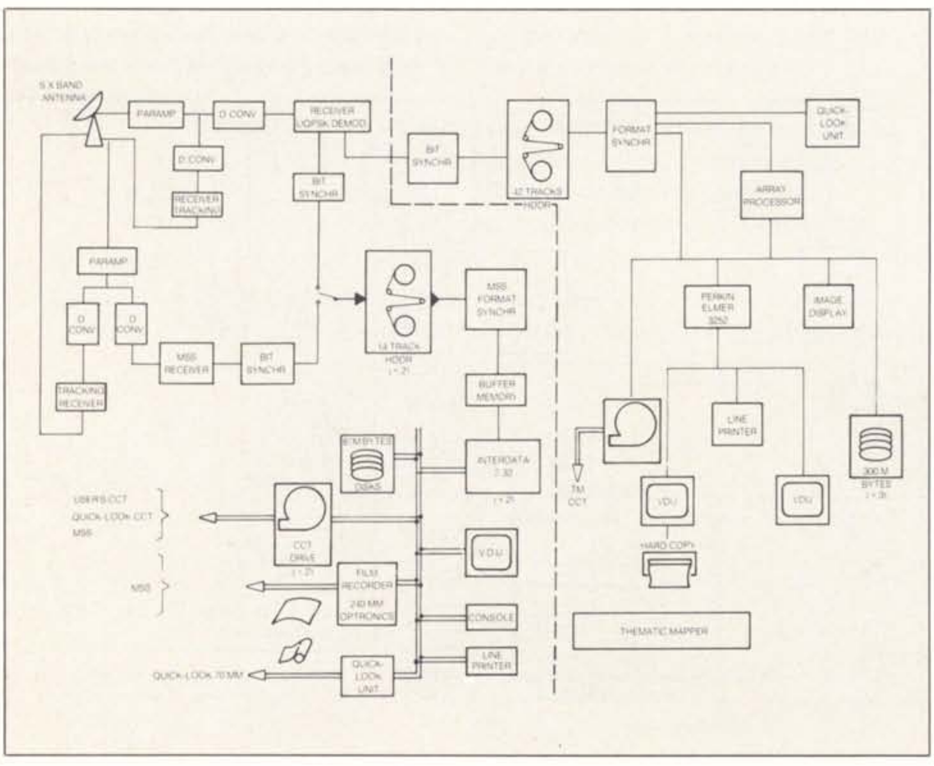
Figure 3b – The Kiruna Earthnet ground station

The importance of ensuring reception and distribution of Landsat-D and D′ data in Europe through Earthnet was recognised by ESA Member States from the outset of the programme. In December 1980, Council approved the funds required to upgrade the Earthnet Landsat stations for Landsat-D and D′, as well as the associated operational funding needed for the period 1982–1985.

The modifications to the existing Landsat facilities needed to make them compatible with Landsat-D and D′ include:

- the addition of an X-band reception capability to the present S-band type systems. The financing of these systems has been provided on a national basis by the Swedish Space Corporation (SSC) and Telespazio, who retain ownership of the respective facilities
- the integration of the necessary radio-frequency equipment for the reception of Landsat-D bit streams
- the procurement and installation of High-Density Tape Recorders (HDTR) for recording and archiving TM data
- the procurement and installation of two identical TM digital processing chains for the two Landsat stations (Fig. 4)
- the development and installation of film-recording subsystems for the two stations, capable of meeting the demanding requirements of the TM reliably
- the adaptation of the existing MSS processing chains at Fucino and Kiruna to make them compatible with the Landsat-D and D′ MSS instruments, which differ slightly from the similar Landsat instruments presently in operation.

All of the above investments, with the exception of the first item, are being financed by the Agency and monitored by the Earthnet Programme Office. The TM chain used for software development, integration and testing, will be retained in Frascati for Landsat-product quality control and software maintenance and adaptation.



The main contractors involved in the upgrading project, valued at approximately 5.6 MAU (± US$6.7 million), are:

- MBB, as prime contractor for the TM processing-chain development
- Schlumberger for the high-density tape recorders
- SEP for the film recorders, and
- SSC and Telespazio for the integration and adaptation tasks.

The schedule of upgradings
Based on the Landsat-4 instrument switch-on schedule announced by NASA to foreign station operators, the following milestones have been envisaged:

- acquisition and recording of Landsat-4 MSS data 10/08/82 (Fig. 5)

Figure 4 — The Thematic Mapper processing chain for Landsat-4 processing at the two Earthnet stations

Figure 5 – First Landsat-4 MSS scene generated by Earthnet, showing the Trieste area of Northern Italy

- generation of standard MSS products 1/11/82 Fucino 1/01/83 Kiruna
- acquisition and recording of TM data 1/11/82 Fucino 1/02/83 Kiruna
- processing of TM data 1/05/83 Kiruna 1/08/83 Fucino
- quality control at Frascati 1/10/83

This schedule should be compatible with NASA's planned availabilities for Landsat-4 data, which are:

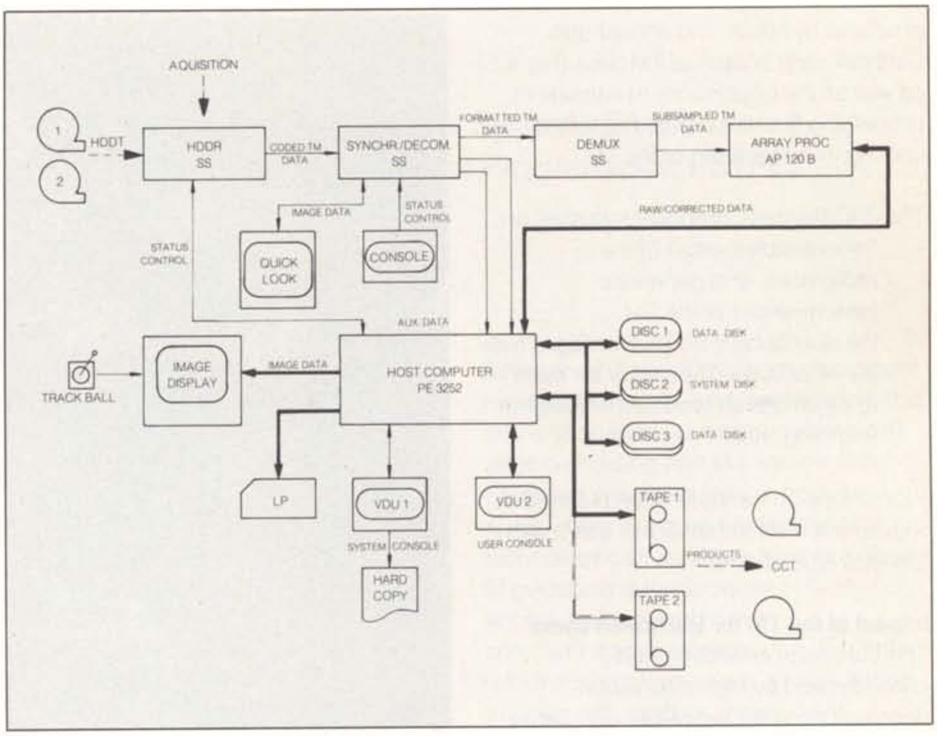
- 10 August 1982 for routine MSS acquisition
- late 1982 for experimental TM readout, and
- mid 1983 for routine TM acquisition.

Refurbishment of the Fucino antenna is expected to result in a full month of down-time for its acquisition and recording functions, but European coverage will be only marginally affected as Kiruna will extend its area of acquisition as far south as possible during this period. No corresponding break in operations at Kiruna is planned because the X/S-band reception capability will be provided in addition to the present S-band antenna, which will continue to operate throughout the refurbishment period.

LIDQUA

In conjunction with the Landsat-D launch, NASA has organised what is called the 'Landsat Image Data Quality Assessment' (LIDQUA) programme, aimed at characterising Landsat-4 performance and in particular that of its sensors.

This activity has been planned as a primarily US scientific undertaking, handled through an Announcement of Opportunity (AO) to the scientific community. The AO has been extended to foreign Landsat ground-station operators, and Earthnet, together with the Joint Research Center (JRC) of the Commission of the European Community (CEC), has submitted a proposal for technological and application validation experiments. This proposal has now been



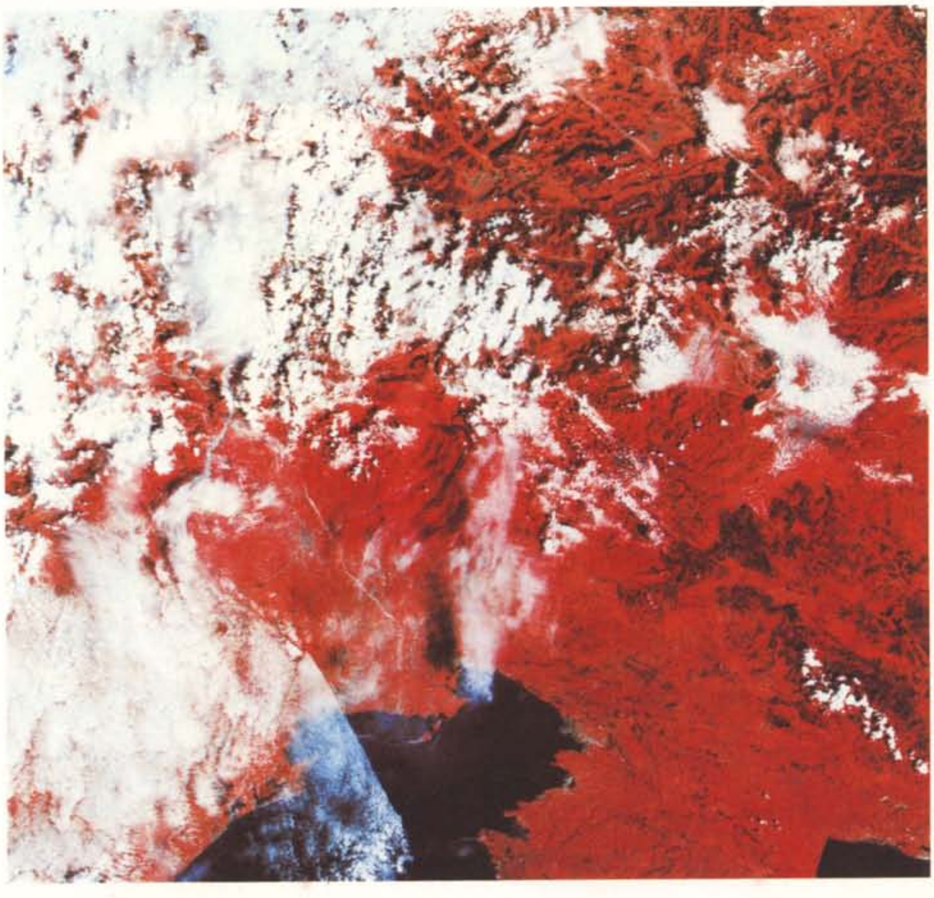


Figure 6 – First Landsat-4 TM scene released by NASA, showing Detroit on the western edge of Lake St. Clair (top right corner) with Lake Erie below

accepted by NASA and should give Earthnet early access to TM data (Fig. 6), as well as the opportunity to validate its processing facilities before the formal coming into operation of the TM.

The JRC/Earthnet proposal focusses on:
- the characterisation of the radiometric and geometric performances of the TM
- the applicability and advantages over the MSS of the TM sensor for such applications as land use, ecological mapping, etc.

Workshops on Landsat-4 are planned at regular intervals to familiarise users with this new type of data.

Impact of the TM for European users

The European environment is characterised by high population densities, complex but rather accurately known landscapes, and average field sizes that are rather small. All are reasons why MSS data have been of more limited value to Europe than to other larger countries, such as Canada, Brazil, Australia, etc. The geometric and radiometric characteristics of the TM data match European requirements to a greater extent, particularly in such fields as geology, agriculture, forestry, land use, etc. These characteristics are complementary to those of the French Spot satellite, planned for launch in 1984, which will offer very high resolution, multispectral and panchromatic imagery, with a stereo capability, and will therefore provide valuable contributions to cartography, mapping and land use.

Early availability of TM data to European remote-sensing users will therefore be very important for:
- familiarisation of users with the first of the 'second generation' of optical sensors
- starting of demonstration projects in various fields of application
- progressive transfer of remote sensing from the research to the applications domain.

This evolution is called for because both the US and France have decided to adopt cost-recovery policies for their Landsat and Spot programmes and the target dates when these policies will be enforced are rather near, i.e. in the second half of the '80s.

Conclusion

After ten years of successful Landsat operations, Landsat-4 is bringing new challenges and potential growth to the remote-sensing community. Earthnet – in cooperation with its station operators, National Points of Contact and industrial companies involved in the upgrading process – is actively engaged in adapting its facilities for this mission, which it sees as a new opportunity to reinforce its ties with the European remote-sensing community and to redouble its efforts to meet their requirements and objectives in both research and applications. This project is also providing a unique opportunity to review the activities with which the Agency will be involved when it launches the first European Remote-Sensing Satellite (ERS-1).

The SPINE Programme and the Associated Demonstrations at UNISPACE 82

C.D. Hughes, Communications Systems Division, ESA Directorate of Applications Programmes, ESTEC, Noordwijk, The Netherlands

Satellite communications provide a unique facility for selecting items from the vast stores of digitally-coded information available from modern data-collection facilities and delivering them simply and cheaply to users. The satellite link provides both a capacity many times greater than conventional lines and the flexibility to serve users without special regard to their geographical location.

The UNISPACE demonstration provided two examples of such data access and transfer: earth-observation images from the Meteosat, Landsat and Seasat satellites, and high-speed facsimile transmissions of documentation.

The quantity of information available on a global scale in digitally coded form has increased dramatically in the last decade. Many of these data are of great potential benefit to developed and less developed countries alike. For example, information about the condition of and changes in the Earth's surface available from Earth-observation satellites can be of valuable assistance to agriculture, in the monitoring and control of pests, and for water-resource management (Fig. 1). The effects of pollution can also be studied to alleviate harm to the environment. Scientific data, educational information, and technical knowhow are further examples of the ever-increasing volume of knowledge stored in digital form.

Because of the relatively large investment needed for storage and classification, the information tends to be concentrated in large computing and storage centres which are very often remote from the areas where it can be applied. Space technology can provide a flexible means of overcoming this problem of data access and retrieval in that communications satellites can distribute information at high speed, in digital form, to users with relatively inexpensive reception facilities. Moreover, since communications-satellite footprints tend to cover a very wide geographical area, there are few restrictions on the user's location. Simplification, and consequent reductions in the cost, of earth-terminal

Figure 1 — Typical remote-sensing image from NASA's Landsat satellite available via the ESA Earthnet system

Figure 2 — General arrangement of the SPINE network

facilities is also making it much easier for approved users with very simple equipment in relatively remote areas to access sophisticated data bases in the major technical centres of Europe.

In 1980 the Agency, supported by a number of its Member States, decided to set up a digital communications experiment using its Orbital Test Satellite (OTS), to investigate the feasibility of exchanging large quantities of data between data banks. This experiment, called 'SPINE' (Space Informatics Network Experiment), now has six earth stations in operation, the locations of which are shown in Figure 2. The initial phase of SPINE involved installing transmit/receive earth stations at the data banks themselves, and information is now regularly exchanged between the locations shown.

The demonstrations at UNISPACE 82

SPINE is now concentrating on establishing much simpler user earth stations which can access data from the network. In support of the United Nations Conference on the Peaceful Uses of Outer Space (UNISPACE), the Agency assembled such a station in Vienna last August. From the Conference site it was possible to select sample data sets from the SPINE data banks in the United Kingdom, The Netherlands, Italy and Sweden and have them transmitted in real-time for immediate display.

The examples demonstrated at the Conference included:

- digitally coded pictures from the remote-sensing satellites Landsat, Seasat and Meteosat
- selection and transmission of documentation by high-speed facsimile (1 Mbit/s).

Figure 3 is a block schematic of the Vienna receive-only terminal, together with a typical SPINE transmit/receive station. For the Vienna demonstration the request for information and the catalogue search were made via the ESANET terrestrial line system.

At a typical transmit/receive SPINE station, the information to be sent is identified in

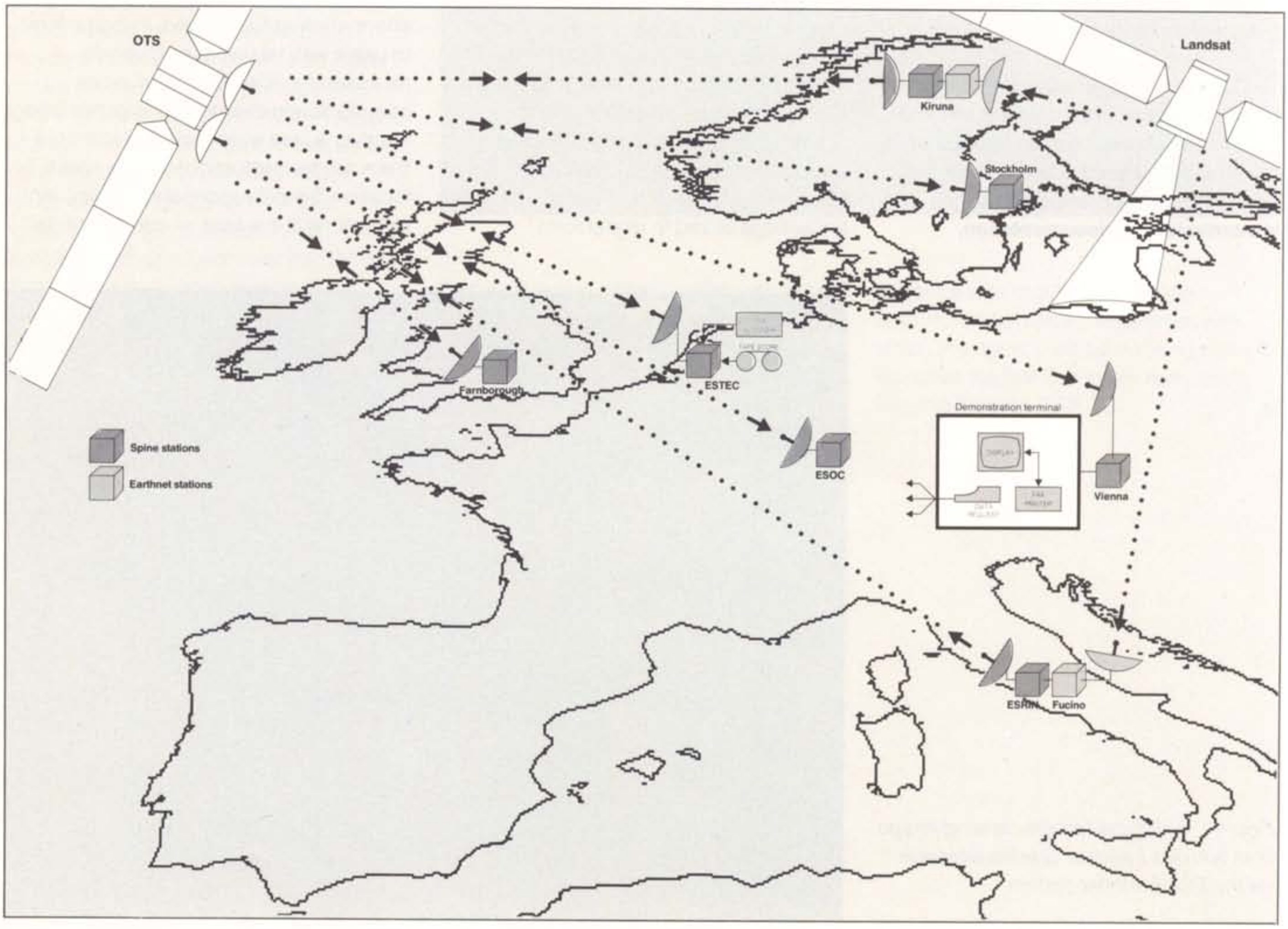
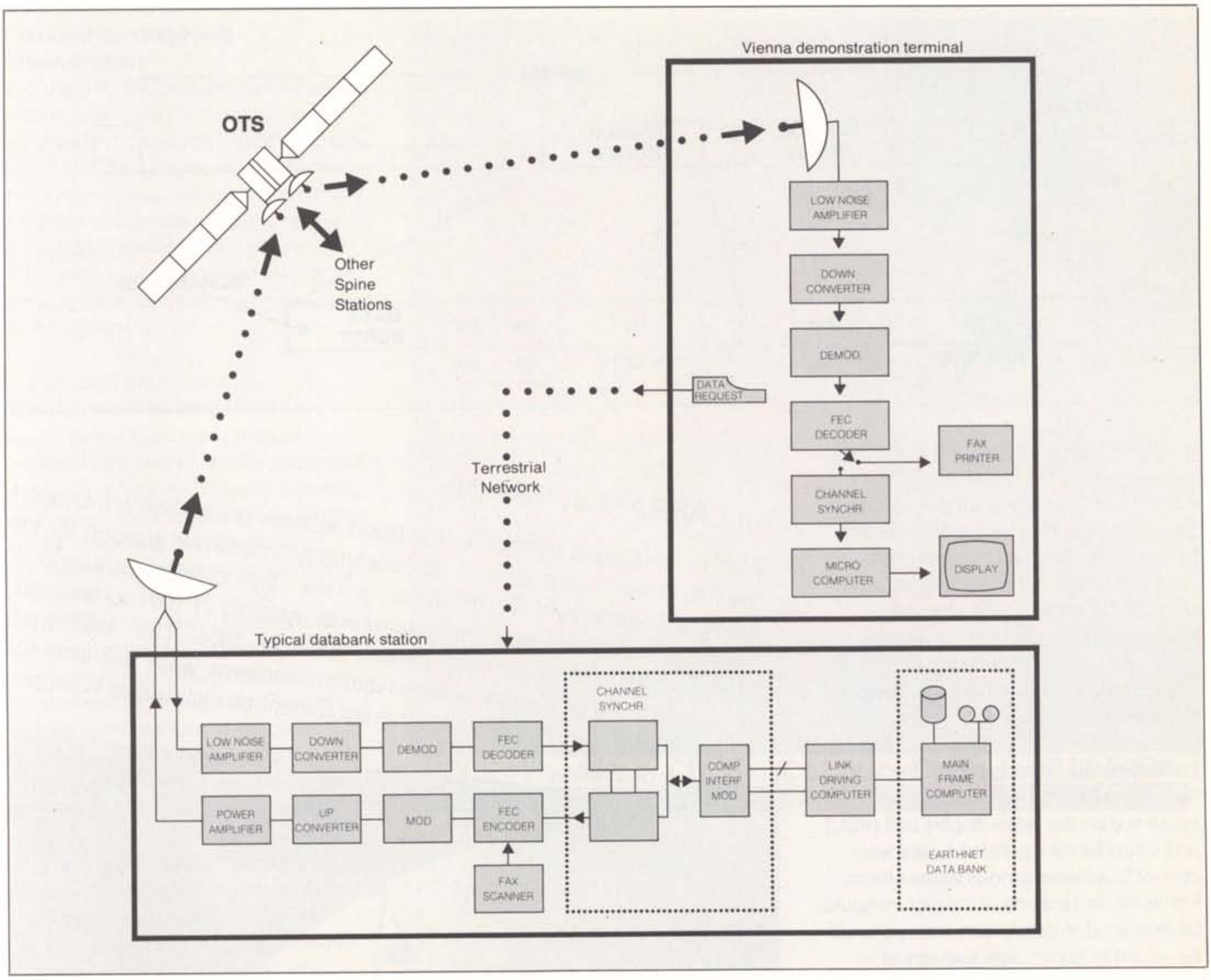


Figure 3 – Simplified block diagram of the receive-only SPINE terminal at Vienna and a typical SPINE transmit/receive terminal



the data bank and then formatted and buffered in the Link Driving Computer (LDC). The Communications Interface Module (CIM) converts the 16-bit parallel data into serial form for transmission and adds the appropriate addresses and flags so that the data can be recognised at the receive terminal. The channel synchroniser puts the data into 252 ms transmission frames, adds unique words for synchronisation purposes, and scrambles the data part of the burst.

The transmission frame is shown in Figure 4. It can be seen that a number of data bursts from the different stations can be accommodated in a single transmission frame. Forward Error Correction (FEC) is used to improve the Bit Error Rate (BER) over the satellite path from 10^{-5}, which is the clear-weather performance planned for the basic satellite link, to 10^{-9} which is a very low error rate suitable for data communications of this type. The FEC encoder, shown in Figure 3, has an input bit speed of 1 Mbit/s and an output speed of 2 Mbit/s. The modulation method employed is Binary Phase-Shift Keying (BPSK) with 100% roll-off filters equally divided between the transmit and receive systems.

After two-stage upconversion to 14 GHz, the signals are amplified to a power level of about 50 W and applied to a 3 m diameter antenna for transmission through OTS to the receive terminal, which in the case of the UNISPACE demonstrations was located in Vienna.

The Vienna terminal, employed a 3.3 m diameter antenna with appropriate low-noise amplification and down conversion to 70 MHz. The 2 Mbit/s digital output of

Figure 4 — The frame structure for the SPINE transmissions

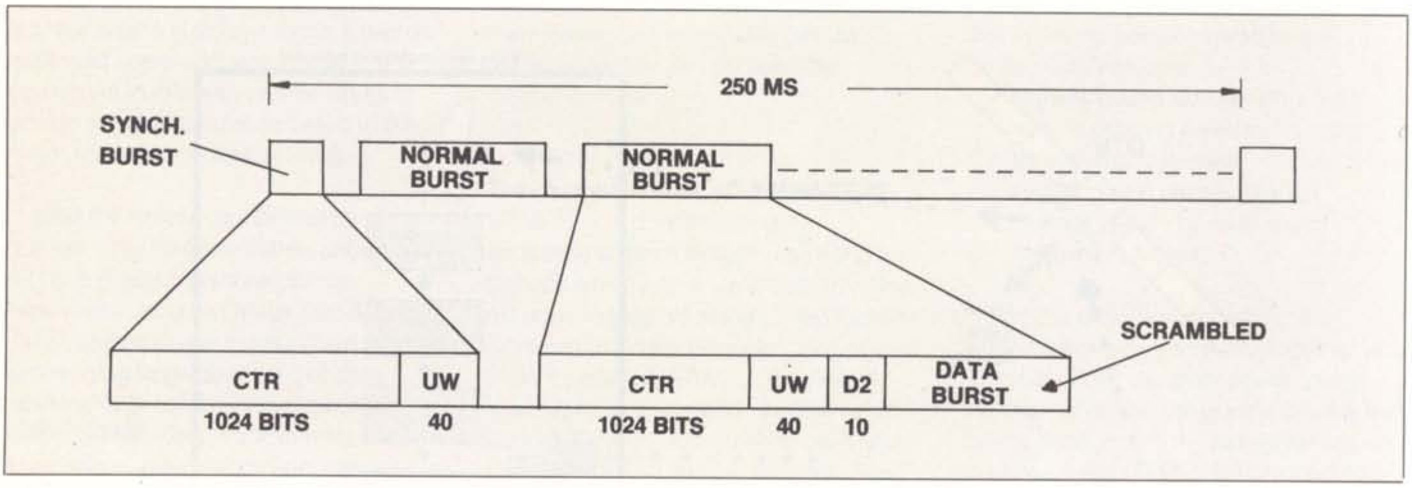
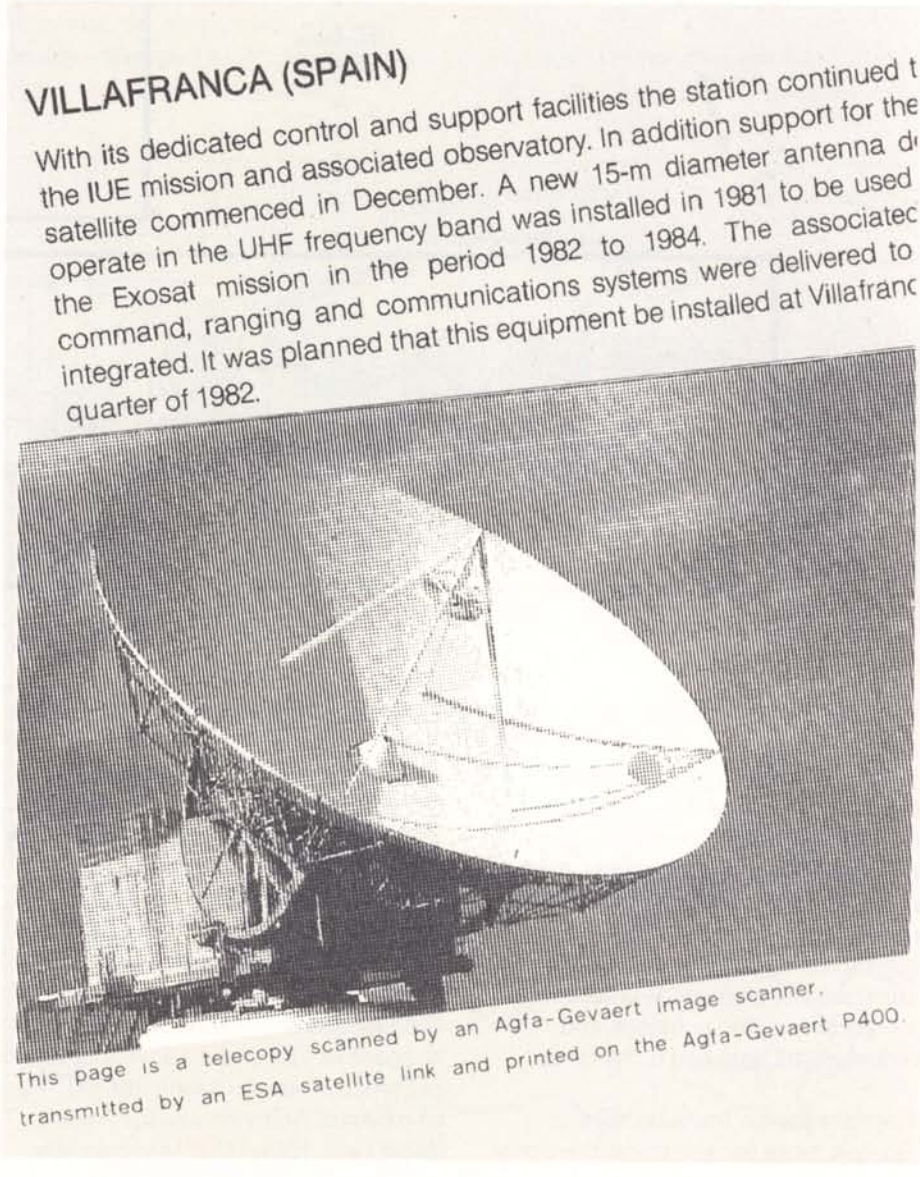


Figure 5 — Example of the facsimile information received at UNISPACE (small section of an A4 page)



VILLAFRANCA (SPAIN)

With its dedicated control and support facilities the station continued t
the IUE mission and associated observatory. In addition support for the
satellite commenced in December. A new 15-m diameter antenna d
operate in the UHF frequency band was installed in 1981 to be used
the Exosat mission in the period 1982 to 1984. The associatec
command, ranging and communications systems were delivered to
integrated. It was planned that this equipment be installed at Villafranc
quarter of 1982.

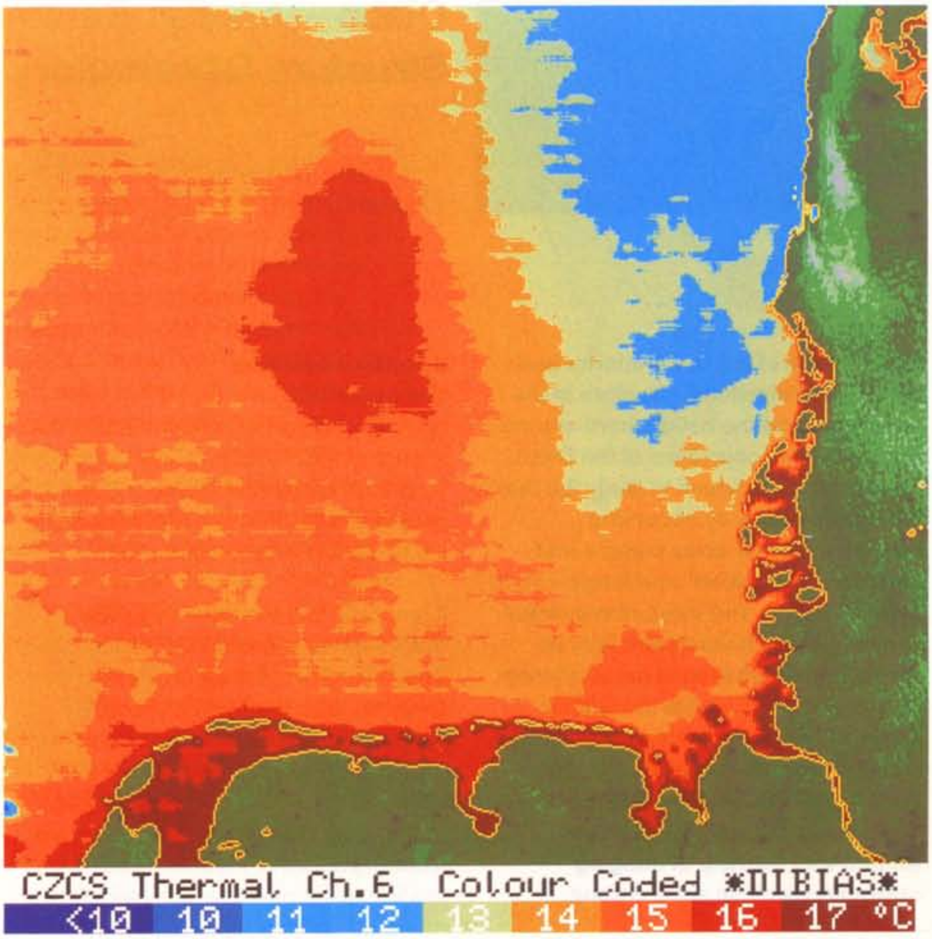
This page is a telecopy scanned by an Agfa-Gevaert image scanner, transmitted by an ESA satellite link and printed on the Agfa-Gevaert P400.

the demodulator was applied to the FEC decoder, where the digital redundancy was removed, thus providing a 1 Mbit/s data stream to the channel synchroniser of very low error rate. The bit stream at this point contained information from other SPINE stations. The channel synchroniser stripped out the wanted data, removed the scrambling and presented the data in 16-bit parallel form to the microcomputer.

For the remote-sensing part of the demonstration, the information was presented on the video display unit (VDU) and could be manipulated by software control to achieve various visual effects. For example, sections of the picture could be examined in detail, false colours could be added to accentuate features of particular interest, etc.

The digital information from the FEC decoder could also be applied to a high-speed facsimile printer, which operated in conjunction with a complementary scanner located at another of the SPINE earth stations. The wide range of documentation selected for the Conference demonstrations served to illustrate the speed and high resolution of facsimile transmission via SPINE. The resolution of the facsimile transmissions was 8 dots/mm and the document transmission rate 4 s per A4 page. A small example of the facsimile quality that was provided is shown in Figure 5.

Figure 6 — Processed image of the German Bight, showing temperature variations in the North Sea. This image, presented by courtesy of DFVLR, was prepared from Nimbus-7 Coastal-Zone Colour Scanner (CZCS) data



Results of the UNISPACE demonstrations
The UNISPACE Conference provided a unique opportunity to demonstrate the progress and capabilities of SPINE. Many UNISPACE delegations expressed interest in the Agency's activities in this area and a number of scientific institutes operating in the field of remote sensing were particularly interested in the low-cost SPINE terminal currently being developed by the Agency.

In addition to the continuous demonstrations on the ESA stand, a special presentation of European activities in the field of remote sensing was given by the Agency's Director General, Mr. E. Quistgaard, to the Plenary Session of the Conference. This presentation included material transmitted live in digital form to the Conference via the SPINE/OTS link and displayed on a large-screen projection TV system. The presentation also included colour composites supplied by DFVLR which showed some of the many applications for remote-sensing data. Figure 6 is one such picture where the variation in the temperature of the sea is clearly shown.

Much of the demonstration hardware for UNISPACE was contributed free of charge by European manufacturers; these included Dornier System, who provided the earth station; Agfa Gevaert, who provided the high-speed facsimile equipment; and Sigma Electronics, who provided the display computer. The help of these manufacturers was greatly appreciated by the Agency. The level of support provided serves as an indication of the good co-operation available on a European basis to support this important type of international event.

Acknowledgements
The help and co-operation of the following organisations is also gratefully acknowledged:
- Royal Aircraft Establishment, Farnborough
- Swedish Space Corporation
- EUTELSAT and its member administrations
- ESA Earthnet Programme Office
- DFVLR, Oberpfaffenhofen
- Université de Lille, Laboratoire d'Optique Atmospherique.

The Agency's Next Scientific Satellite*: Disco, ISO, Kepler, Magellan or X-80?

Disco – A Solar-Seismology and Heliospheric-Structure Observatory

V. Domingo, Cosmic-Ray Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

Investigation of the Sun's interior and the three-dimensional structure of the solar wind and the heliosphere are the main scientific objectives of the Disco mission. It is proposed to study the Sun's internal structure by observing oscillations of the solar surface and variations, both short- and long-term, in solar radiation. The three-dimensional structure of the heliosphere is to be studied by simultaneous measurement of particles and fields in the ecliptic plane by Disco, and at high latitude by the International Solar-Polar Mission (ISPM). The link between the Sun's interior and the solar wind will be studied with the help of imaging observations of the solar corona.

* This series of five articles describes the scientific aspects of the five projects from which ESA will select its next scientific satellite. It should be emphasised that the payloads discussed are models only and that the final instrument complements will be chosen by the usual competitive procedures within the Scientific Committees. Presentations are to be made to the scientific community at the end of January 1983 and the first steps in the selection process will commence the following month.

Scientific objectives

The global Sun

Remotely-sensed information about the interior of the Sun can mainly be obtained by detecting solar neutrinos or observing oscillations of the solar surface and variations in the radiation output.

It has been shown that with sufficiently refined measurements of amplitudes and frequencies of the solar oscillation p-modes (acoustic) and g-modes (gravitational) one can set narrow limits to a unique density model of the Sun's interior and quantify the gravitational quadrupole moment J_2. This in turn will allow gravitational theories to be tested in relation to the precession of planetary orbits. So far, solar oscillations have been observed from the ground mainly by measuring velocity oscillations (Doppler effect), and fluctuations in the diameter and radial limb-darkening functions. Current studies show that it is possible to measure low-degree p-mode and g-mode amplitudes and frequencies that are dependent on the solar interior density stratification and on the radial distribution of the solar rotation rate.

Measurements from ground observatories are limited mainly by two factors: the noise introduced by transparency and refraction fluctuations in the Earth's atmosphere, and the limitations imposed on frequency-spectra observations by the Earth's rotation, i.e. by the day/night interruptions. Continuous measurements from Disco's orbit will avoid both problems.

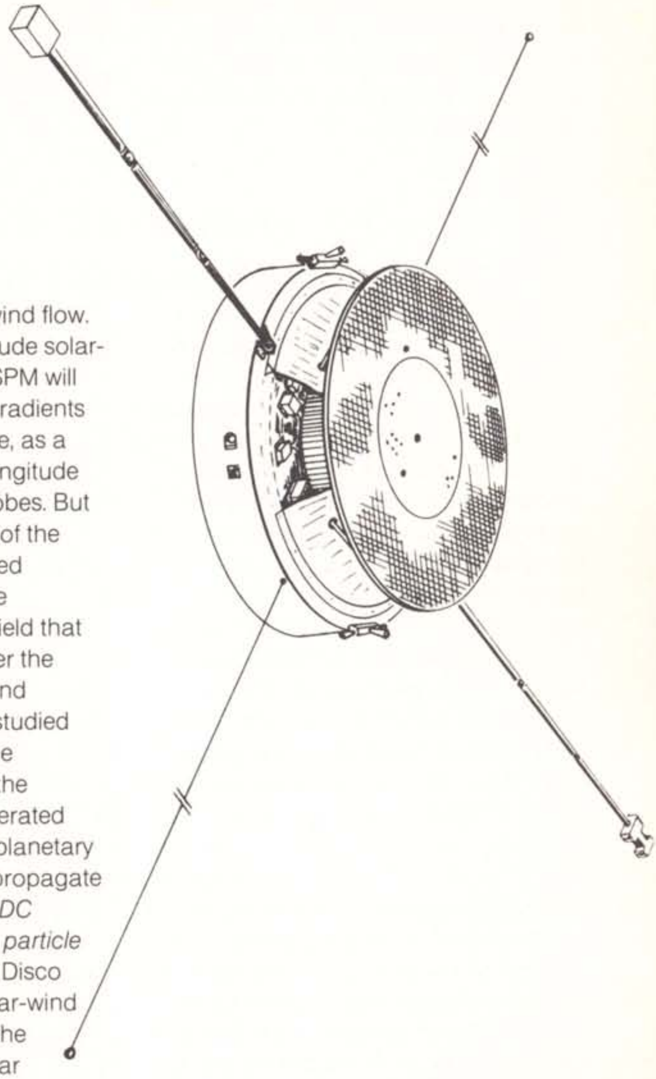
To perform the solar-oscillation measurements, a *high-resolution spectrometer*, based on a sodium-vapour optical resonance cell to obtain fine Doppler-shift measurements, forms part of the model payload. It will determine velocity oscillation amplitudes with a precision of about 1 mm/s.

The dynamical oscillations measured in velocity are also detected in integrated light. The amplitude and relative phases of velocity and white-light oscillations depend on the reaction of the upper layers of the convection zone to oscillations with periods comparable with the eddy turnover time. A knowledge of this reaction is important for understanding not only the dynamics of the solar convection zone but also the driving and damping of certain classes of intrinsically variable stars, such as the cooler Cepheids and the RR Lyrae variables. Solar-luminosity fluctuations/oscillations could be measured by a *Sun photometer* operating at several different wavelengths.

Besides blocking of the radiation by sunspots, changes in the efficacy of convection brought about by magnetic buoyancy, and variations in the depth of the convection zone are among the phenomena that may induce changes in the balance between thermal, gravitational and other forms of energy, and hence may be observed in the form of variations in the solar luminosity induced by solar activity and the solar magnetic cycle.

The association between variations in the solar constant and sunspots already

Figure 1 — Disco spacecraft



demonstrated by the Solar Maximum Mission and the indication of a change in the solar constant over a two-year time span reinforce the interest in a search for the solar-constant variation with the solar cycle that has often been predicted. It is proposed to monitor medium-term (hours to years) variations in solar irradiance with two independent *absolute radiometers* that cross-check each other and provide a baseline for earlier and future measurements of solar constant.

The solar corona and structure of the solar wind

Solar-wind fields and particle measurements made near the Earth and in deep space in or near the ecliptic plane during the last two solar cycles have provided some insight into the solar-wind structure around the solar equatorial region and into its relation to the coronal holes and other coronal activity. However, the interpretation of the observed phenomena is limited by the narrow latitudinal band of in-situ observations of the solar wind. The presence of ISPM at high latitude offers the first opportunity for a three-dimensional study of the solar wind and its origin.

A far-ultraviolet spectro-heliograph of modest spatial resolution ($\sim$15 arcsec), operating in the wavelength range 10–150 nm, is proposed in the model payload to delineate the structure of coronal holes, major loop systems, and the distribution of hot, dense active regions. Spectro-heliograms in this wavelength range have not been obtained before, and we can expect important and decisive results, particularly if the density and temperature profiles obtained near the solar limb can be correlated with in-situ plasma observations from ISPM at high heliocentric latitudes, and from Disco in the ecliptic plane.

Measurements of solar-wind bulk flow parameters – density, velocity and temperature – using a *plasma analyser* (both ions and electrons) will provide the in-ecliptic conditions for solar-wind flow. Comparisons with the high-latitude solar-wind measurements made by ISPM will provide indications of latitude gradients and also of large-scale structure, as a function of solar latitude and longitude differences between the two probes. But the large-scale structural study of the solar wind can only be performed properly if complemented by the measurement of the magnetic field that appears 'frozen into it'. Moreover the dynamics of the solar corona and interplanetary medium can be studied particularly well by observing the propagation characteristics of the energetic particles that are generated both at the corona and in interplanetary space, by plasma shocks that propagate through the solar wind. Both a *DC magnetometer* and *low-energy particle telescopes* are proposed in the Disco payload to complement the solar-wind measurements and to provide the necessary baseline for the similar ISPM measurements.

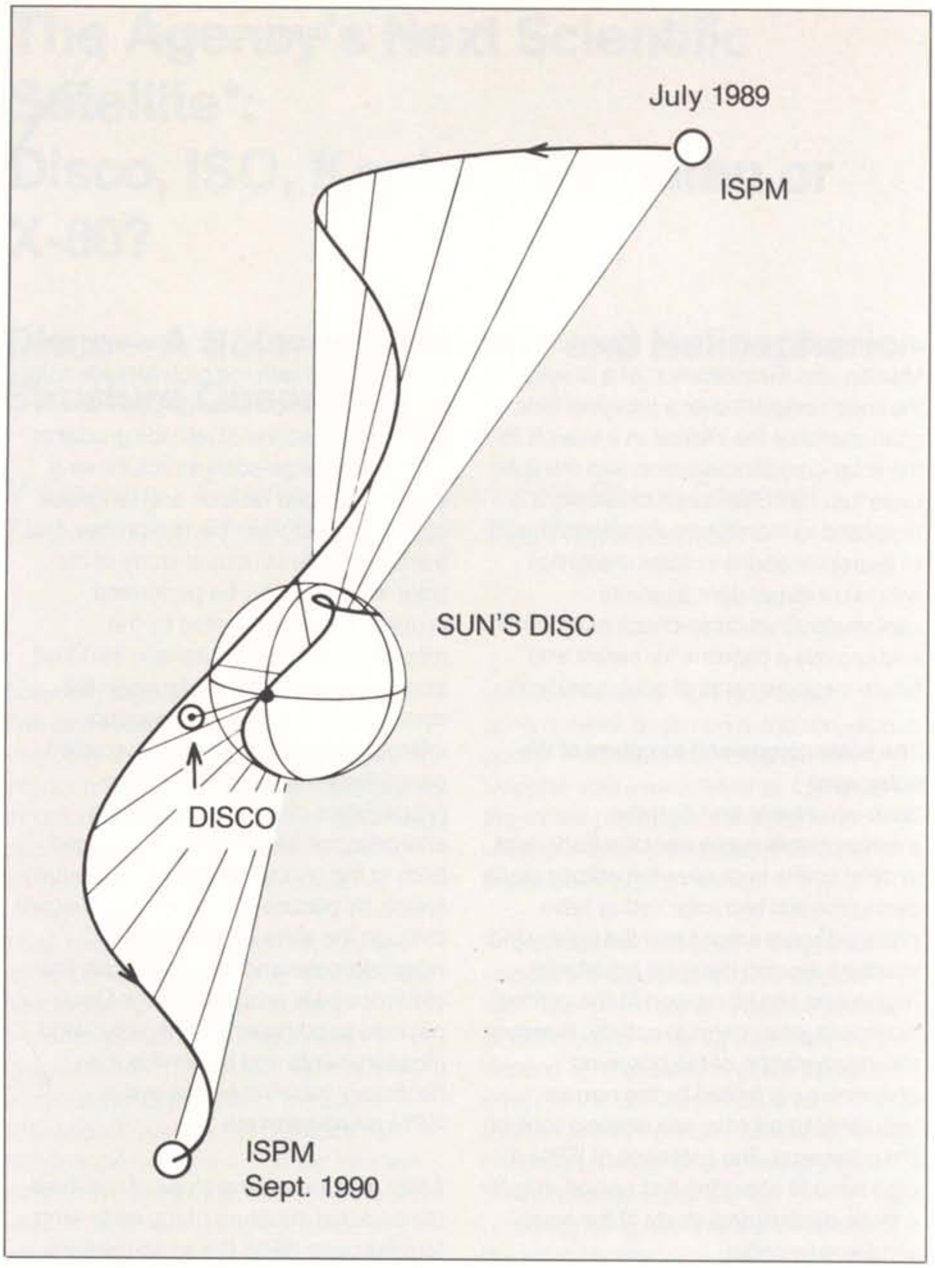
Aside from permitting study of the three-dimensional structure of the solar wind together with ISPM, the spacecraft will allow solar-wind plasma fields and particle phenomena to be examined in detail. Disco, with its spin axis pointing to the Sun, will, for the first time, allow plasma measurements with a time resolution unlimited by satellite spin (Fig. 1).

Unique insight into the large-scale topology of the heliospheric magnetic field can be gained by observing the radio emission associated with fast electron streams emitted from the Sun. As the electrons' guiding centre motion takes them along the interplanetary magnetic field line, they excite oscillations at the local plasma frequency. The resulting radio emission – type-III bursts – can be followed by spacecraft *radio receivers.* Triangulation from two spacecraft, in this case ISPM and Disco, can resolve the source of the emission in three dimensions and thus trace specific magnetic field lines from the Sun to 1 AU and beyond. Such observations constitute a valuable calibration, at specific times, of the three-dimensional heliospheric field model as deduced from the continuous observation of the in-situ magnetic field.

Table 1 — Model payload

Helio-seismology	High-resolution spectrometer Sun photometer (spectral) Two absolute radiometers
Solar corona	Far UV spectro-heliograph X-ray detector
Solar wind	Radio-wave analyser Magnetometer Ion/electron analysers Low-energy particle telescopes
Outer heliosphere	Medium- and high-energy cosmic-ray detectors
Galactic	Gamma-ray burst detector

Figure 2 — Projections of ISPM's trajectory and Disco's location on the Sun's disc, during the period when ISPM crosses over the solar poles (assuming an initial northern trajectory)

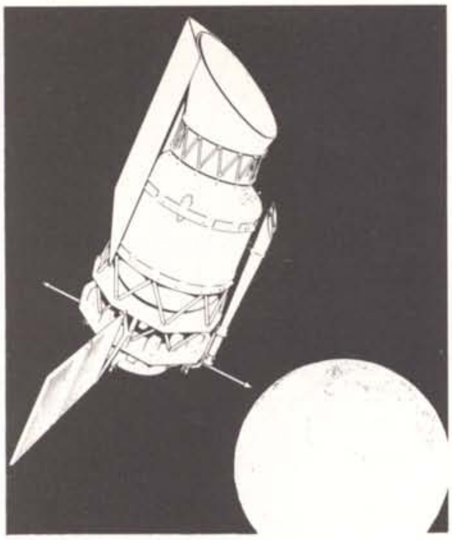


The outer heliosphere
The modulation of galactic cosmic rays and the anomalous component of medium-energy cosmic rays are the main sources of information about the dimensions, structure and size of the heliosphere. The measurements to be made of cosmic-ray particles at high heliographic latitudes by ISPM can only be fully interpreted if simultaneous measurements are made in the ecliptic at 1 AU, thereby allowing comparison with the modulation measurements made at the Earth over about two decades. For that reason *medium-* and *high-energy particle telescopes* are included in the model payload.

Other investigations
There is a *solar X-ray and cosmic gamma-ray burst experiment* included in the ISPM payload, specifically designed for simultaneous measurements by two spacecraft at the time when there were still two spacecraft foreseen for that mission. The scientific value of its measurements would be largely restored if the same experiment were to be included in the Disco payload. Its aims, in solar terms, are the determination of the anisotropy of solar X-rays and the height of their generation in the solar corona during flares, and, in astrophysical terms, the location of γ-ray burst locations with an angular resolution of better than 1 arcmin.

A recently held workshop on 'Global Sun and the Heliosphere' has shown that the orbit and attitude of Disco will provide a very good base not only for the experiments proposed in the model payload, but also for a number of other studies that will have to be considered for the final payload at the time of experiment selection, such as the white-light corona and the Lyman-α corona (coronographs), the mean solar magnetic field (measurement of the longitudinal Zeeman effect), the interstellar gas in the interplanetary medium (Lyman-α observations), zodiacal light, etc.

The spacecraft
To accommodate the payload to meet the above scientific objectives, a spacecraft is proposed that will orbit around the Sun/Earth Lagrangian point (L1). It is designed for a nominal lifetime of two years, but has enough resources to last at least six years. The spacecraft will be spin-stabilised with its spin axis pointing to the centre of the Sun to within 0.5° at all times (Fig. 2). A telemetry rate of 3 kbit/s and a spacecraft mass of 500 kg are proposed. Special attention has been devoted to two aspects: firstly the radial (Sun – spacecraft) velocity is not to be subjected to abrupt changes greater than 1 mm/s, to ensure unperturbed collection of Doppler-shift measurement of the solar surface velocities; secondly, uninterrupted data collection is to be maintained during most of the nominal lifetime. Adequate on-board memory and special precautions in ground-station operations are therefore envisaged, to obtain time-sequential data that can be frequency-analysed without the complexities that would be introduced by the existence of gaps in the data.



The Infrared Space Observatory (ISO) – A Study for a Cooled Telescope in Space for Infrared Astronomy*

R. Emery, Astronomy Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

This is an ESA study for an infrared observatory satellite, consisting of a cooled 60 cm diameter telescope with a range of photometric and spectroscopic instruments for making measurements at wavelengths from 2 μm out to beyond 100 μm. ISO is a three-axis-stabilised free-flyer, designed for an Ariane launch, and to have an operational lifetime of at least 1.5 years.

ISO resulted from a proposal submitted to ESA in 1979. The assessment study was presented one year later and, after further study of cryogenic systems appropriate for long-term flight, the industrial Phase-A study was started in September 1981. This work was guided by the results of the earlier cryogenic studies, which recommended the use of a dual cryogen system involving liquid hydrogen and superfluid helium. The instruments to be mounted at the focal plane of ISO will be selected from proposals submitted by the scientific community following an Announcement of Opportunity. For the purposes of the Phase-A study, a model instrument payload has been developed and studied with the support of a consultant group to derive typical requirements and operating characteristics for instruments appropriate for an observatory mission.

Basic considerations

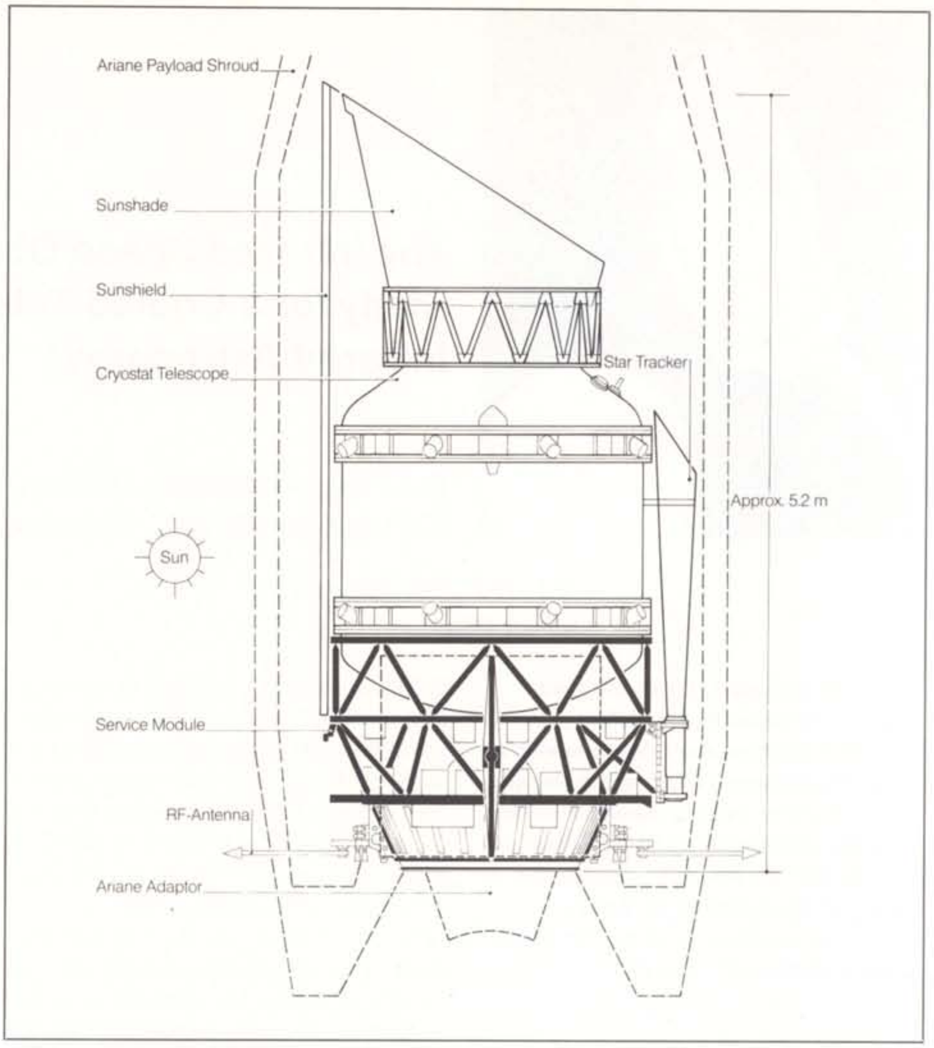
The Earth's atmosphere is opaque for most of the infrared/submillimetre spectral range. This causes a problem not only by attenuating the weak infrared radiation received from astronomical sources, but also by swamping it with thermal emission from the warm atmosphere. Thermal emission from the optics is also a contributing problem. The recent important developments in infrared astronomy have taken place in the face of these difficulties, often using specially designed telescopes at mountain sites, at those wavelengths where the atmosphere has reasonable transparency. These measurements, however, are severely limited both in sensitivity and wavelength coverage by the atmosphere. Using smaller telescopes which have been designed for high-altitude observation from aircraft or balloons, the situation is improved but the sensitivity is still very restricted by the residual atmosphere and the thermal emission of the warm optics. It is only by operating in the space environment and cryogenically cooling the optics that these limitations are removed.

ISO is a cooled infrared telescope designed to match this situation, and so provide sensitivities closely approaching the much lower limits set by the naturally occurring astrophysical background. Analysis of the performance of ISO shows its sensitivity to be a factor 10^2 to 10^4 higher than that of a large ground-based telescope (4 m diameter) operating at atmospheric 'window' wavelengths, or a balloon-borne telescope (1 m diameter). The sensitivity advantage varies over this wide range depending on the measurement wavelength and bandwidth, the size of the astronomical source compared with the telescope field of view, and the efficiency of the instrument/detector system.

Looking at the broader picture of astronomical measurements at all wavelengths from (γ-ray, X-ray, UV and optical, through the infrared and out to radio), it is clear that this improvement is necessary to bring the sensitivity of infrared measurements into line with the rest. Otherwise there will be a significant weakness in the full astronomical picture of important objects gathered from data at all wavelengths, due to a lower

* See footnote on page 16

Figure 1 — The ISO spacecraft



sensitivity in this rather central region covering the infrared.

Objectives

The main objective for ISO is to provide an observatory facility for astronomy at infrared wavelengths with essentially real-time control and an operational lifetime of at least 1.5 years. Initially this has focussed on the wavelength range 2–120 μm, to be directly compatible with the recent development of high-sensitivity photoconductive detectors. The concept of an observatory style of operation for ISO is aimed at involving a wide sector of the astronomical community to take advantage of this enormous increase in sensitivity and obtain the best overall scientific return. The objective of achieving a lifetime of at least 1.5 years arises in part from the recognition of the substantial learning that will inevitably occur during the mission and the consequent need to gain proper advantage from it. In this, the IUE satellite operations serve as a good example.

The astronomical picture

Observations at infrared wavelengths and their interpretation have a very important contribution to make to almost all areas of astronomy. Up to now they have included studies of the atmospheres and surfaces of solar system objects, observations of a wide range of galactic objects and regions in various phases of evolution, studies of so-called 'normal' and 'active' galaxies, and cosmological investigations.

Interstellar dust and other materials at temperatures from a few Kelvin up to thousands of Kelvin radiate most of their energy at infrared wavelengths. Dust is very abundant in most galaxies, including our own, so that a very large portion of the total radiation exchange within the galaxy is in the infrared. Infrared measurements also provide an important probe into regions which are obscured to visible and UV radiation. In this context, star-formation regions are of particular interest. The heating phase arising from gravitational collapse of the parent material is being investigated, leading up to the onset of nuclear burning and the formation of an ionised region which may then be sufficiently free of obscuring material for it to be observable at visible wavelengths.

Apart from direct measurement of the 3K cosmic background, observation of earlier phases of the Universe implies detecting distant and highly redshifted galaxies. Here the normal optical spectra are shifted into the infrared. An important though speculative prospect is the possibility of extending this to the observation of protogalaxies.

The infrared spectral region encompasses most of the fundamental vibration-rotation and pure rotation transitions of molecules, including the most abundant molecule H_2. It is also richly endowed with fine structure transitions of neutral and ionised atoms, and recombination lines. All these allow infrared spectroscopic measurements to probe the elemental abundances and conditions in regions throughout our galaxy and also in neighbouring galaxies. Many of the transitions are also appropriate to studying the development of stars from formation through to the late stages with circumstellar shells of dust and gas or perhaps evolution into special objects such as planetary nebulae.

High-sensitivity infrared measurements are also appropriate for examining questions of missing mass, as speculated in the form of halos around spiral galaxies or as dwarf infrared galaxies.

The spacecraft and its operation

The spacecraft design is for an Ariane-2 launch, which allows a lift-off weight for ISO of 2022 kg for the selected orbit. The telescope diameter of 60 cm broadly establishes the size of the cryostat whose weight is consistent with this limit. The cryogenic studies have indicated the considerable advantages to be obtained by using a mixed cryogen system. In the present design, which uses liquid helium and liquid hydrogen, this gives a 1.5 year lifetime with good margins. Generally, the aim is to use established technology wherever possible. This guided the selection of liquid hydrogen in preference to solid hydrogen, for example.

The spacecraft consists of a payload module and a service module (Fig. 1). The payload is made up of the cryostat, which contains the telescope and focal-plane instruments, and the sunshade, which provides part of the optical baffling. Attached to the payload is the sunshield, which is part of the payload's external thermal-control system. The service module incorporates the attitude and orbit control system, the solar panels, power storage and distribution, the on-board data handling and the telecommand and telemetry system.

The telescope, focal-plane instrument assembly and support structure for the cryogen tanks form a rigid structure suspended within the cryostat by fibreglass straps. A series of vapour-cooled shields with multilayer insulation provide thermal isolation between the external vacuum vessel and the cold elements of the payload. The two toroidal-shaped cryogen tanks, one for the liquid hydrogen and the other for liquid helium, are fixed to the cold support structure. The telescope incoporates a cooled optical baffle system which provides part of the stray-light rejection. The sunshade, which is not actively cooled, is mounted at the end of the optical baffle and restricts the range of angles to the optical axis from which radiation may enter the telescope.

A 12 h elliptical orbit, with 2000 km perigee and 39 000 km apogee and a 5° inclination to the equatorial plane has been selected. This orbit allows essentially real-time operation when two ground stations are used, and makes efficient use of the launch capability of Ariane-2.

Starting with the spacecraft at perigee, normal operation of ISO can be maintained from hour 1 to hour 11. This enables long integration times to be used for the observation of very distant objects.

Table 1 — Model instrument payload

	Camera array (InSb 32 × 32 CID array)	Two spectrometers (rapid-scan Michelson interferometers)	Photometer (Si and Ge photo-detectors with bandpass filters)
Wavelength range	1–5 µm Possibly 6–12 µm with another array	2–70 µm covered by two interferometers 2–14 and 30–50 µm 10–31 and 47–70 µm	8–120 µm
Resolving power $\lambda/\Delta\lambda$	Set of narrow-band filters and continuously variable filter	10^2–10^5	3 or 4 bands in the range

When the spacecraft is within the Earth's radiation belts, the photoconductive detectors will register the particle impacts and at times saturate, so that normal operation within this zone is not anticipated.

A model instrument payload

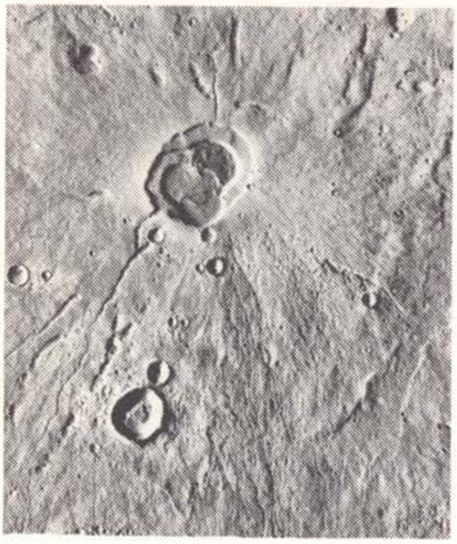
A range of instruments appropriate to ISO are being studied, which together make up a model instrument payload. This payload is used to define a realistic operating environment for the instruments in terms of electrical, thermal and mechanical requirements, and to explore possible performance capabilities. Table 1 provides a summary of the model and some of the characteristics.

The CID camera array provides for two-dimensional imaging and multiband photometry. In the 1–5 µm wavelength range, an InSb array can be used.

The Michelson interferometric spectrometers offer a combination of performance and flexibility for fulfilling the observatory nature of ISO. The instruments can be relatively compact and also give selectable resolving powers while exploiting the multiplex, throughput and wavelength-coverage advantages. The interferometers are of the rapid-scan type with a translation speed in the range 0.5–5 mm/s. Their output is split into two wavelength ranges in such a way that together they give continuous coverage from 2 µm to 70 µm.

The photometer system is an array of discrete detectors with individual field optics covering three or four wavelength bands in the range 8 µm–120 µm. Focal-plane chopping will be used to obtain absolute flux values, and a wire-grid polariser may also be an option for making linear-polarisation measurements.

The instruments will be mounted at the focal plane and operated in the 8 K temperature environment of the focal plane assembly. The 20 arcmin field of view of the telescope will be distributed to the instruments by a pyramid-shaped mirror system situated on the optical axis and involving no moving parts. At least a 3 arcmin unvignetted field of view is available to each instrument, and instrument selection is achieved by suitable pointing of the telescope. A quadrant star sensor is situated on a line through the apex of the pyramid mirror, on the telescope's optical axis, for calibrating the telescope pointing with respect to the external star-tracking system.



Kepler – A Mission to The Planet Mars*

R. Grard, Space Plasma Physics Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

A scientific spacecraft in orbit around a planet other than the Earth is a goal that ESA has been contemplating for a number of years. The technical problems associated with such an ambitious mission are currently being investigated by European industry. A proposal to take a closer look at Mars, with the aim of answering some of the countless questions relating to the planet and its environment, will be submitted to the selection committees of the Agency in early 1983. If this mission is approved, the Kepler spacecraft will be launched by Ariane in July 1988, to begin orbiting Mars in January 1989.

Mars has a diameter about half that of the Earth and its period of rotation is 24 h 37 min. It performs one complete revolution around the Sun in 687 days, on a path that has an average radius 50% greater than the orbit described by the Earth. The mission takes its name from the famous astronomer Johannes Kepler (1571–1630), who derived the fundamental laws of gravitation from his observations and thus explained the apparently capricious motion of Mars on the canopy of the heavens.

Several spacecraft have already been sent to Mars by NASA and by Interkosmos, with impressive results. More than 50 000 pictures have been taken and two landers have sampled the planet's surface. However, these programmes concentrated largely on imaging and the search for life, so many aspects remain totally unexplored. Few, if any, of the main scientific objectives of the Kepler mission can be resolved with the existing Martian data sets or with future telescope observations made from Earth orbit.

Scientific objectives

The interior and surface of Mars

Information about the internal structure of the planet can be derived from measurements of its gravity and magnetic fields as well as by determining its topographic features. These measurements must be made from as low an altitude as possible, typically 150 km, and should cover the planet's entire surface.

The spacecraft's orbit can be accurately determined by evaluating Doppler effects on the radio link with Earth. The orbit perturbations reflect the mass distribution within the planet and provide a clue to its evolution and dynamics. A gravity-field model can therefore be considered a byproduct of the tracking operations. It may be possible, for example, to characterise the planetary body's elastic response to the Sun's influence from the tidal fluctuations of its gravity field.

Study of the magnetic properties of Mars, which are presently little known, is given a very high priority. Positive identification of the field strength and alignment of an intrinsic magnetic moment will give important clues as to the possible existence of a fluid core. If such an effect is not measurable, the crust's paleomagnetism may well exhibit anomalies that are evidence for the earlier presence of a strong field.

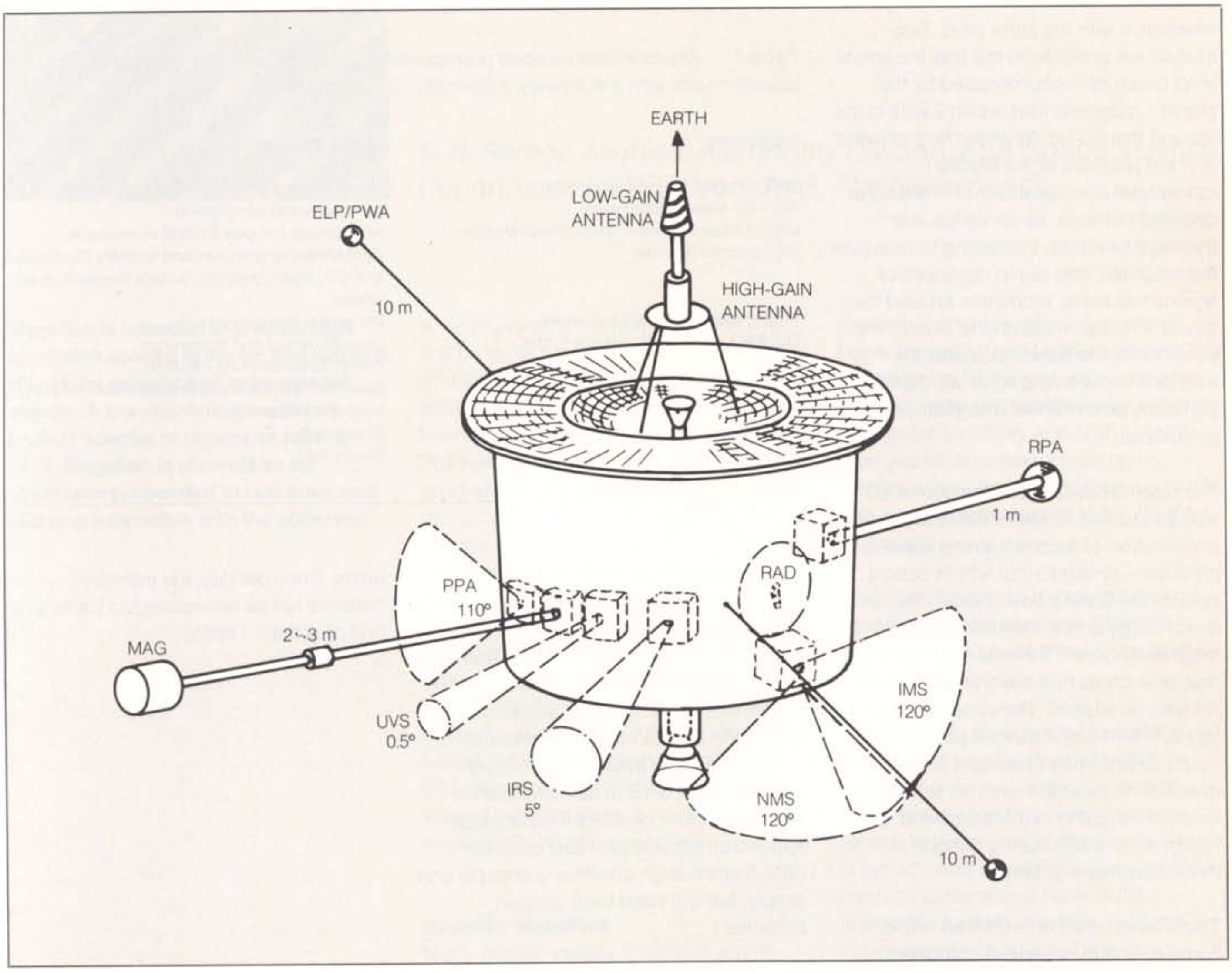
The Martian topography can be surveyed with a radar altimeter. Global mapping will complement the gravity measurement and allow problems related to hydrostatic equilibrium, solid-state convection and crustal thickness variations to be studied. Optical mapping in the infrared band will provide information on surface temperature, pressure and albedo as well as on the formation of dust clouds. These aspects can also be investigated by remote-sensing in the visible and near-ultraviolet spectral ranges.

The aeronomy of Mars

The gross properties of the lower Martian atmosphere are known from previous missions; it is mostly composed of CO_2

* See footnote on page 16

Figure 1 – Configuration of the Kepler orbiter, showing the locations and fields of view of the various instruments (identified in Table 1)



(95%) and the surface pressure is about 1% of that on Earth.

The Kepler orbiter will monitor the planet's global temperature field by remote sensing and contribute to our understanding of the atmospheric circulation; the role of diurnal and seasonal changes caused by the Sun and the occurrence of topographically-driven wave motions are prime study objectives. The daily and seasonal variations in the vertical profiles of several atmospheric constituents will be measured with ultraviolet and infrared spectrometers. Knowledge of the water-vapour distribution, in particular, is necessary for investigation of transport, loss and evaporation mechanisms. Mapping of the abundance of CO_2 is also required for the study of periodic fluctuations in atmospheric pressure; CO_2 condensation and sublimation at the poles are responsible for seasonal variations in atmospheric pressure, which exceed 25% of the median value at mid-latitudes. The evolution of major dust storms will be followed with infrared emission measurements, and possible associated lightning occurrences will be detected with electromagnetic wave sensors.

The composition and temperature of the upper atmosphere and ionosphere of Mars will be analysed in-situ by neutral and ion mass-spectrometers. In addition, the electron and ion temperatures will be measured with retarding potential analysers and Langmuir probes. This combination of instruments will permit quantitative evaluation of the photochemistry, energetics, and dynamics of the atmosphere and ionosphere.

The interaction between the solar wind and Mars

A major objective of the Kepler mission is to determine the nature of the planet's interaction with the solar wind. Two models are possible; in the first, the solar-wind pressure is counteracted by the planet's magnetic field, as on Earth; in the second there is no magnetic field present and the pressure of the Martian ionosphere counteracts that of the solar charged particles, as on Venus. It is therefore extremely interesting to measure the magnetic field out to distances of several thousand kilometres around the planet. It is also important to identify the positions of the bow shock and the interface between the solar wind and the planetary environment (magnetopause or ionopause).

The plasma flow around the planet will also be studied, together with the possible acceleration of backstreaming solar-wind particles – similar to that which occurs outside the Earth's bow shock. The morphology and the dynamics of the magnetosphere, if it exists, or of the mantle such as that observed on Venus, will also be studied. The observation of tiny substorms and auroral phenomena could be extremely important. It is also desirable to establish whether ionospheric ions are escaping in the solar wind, as happens on Earth during periods of magnetospheric activity.

These aims could be achieved with a combination of wave and charged-particle instruments, including a magnetometer, wave detectors, plasma analysers, Langmuir probes and an ion mass-spectrometer.

Table 1 — Kepler model payload (composition purely illustrative). Final experiment selection rests with the Agency's Scientific Committees

Experiment	Measured parameters
NMS – Neutral Mass-Spectrometer	Upper atmosphere density and composition
IMS – Ion Mass-Spectrometer	Ion density and composition
UVS – Ultraviolet/Visible Spectrometer Mapper	Atmospheric composition and temperature.
IRS – Infrared Sounder	Atmospheric temperature and humidity. Dust opacity and CO_2 partial pressure. Surface temperature and albedo
RPA – Retarding Potential Analyser	Ion density and temperature
ELP/PWA – Electron Langmuir Probe	Electron density and temperature
Plasma Wave Analyser	Energy spectrum (1 Hz – 80 kHz)
PPA – Plasma Particle Analyser	Solar-wind electrons and protons (10 eV – 40 keV)
MAG – Magnetometer	Magnetic-field vector
RAD – Radar Altimeter	Topography
Doppler Ranging	Gravity field

The spacecraft and its operation

The Kepler spacecraft would be launched on an Ariane-3 vehicle in July 1988, to arrive at Mars in January 1989. It would then be inserted into an eccentric polar orbit with pericentre and apocentre altitudes of the order of 150 and 3700 km, respectively. The orbital period would be 4.8 h (1/5 Earth day). The nominal duration of the mission would be one Martian year, i.e. 687 Earth days.

The spacecraft will weigh more than 800 kg at launch, half of this mass representing the propellant to be burnt during orbit insertion. In its present configuration, it has a cylindrical body with a diameter of 2.8 m and an overall height of 3.3 m. The nominal spin rate is 5 rpm and the spin axis will constantly point to Earth, to ensure that the high-gain antenna, a 1.5 m diameter dish, is always properly oriented. This unusual spacecraft attitude provides optimum data-transmission conditions cheaply and simply, without need for a despun antenna.

The solar array is designed to deliver 150 W, and its configuration is unusual in that it is disc-shaped and surrounds the high-gain antenna.

A number of booms allow the sensors of several of the scientific instruments to be sited 1–3 m from the spacecraft's surface. Ten-metre cables serve as antennas for wave measurements.

The scientific payload weighs approximately 46 kg and has a peak power requirement of 59 W (Table 1).

The data will be acquired at variable bit rates and stored in the on-board 16 Mbit bubble memory during one in every five orbits. Once per day, the memory's contents will be telemetered to Earth, at a rate of at least 1 kbit/s.

Magellan – A Far- and Extreme-Ultraviolet Spectrographic Observatory*

S. di Serego Alighieri, Astronomy Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

Magellan is intended to provide high-resolution spectra in the far and extreme UV of faint galactic and extragalactic objects. A low-resolution mode will provide spectra of objects as faint as $18^{m}.5$. Magellan is planned as an observatory, operated in real time, and allowing interaction with the observer.

An instrument of the Magellan type was first proposed to NASA in 1978 by French and American groups under the name of MISIG (Milieu InterStellaire et InterGalactique) to fly on Spacelab. Following the delays in the Space Shuttle programme, the laboratory studies of the instrumentation were continued and a proposal for the Magellan project was presented to ESA in July 1980 by A. Vidal-Madjar of the Laboratoire de Physique Stellaire et Planetaire, representing a wide international community of scientists and institutes working in the field of ultraviolet astronomy. An assessment study on the mission was carried out during the first half of 1981 by European scientists and ESA engineers and a Phase-A study to establish the feasibility and cost of the mission is currently in progress.

Scientific objectives

Many astrophysically important atoms and ions have the majority of their resonance lines in the far and extreme ultraviolet. Nevertheless the ultraviolet region below 1100 Å has been only explored in a preliminary way so far, by a few rocket experiments and by a limited number of observations made by Copernicus on very bright objects and by Voyager at low spectral resolution. These observations have demonstrated, among other things, that the hydrogen density around the Sun is much lower than was previously thought.

The limitation of current ultraviolet missions to wavelengths longer than 1100 Å has been dictated by the lack of transparent optical material and of highly efficient and stable reflective coatings below this limit. The Magellan observatory is planned to fill this gap with a far and extreme ultraviolet spectrometer achieving both good sensitivity and high spectral resolution in a compact instrument, therefore being a natural follow-up to IUE and a useful complement to the Space Telescope.

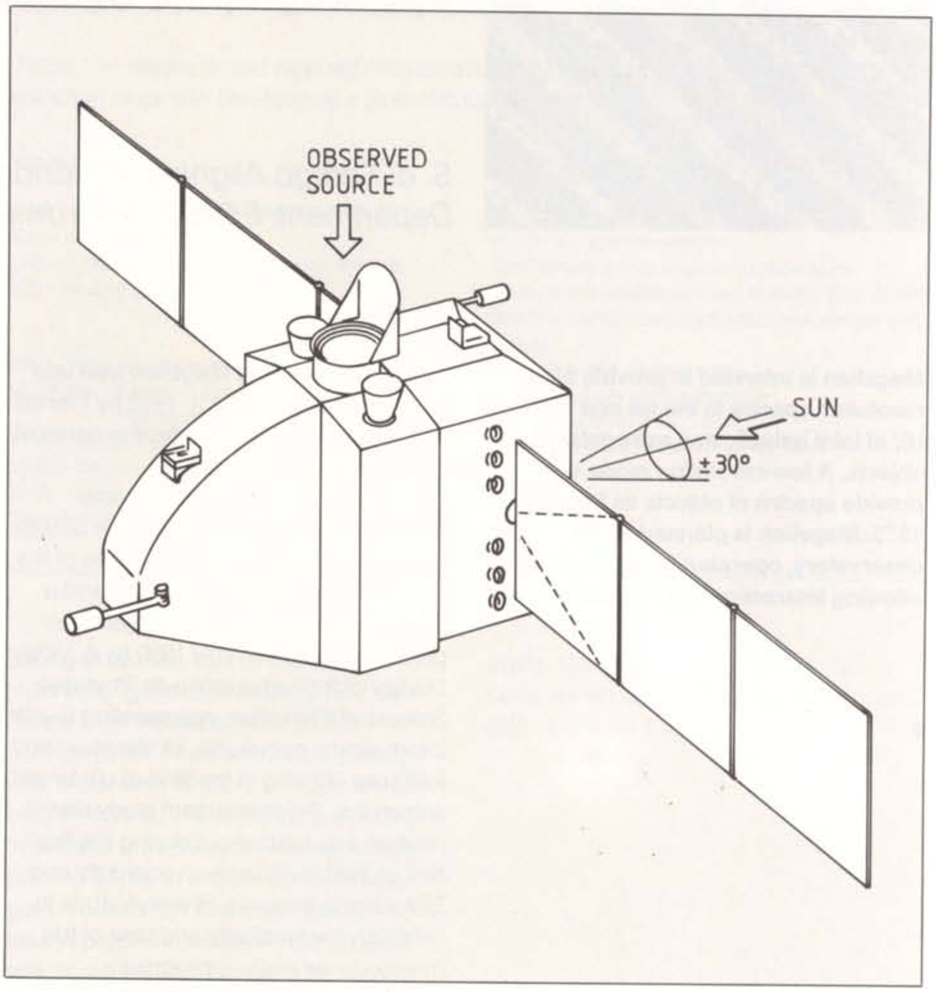
Magellan is planned to operate as an observatory, with real-time observer interaction, and is intended to be used by astronomers like IUE.

Magellan can be expected to make a significant and often fundamental contribution to our understanding of many of the objects and mechanisms related to the evolution of galaxies. Matter is cycled continuously from the interstellar medium to stars, and back to the interstellar medium via mass loss and explosions, while a part of it ends up locked inside stellar matter. Magellan will observe the dynamical, physical and chemical state of this matter during most of its phases: inside the hot, warm and cold phases of the interstellar medium, in the atmospheres of stars, in stellar winds and ejecta, and even at the surface of stellar remnants, such as nuclei of planetary nebulae, white dwarfs and, possibly, neutron stars.

Cosmology can also be tackled through the study of the abundance of deuterium in unevolved galaxies, where the matter practically retains the primordial composition. The haloes of other galaxies and the intergalactic medium are also within reach of Magellan, through their

* See footnote on page 16

Figure 1 — The Magellan spacecraft



absorption lines superimposed on the spectrum of background objects.

Observation of the extreme ultraviolet spectrum of extragalactic objects, such as Seyfert galaxies, galactic nuclei and quasars, will provide important information on the physical conditions in these objects and their immediate surroundings.

With its high sensitivity, spectral and spatial resolutions and wide field of view, Magellan is of undoubted interest for studies in the solar system such as the determination of the composition and behaviour of the upper atmospheres of all the outer planets, the solution of specific problems related to the correlated dynamics of the atmosphere/magnetosphere systems of Jupiter and Saturn, the investigation of atmospheres and plasma tori around all giant planets, and the study of comets.

The spacecraft and its operation

An efficient spectrograph for the far and extreme ultraviolet requires a design which either uses all grazing incidence optics or minimises the number of reflecting surfaces at normal incidence. The Magellan instrument concept exploits this latter alternative using an objective holographic grating as the single reflecting surface. Mounted in an improved Wadsworth configuration, the grating collects the star light, diffracts it and focusses the spectrum on the detector. The slitless configuration provides the spectra of all the sources – point-like and extended – in the field of view of the grating. This field of view is limited to a fraction of a square degree by a mechanical collimator consisting of a number of coaligned grid plates, to reduce the diffuse background, the stray light and the probability of overlapping spectra in crowded fields.

A ray-tracing study has demonstrated that for the best optical quality the detector must be kept on the grating axis. The first-order spectrum will be spread over an arc too long to be recorded simultaneously by a single detector. The grating and detector are therefore rotated together to select the desired wavelength range. This solution allows for very tight and efficient baffling around the detector to reduce the internal stray light.

A windowless detector must be used in the Magellan wavelength range and, in order to exploit fully the information available on the focal plane, a bidimensional photon-counting detector is used.

The low resolution mode has been introduced as a complement to the main high resolution mode to allow observation of very faint galactic and extragalactic sources with a larger instantaneous spectral coverage. This is achieved by shaping and ruling the back surface of the grating blank, to act as a second grating.

Magellan will be operated as an observatory from a ground control station allowing real time interaction with the observer, in a similar manner to IUE and Exosat. Since the detector is operated in photon-counting mode, the real-time interaction will be improved over the IUE concept, because the observer will be able to monitor the observation while the data are integrating during an exposure. This facility will certainly improve the efficiency of the observations, as has been already demonstrated by ground-based systems.

The main features of the Magellan spacecraft are listed in Table 1 (see also Fig. 1). Magellan is designed to fit into the lower – and smaller – Sylda envelope of the Ariane dual-launch system, making a shared launch with a communications satellite feasible.

Conclusion

The extreme ultraviolet range of the electromagnetic spectrum contains the majority of the resonance lines of the most abundant atoms, ions and molecules, and is of fundamental importance in the study of a variety of astrophysical objects, from the interstellar matter in the disk and halo of our and other galaxies, to stellar envelopes, hot and evolved stars, clusters, intergalactic matter, nuclei of galaxies, quasars, and, finally, planets and satellites.

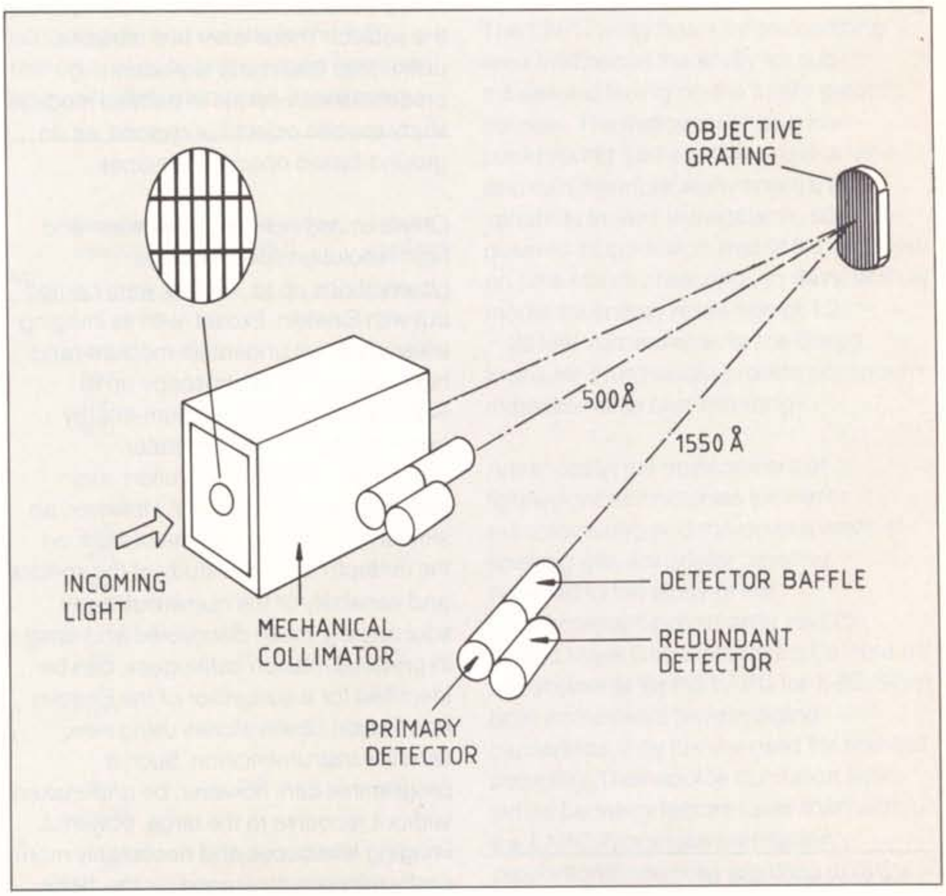
Nevertheless the wavelength region below 1100 Å is still basically unexplored and current ultraviolet missions are limited to longer wavelengths by the technical choices that had to be made to accomplish their particular objectives.

Magellan is meant to fill this gap with an extreme ultraviolet spectrometer (wavelengths between 50 and 140 nm) achieving both good sensitivity and high spectral resolution in a compact instrument.

Table 1 — Magellan spacecraft characteristics

Launcher	Ariane, dual launch
Orbit period	48 h
Perigee altitude	1000 km
Apogee altitude	120 000 km
Minimum operating altitude	40 000 km
Ground-station coverage (from Villafranca and Carnavon)	70% (above 40 000 km)
Pointing accuracy (2σ)	1 arcmin
Pointing stability (2σ)	5 arcsec (over 20 min)
	0.5 arcsec (over 1 s)
Absolute pointing measurement (2σ)	1.5 arcsec at 1 Hz
Mass: Payload	192 kg
Service module	430 kg
Fuel	124 kg
Margin	91 kg
Total	837 kg
Lifetime	2 years
Possible launch date	1988

Figure 2 — Magellan instrument concept



X-80 – A Spectroscopy, Transient and Timing Mission for X-Ray Astrophysics*

B G Taylor, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

X-80, a mission to perform in-depth studies of the spectral features and temporal behaviour of cosmic X-ray sources, ranging from nearby active stars to the cosmologically distant quasars, is a candidate for selection as one of the next satellites in the ESA scientific programme. It is seen as the logical successor to Exosat, to probe the mysteries of sources and situations in the Universe which involve colossal concentrations of energy or where massive energy releases are taking place.

Uhuru (US), Ariel V (UK), SAS-3 (US) and HEAO-1 (US), missions executed in the 1970s to search for and give the first glimmers of understanding of cosmic X-ray sources, established X-ray astronomy as one of the exciting and productive branches of astrophysics. Outstanding results have been obtained in the more recent past at longer wavelengths with the telescope of the Einstein Observatory (US), while the ESA mission Exosat, to be launched at the end of this year, can be expected to make fundamental contributions to the scope of the subject. These latter two missions, unlike their essentially sky-scanning predecessors, operate in pointed mode to study specific objects or regions, as do ground-based optical telescopes.

Only a limited number of medium- and high-resolution spectroscopic observations up to ~4 keV were carried out with Einstein. Exosat, with its imaging telescopes, will undertake medium- and high-resolution spectroscopy up to ~2 keV, and with its medium-energy experiment and gas-scintillator experiment, medium-resolution spectroscopy up to 35 keV. However, an almost limitless programme of work on the in-depth, sensitive study of the spectra and variability of the numerous X-ray sources, e.g. those discovered and listed in previous mission catalogues, can be identified for a successor of the Einstein and Exosat observatories using new, sensitive instrumentation. Such a programme can, however, be undertaken without recourse to the large, powerful, imaging telescopes and necessarily more costly missions envisaged for the 1990s.

Scientific objectives

X-rays are generated in high-temperature ($T > 10^6$ K) plasmas or by the interactions of highly energetic charged particles with magnetic fields or photons. They are, in general, associated with sources and situations in the Universe which involve large concentrations of energy or where large energy releases are taking place. X-rays have been detected from within the Galaxy from nearby active stars and stellar coronae (the Sun emits a flux of X-rays during solar flares), from supernova remnants, the mantle of gas expanding from the explosion of a star nearing the end point of its evolution and from double or binary star systems containing a collapsed object in the form of a white dwarf, a neutron star or perhaps a black hole. X-rays have been detected from extragalactic sources from the members of the local group, from the more distant clusters of galaxies, and from active galactic nuclei and quasars that may contain super-massive black holes. With instrumentation of a given sensitivity level, these observations of course imply that nearby sources are the least powerful and the far sources the most powerful.

High-resolution spectroscopy in the energy range 0.5 – 10 keV permits the study of the physics of energetic coronal and photo-ionised plasmas which are known to be present in many X-ray sources both inside and outside our Galaxy. Measurements of emission-line intensities in these plasmas will allow estimates of gas temperature, density and ionisation state, elemental abundance and gas velocity to be made for objects

* See footnote on page 16

such as supernova remnants, binary sources and clusters of galaxies.

Variability on all measured time scales (milliseconds to years) is an almost universal characteristic of both galactic and extragalactic sources, and its study is a valuable tool for the investigation of their nature and emission processes. It ranges from the submillisecond quasi-periodic bursts exemplified by Cygnus X-1 (the prime black-hole candidate) to the single outbursts of bright galactic transient sources occupying many months, and possibly never recurring. In between there is a wide variety of behaviours, periodic and aperiodic at all time scales, and intensities reflecting the behaviour of pulsars, rotating neutron stars, orbital motions in binary systems and recurrent or one-off cataclysmic events in transients and bursters.

Spectral features above some 15 keV have been discovered in a number of sources, such as Her X-1. If the Her X-1 features are interpreted as cyclotron emission, they may provide a powerful tool for the study of the magnetic fields of neutron stars. Many of the X-ray sources associated with active galaxies exhibit very hard spectra which suggests that much of the X-ray luminosity may be found in the energy range above 15 keV.

The scientific aims of high-resolution spectroscopy and the study of transient and timing behaviour require a combination of narrow field-of-view (FOV) instruments and wide-field instruments. The former allow the detailed study of spectral and temporal behaviours of selected, known sources, while the latter enable long-term monitoring of galactic and extragalactic sources, as well as the positioning and temporal and spectral study of high-latitude transients and bursters.

As in all branches of observational astronomy, furtherance of understanding normally comes with the development and implementation of new concepts and technologies, and central to the X-80 mission and its scientific return has been the careful definition of an appropriate model payload and variants. Model payload elements (Table 1) include Bragg Crystal Spectrometers (BCS), and a Phoswich detector, together with either a Large-Area Proportional Counter (LAPC) or a Concentrator/Spectrometer (C/S) and a Coded Mask Gas Scintillation Camera (CMGSC) as the narrow field instruments, and four wide field-of-view Dicke or Transform Cameras (WFC). A small Gamma-Ray Burst Monitor (GBM) is also included.

The Bragg spectrometer offers good spectral resolution in four narrow energy bands centred on the strongest X-ray lines emitted by highly ionised atoms of the most abundant species (oxygen, silicon, sulphur and iron), over a wide range of plasma temperatures from $\sim 10^6$ K to above 10^8 K. Spatially resolved spectral maps of extended sources can be produced with a resolution of a few minutes of arc.

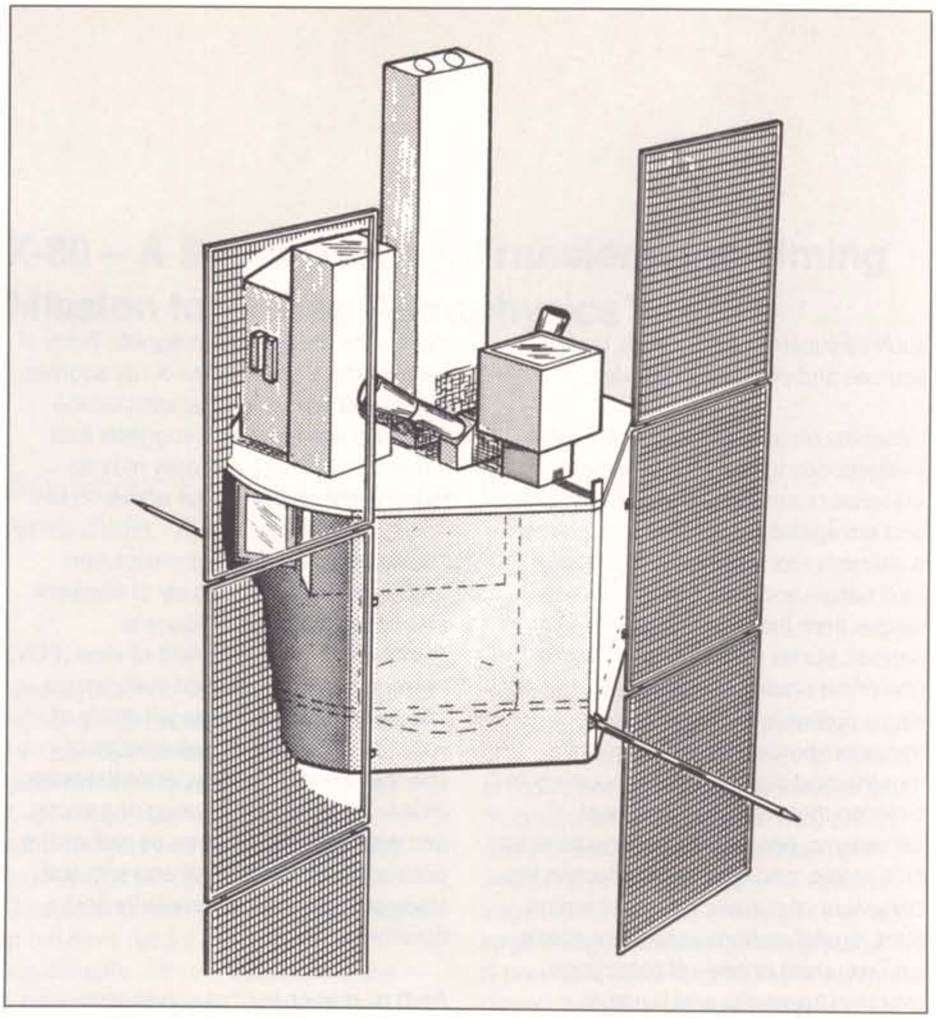
The LAPC array has a large collecting area and hence the ability for sub-millisecond timing on the bright galactic sources. The instrument has a low background and a narrow field-of-view, and can therefore study spectra and variability in faint extragalactic sources down to its confusion limit of 0.3 milli-Crab on time scales of seconds to days. With its moderate energy resolution of 1.2 – 20 keV, it complements the Bragg instrument and would provide continuum measurements over this range.

Advances in the development of lightweight technologies for mirror manufacturing and the development of imaging gas-scintillator cameras have led to the study of the Concentrator/Spectrometer and the Coded Mask Gas-Scintillation Camera as replacements for the LAPC for X-80. Since both instruments have imaging capabilities, they can be used for spectral mapping. Their source confusion limits would be many factors lower than with the LAPC. Since gas-scintillation proportional counters are used in both

Table 1 – X-80 payload characteristics

Instrument	Energy/ (wavelength) range	Energy/ (wavelength) resolution FWHM	Sensitive area (cm^2)	Field of view (FWRZ)	Angular resolution
BCS					
LiF (200)	Fe, 1.7 – 2.0 Å	2.3 mÅ	1440		
PET 1	S, 4.8 – 5.5 Å	4.0 mÅ	930	6°	~1′ – 5′
PET 2	Si, 6.1 – 6.8 Å	6.1 mÅ	695		
T1AP	O, 18 – 22 Å	92 mÅ	1470		
LAPC	1.2 – 20 keV	19% at 6 keV	2500	1.5°	–
C/S	0.2 – 10 keV	7% at Fe	45		
		9% at S	400	30′	~2′
		12% at Si	550		
		20% at O	700		
CMGSC	2 – 30 keV	9% at 6 keV	700	3°	~2′
Phoswich	15 – 200 keV	30% at 20 keV 12% at 200 keV	650	4°	–
WFC (4)	2 – 20 (imaging) 2 – 50 (timing)	20% at 6 keV	320 (each)	34°	~2′
GBM	30 – 130 keV	–	50	120°	~10′

Figure 1 – The X-80 spacecraft



instruments, the spectral resolution obtainable would be a factor of two to three better than with the LAPC. Though of lower area, the C/S, sensitive to lower energies, retains a millisecond timing capability.

The WFCs will be able to image the X-ray sky with an accuracy of a few arc minutes from 2 to 20 keV in order to detect, locate and measure X-ray transient events. They will provide a very efficient means of monitoring, on a regular basis, all bright X-ray sources on time scales of days to years. Coordinated observations between X-80 and ground observatories, and indeed the Space Telescope, should prove particularly fruitful. The WFCs can provide an alert to ground or other space facilities for transient-type phenomena.

The Phoswich will extend the range of the spectral and timing studies, while the GBM, with its wide field of view, is intended to be capable of locating, to a precision of about 10 arc min, 25 or so high-luminosity gamma-ray bursts expected per year.

The spacecraft and mission parameters
The mission can be readily undertaken on a free-flying satellite with modest performance requirements on three-axis attitude control (~5 arc min), attitude measurement (~1 arc min), average data rate (~40 kbit/s), power (~900 W) and mass (~1 t). The spacecraft concept as proposed by Dornier (Phase-A study contractor) and shown in Figure 1 would be the upper passenger in a dual Ariane launch and would be placed in a 600 km circular equatorial orbit, the best that can be envisaged from the background point of view, and operated for a minimum of three years.

Generally speaking, targets will be examined by the narrow-field instruments for $10^4 - 10^5$ s. On the other hand, the minimum observation time will be of the order 10^3 s, since the spacecraft will not adopt more than one pointing attitude per orbit. A complete sky survey of the sensitivity of the Uhuru mission will require some three days with the WFCs.

It should be borne in mind that simultaneous observations are possible, on different fields, with the narrow- and wide-field instruments.

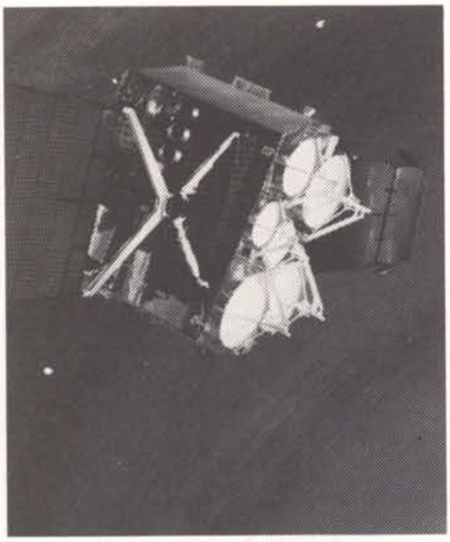
Data accumulated over an orbital period would be acquired from the satellite at the end of the orbit using a single ground station. The data would then be routed to ESOC and from there to the principal investigator institutes for quick-look verification. For the low-data-rate instruments the bulk of the data may be passed in this manner, while for the high-rate instruments (WFCs, C/S, LAPC) it would be necessary to resort to accumulation and storage on tape at ESOC. While the instruments would be provided by collaborations of institutes, it is intended that a large fraction of the data would be made available to guest observers, as in the case of Exosat.

Table 2 outlines the data base output from an observing programme for a three-year mission.

Table 2 – X-80 output data base

- High-resolution spectra of ~200 sources
- Medium-resolution spectra of ~3000 sources
- Spectral variability of these in snapshots of 10^3 to 10^5 s
- Spectral images of ~10^4 fields (~1°)
- Spectral images of ~10^4 fields (35° × 35°)
- A series of ~100 all-sky catalogues to 1 millicrab sensitivity (≡ Uhuru)
- Light curves of ~300 sources routinely sampled

Conclusion
X-80 represents the next logical step in high-energy astrophysics, following Exosat as a purely European venture. With the proposed instrument complement, hitherto inaccessible data will be obtained to reveal details of some of the most energetic processes in nature, to extend man's knowledge of the end points of stellar evolution, and to provide further glimpses of the cosmologically distant past.



A Portable Program Package for Geostationary Orbit Control

E M Soop & T A Morley, Spacecraft Trajectory Branch, Orbit Attitude Division, European Space Operations Centre (ESOC), Darmstadt, Germany

ESOC is preparing to support the European Communications Satellites (ECS) in geostationary orbit from a dedicated Control Centre at Redu in Belgium. The orbit-control tasks will be performed with the aid of six portable Fortran programs, which will also be suitable for supporting other future geostationary spacecraft missions. These orbit-control programs support spacecraft operations by calculating orbit parameters and preparing orbit-control manoeuvres.

To date, ESA's geostationary spacecraft have been supported, like the Agency's other satellite missions, by general-purpose orbit programs forming part of ESOC's Multi-Satellite Support System (MSSS). A general-purpose computer program capable of servicing many different types of missions is by necessity more complex than a program tailored to the requirements of one specific mission. The general-purpose approach has nevertheless been more cost-effective for a multi-mission control centre like ESOC because it allows optimum use of staff expertise for software operations and maintenance. The trade-off is, however, changing with the increasing use of geostationary orbits, particularly by three-axis-stabilised communications spacecraft. The trend for such missions is to operate the spacecraft in its geostationary phase from a dedicated control centre. There is then a need for specialised orbit-control software, written to support only geostationary spacecraft.

The Spacecraft Trajectory Branch of the Orbit Attitude Division within the ESA Computer Department at ESOC is producing the mission-specific computer programs* to support orbital control of the European Communications Satellites (ECS) from the Agency's Control Centre at Redu (Belgium). The new approach implies that ESOC's orbit experts will no longer be directly involved in the day-to-day orbit-control activities, but will instead deliver the software and the operating instructions needed to support by the spacecraft operators.

* Portable ECS Package for Synchronous Orbit Control (PEPSOC).

Systems overview

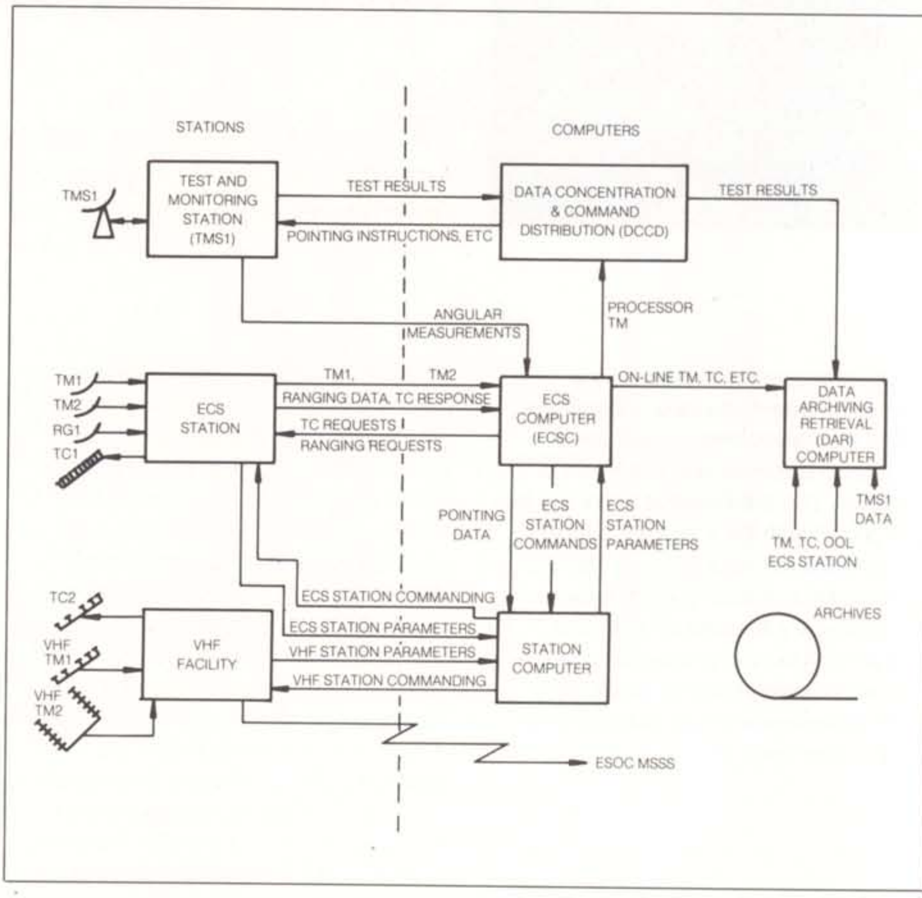
The Redu/ECS ground system is illustrated in Figure 1. At the core of the computer system are two Siemens R 30 processors. The prime machine (ECS) monitors and commands the ECS spacecraft and monitors and controls the ECS station. All the data from the ECS spacecraft is archived on the DAR (Data Archiving & Retrieval) computer, from which it is easily retrievable. The DAR also serves as the back-up to the ECS computer.

The orbit-control software will be implemented on the DAR computer and two or more satellites can be supported in parallel. The complete support package has four elements:

- the portable orbit-control programs
- the standard computer facilities existing at the installation, which are used to operate the orbit-control programs: interactive display system, operating system, Fortran compiler, line printer, file-handling system, etc.
- program operations manuals, procedures documents and other handbooks needed for orbit-control operations
- expertise/manpower for testing and trimming the system in situ, evaluating systems performance, operator instruction and training, and software maintenance.

The programs are designed to be run by the spacecraft operators, with the aid of documentation, after an initial training

Figure 1 – The Redu ECS ground system and data flows. For clarity, connections between the ECSC and the VHF facility have been omitted



period. Special efforts are therefore made to make the programs easy to handle. A high degree of safety is important to prevent errors from remaining undetected or from corrupting the system.

At the start of the design phase, it was clear that two diametrically opposed systems-design principles could be followed: automatic or manual. Regardless of the system selected, however, the operator must have a basic understanding of geostationary-orbit mechanics.

The design selected is largely manual, which means that the operator has to start programs after setting the appropriate input parameters and then check that the result is satisfactory. In other words, the design philosophy is for mathematical calculations to be made by the computer programs, whereas the operational decisions are to be taken by the operator.

The programs

The orbit-control programs are designed to support the orbit-determination, scheduling and station-keeping-manoeuvre preparation tasks in the routine geostationary-orbit phase. In addition, certain non-routine operations like longitude shifts and longitude re-acquisition are also supported.

The source code of the package of six orbit-control programs consists of approximately 18 000 Fortran statements (including comments), of which about 7500 lines are executable code. Fourteen data files per spacecraft serve as interfaces between programs and as input from the operator to each program.

The largest and most complex program, the *Orbit-Determination Program*, runs with 64 kbytes of memory, using overlay techniques. The orbit is determined by iterated, least squares fitting of an orbital arc to one or more days of tracking observations (ranging and antenna-

pointing data from one or more ground stations). For practical reasons, the incoming tracking messages are first converted to geometrical observations in a separate *Preprocessing Program*. This program also smooths and reduces the raw data, rejects bad data, and applies calibration and time corrections.

The orbit-determination program is able to estimate the solar radiation pressure coefficient and calibrate executed manoeuvres in addition to its routine determination of the orbital elements.

The orbit determined can be extrapolated forward up to 100 days by the *Orbit-Prediction Program*, which also takes into account the effects of manoeuvres already planned. The *Orbit-Information Program* provides auxiliary information on the present and future orbits that the operator needs to schedule spacecraft operations.

Typical examples are the occurrence of eclipses, times when the Sun will blind the satellite's infrared earth sensors, and pointing data for each station antenna.

Orbit manoeuvres are planned with the aid of the two manoeuvre-preparation programs: the *Longitude* and the *Inclination Station-Keeping Manoeuvre Planning Programs.*

In all of the programs orbit propagation is computed by numerical integration, in double precision, of the spacecraft position and velocity in cartesian coordinates, using a standard multistep method. A high-precision analytical Sun and Moon ephemeris is used to compute the third-body perturbations. The Earth's gravity potential is obtained from a multipole expansion. Analytical models are used to model the motion of the celestial coordinate systems.

A detailed printout from each program run gives the operator complete insight into the calculations that have been performed.

Documentation

The documents required by the operator to run the orbit control system can be grouped into four categories.

The first item needed is a 'textbook' covering the theory and practices of the geostationary-orbit mechanics. Classical celestial-mechanics textbooks are generally not directly suitable and ESOC is therefore providing its own 'textbook', the first part of which has already been written.

The second category of documentation is the set of User Manuals for the six orbit-control programs. These documents are essentially independent of the particular mission and computer installation in use. They describe all the operating modes of which the programs are capable.

The third type documents the computer-dependent program environment. It is essentially an extract from the computer manual and describes how to update the relevant input data files and how to start running the orbit-control programs.

The fourth type of documentation is the procedures document, which will contain the mission-dependent parameters and the recommendations for scheduling the orbit-control cycle. This document will be written towards the end of the running-in period so that practical performance data can be included.

Method of operation

The allowable longitude and latitude excursions of a three-axis-stabilised geostationary communications satellite are limited to a fraction of a degree, so that the station-keeping cycle, i.e. the time between manoeuvres, must be relatively short. For ECS the proposed cycle is 14 days. The orbit-control software, which is also run in a cyclic manner, must therefore have a still shorter period. Experience at ESOC has shown that a weekly cycle is most convenient for routine operations (Fig. 2).

About ten times per day, at roughly equal intervals, tracking messages are received from the ground stations. The data arrives via a direct link from the station to the orbit-control computers or by telex if originating from a remote station. Normally, this data is processed at the end of the weekly cycle, though more critical tracking measurements, particularly those taken between closely spaced manoeuvres, may be processed immediately after reception.

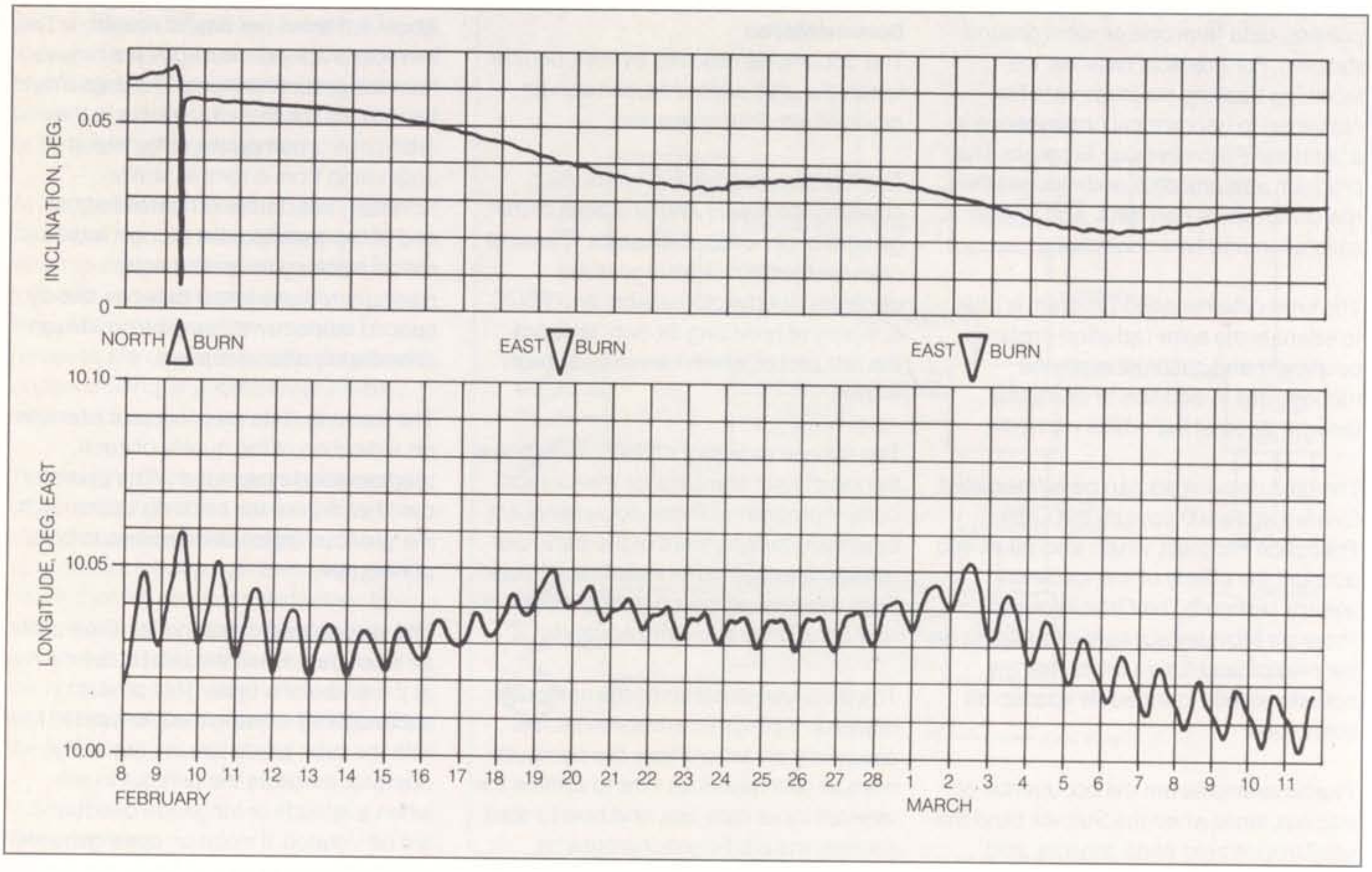
The tracking-data preprocessor provides an indication of the quality of each preprocessed observation. The operator can then repeat the tracking operation if the previous observation proves to be of poor quality.

The preprocessed observations are used as input data when the orbit is determined at the end of the cycle. This orbit is subsequently extrapolated forward in time with the orbit-prediction program. The operator monitors the printout to see when a latitude or longitude deadband will be violated. If violation does not occur within the next week or shortly after, no manoeuvres need be planned. The running of the information program then provides the auxiliary orbit data for the following week's operations and concludes the cycle.

When the operator sees that a deadband will be violated, he plans the necessary station-keeping manoeuvres with the aid of the appropriate station-keeping program. Once a manoeuvre has been planned, the orbit-prediction program is rerun to update the predicted orbit. Again, the subsequent running of the orbit-information program completes the weekly cycle. Figure 3 is a schematic of the orbit-control loop.

When the manoeuvre has been executed, the next orbit determination can be used to estimate its actual magnitude. The calibration is used by the operator to convert from burn size to burn duration for planning future manoeuvres.

Figure 2 – Station-keeping with one inclination and two longitude manoeuvre burns for ESA's Orbital Test Satellite (OTS) over a one-month period in early 1982



At the end of the running-in period a regular orbit-control cycle will be established, which will then essentially be repeated throughout the mission. The cycle could, however, be disrupted due to anomalies either on the spacecraft or in the ground control. The orbit-control software, though, is very flexible and can easily accommodate such deviations from routine operations.

The printout from each program run will be filed by the operator to form an orbit-control log, from which the data files and operations history can be retrieved.

System implementation
At the time of writing, development of the orbit-control software is proceeding at ESOC on the SEL 32/77 computer (Fig. 4).

About two man-years of effort will have been spent on the software's design, development and testing on the ESOC computer when the system is complete. The software's design is based on experience gained at ESOC in operating geostationary spacecraft, and numerous existing modules in ESOC's program libraries are being exploited in its development.

Installation on the Redu computer at the beginning of 1983 is estimated to require three man-months of effort. The programs have been designed with portability in mind, so few changes to the Fortran coding will be necessary, though the job-control language is very much machine-dependent. In addition to setting up the job control, the installation period will include preliminary testing and tuning of system parameters. Thereafter, there will be a six-month, parallel-staffed running-in period whilst the operators become proficient at using the programs.

Subsequent routine maintenance by the orbit experts should not amount to more than one man-month per year.

Similar implementation schemes can be used for other mission applications. Different user requirements, e.g. nonstandard formats for the tracking message, will call for additional effort. Nevertheless, the initial installation time and costs should be seen in the light of single-satellite systems having lifetimes of up to seven years and multiple-satellite systems in excess of ten years.

An experienced operator will need to devote less than one day per week to the orbital control of each satellite, the actual program run time being substantially less than a day. The complete orbit-control system requires only about 5 Mbytes of disk space. The system can therefore be run on a computer as a subsidiary task to

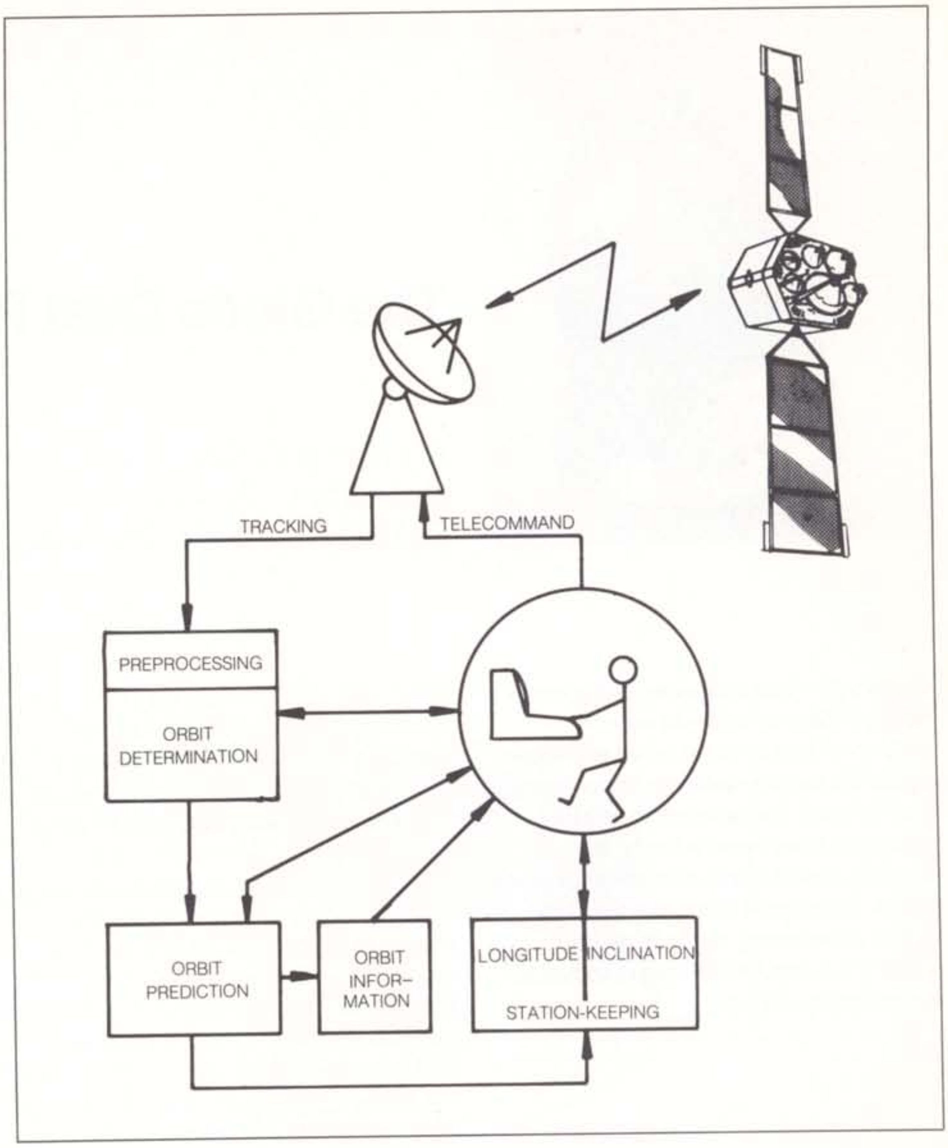


Figure 3 – The ECS orbit-control loop

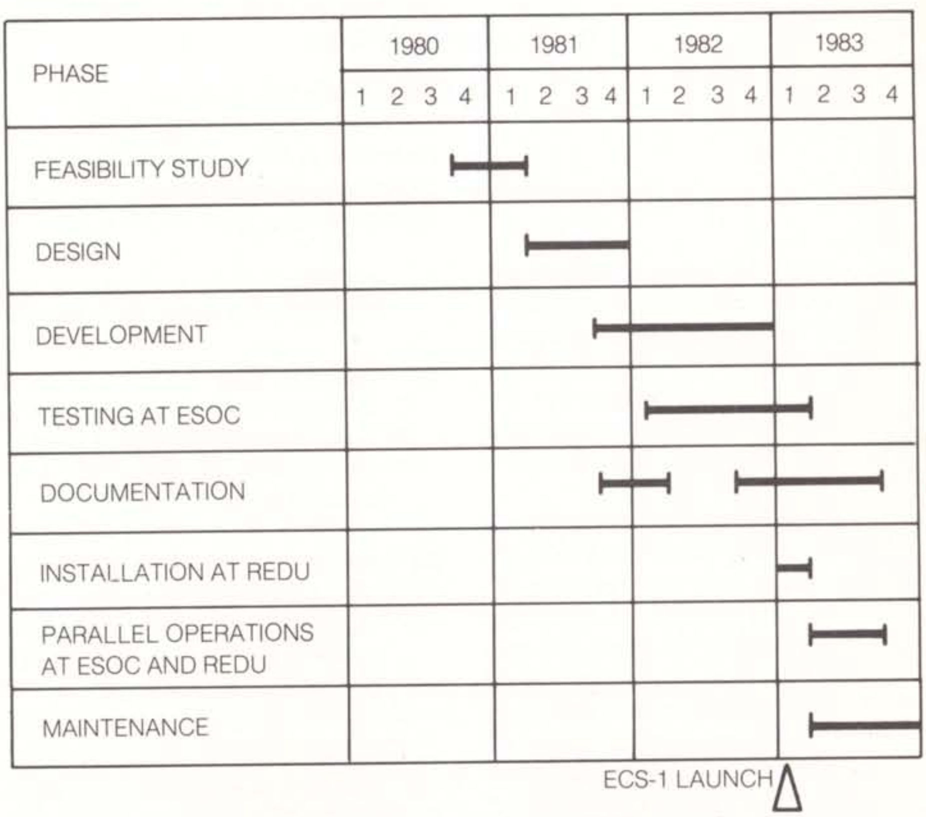


Figure 4 – Orbit-control software development

its primary function, by an operator whose main duties lie elsewhere.

Conclusion

A portable orbit-control software system is being developed in response to the trend towards conducting routine geostationary-satellite operations from dedicated control centres using relatively small computers. The self-contained system will be applicable to other geostationary satellites also, the amount of modification necessary depending on the particular mission. It will be simple to use, cheap to install and operate, and is expected to be very reliable. It will provide the trained operator with an ability that has so far been the exclusive domain of the orbit expert.

The Giotto Dust Protection System

R. Lainé & F. Felici, Giotto Project Team, Scientific Projects Department, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Giotto's planned encounter with comet Halley in March 1986 will take the spacecraft into the dust cloud produced by the interaction between the comet and the Sun. The spacecraft will be protected from hypervelocity dust-particle impacts by a dual-sheet bumper shield, composed of a thin front sheet (1 mm aluminium), and a thick rear sheet (13.5 mm kevlar/foam sandwich) separated by 25 cm.

The spatial mass distribution of the dust cloud around comet Halley has been predicted by a number of specialists and discussed at several scientific workshops*. The dust particles are expected to vary in size between 10^{-14}g and 0.6 g, with densities of the order of 1 g/cm^3. The relative speed of the spacecraft with respect to the dust will be 68 km/s. The magnitude of the problem of collision between the dust particles and Giotto's protective shield is therefore quite new and the tests and analyses performed in the sixties, in particular for the Apollo project, are only a starting point for resolving the Giotto dust protection problem.

The problem was addressed at a dedicated workshop held in ESTEC, Noordwijk, in April 1979 during the project's study phase (Phase-A). It was agreed then that (see ESA SP-153)*:

(i) a 'Whipple shield' was the only feasible solution in terms of mass

(ii) a bumper shield made from 1 mm-thick aluminium with a rear shield of honeycomb sandwich with thick aluminium facesheets was a possible solution

(iii) no ground test could directly reproduce the impact of the dust-cloud particles on the shield, and therefore that analysis must be the primary investigative tool.

* The Comet Halley Micrometeoroid Hazard, ESA SP-153, October 1979.

From this basis, the Giotto project team began a series of test and analysis activities to define the parameters of the protection system in detail, taking into account also all the configuration, mass and operational constraints imposed by the spacecraft and its payload. The results of these tests and analyses were discussed at two further Workshops in January 1981 and August 1981.

The dust protection system

In its 'head on' approach to the comet, the spacecraft will offer a sacrificial, thin aluminium alloy sheet to the impinging micrometeoroids. This surface will be composed of several sections (Fig. 1).

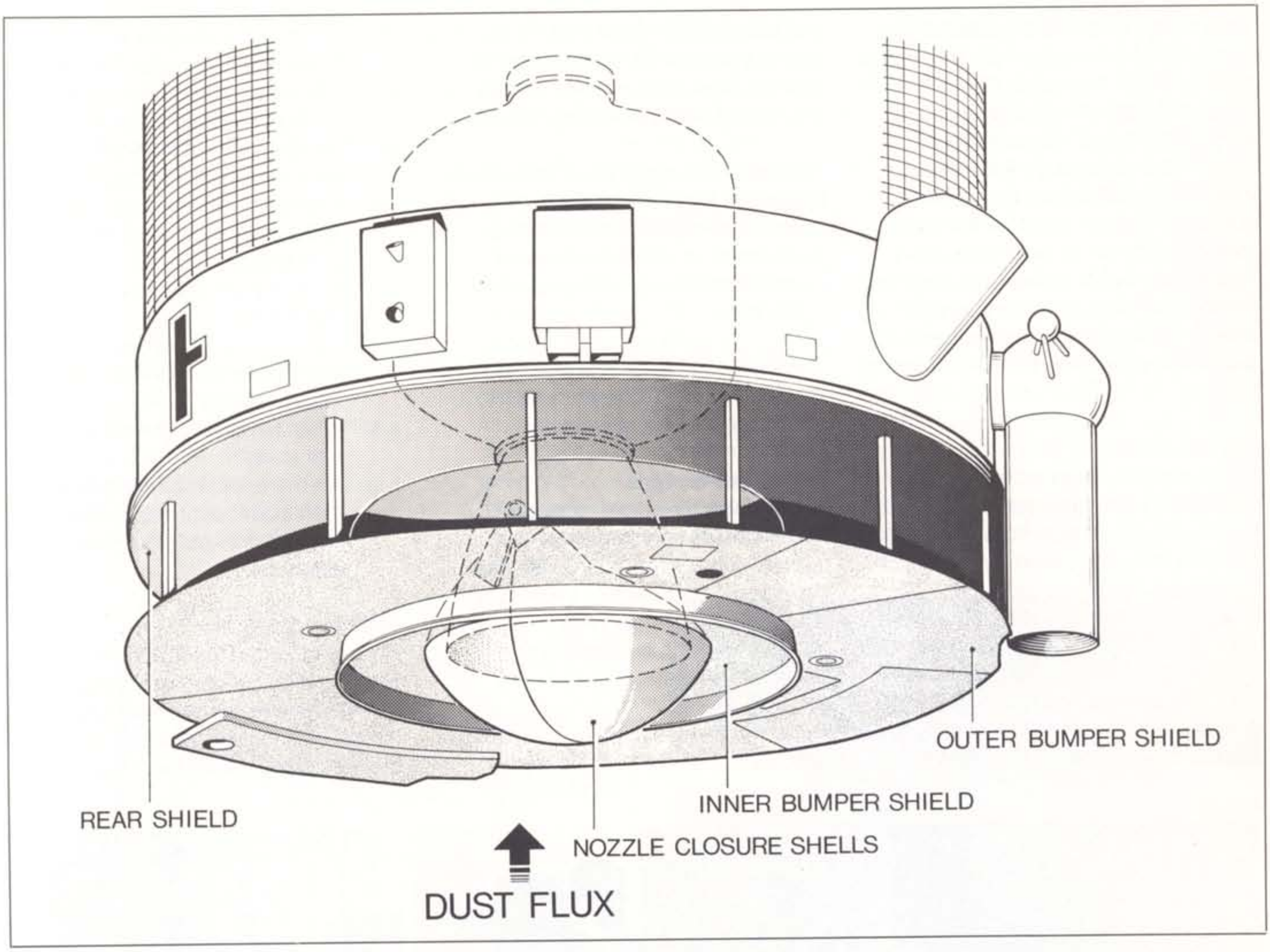
Outer bumper shield

This outermost section is made of 1-mm thick aluminium-alloy sheet. It is stiffened by a structural outer ring and connected by 12 outer GRP struts to the rear shield and by 16 lugs to the structure's cone. It is divided, for manufacturing and experiment reasons, into three sections, the smallest of which is 'acoustically' decoupled from the rest of the structure and supports some of the dust-impact sensors of the DID (Dust Impact Detector) experiment.

A shaped extension protects the PIA (Particle Impact Analyser) experiment that protrudes from the circular profile of the spacecraft; edge cutouts provide the experiments with the requisite fields of view and afford maximum protection to them and to the other spacecraft sensors.

The continuity of the outer bumper shield is partially interrupted by the interfaces

Figure 1 – Artist's impression of Giotto's dust protection system



between the spacecraft and Ariane launcher (separation spring pads and umbilical connectors), by the S-band low-gain antenna, and by another dust-impact experiment (IPM). These items themselves provide the necessary shielding to the rear section and are accurately overlapped with the bumper shield to ensure that there are no gaps for the incoming meteoroids. One further sensor (CIS) for micrometeoroid impacts is to be bonded to the shield's outer surface.

Inner bumper shield
The main structural cone that interfaces with the launcher separates the outer from the inner bumper shield. The latter is also a 1 mm-thick, aluminium-alloy annular sheet fastened to an internal flange of the interface ring.

Nozzle-closure shells
The role of the innermost portion of the sacrificial, thin frontal shield is more that of limiting and containing the impact debris and of ensuring a continuous grounded shield surface to the spacecraft than offering direct protection to the spent (in the encounter phase) Mage-1S motor.

On the other hand, the motor nozzle has to be left free until after the spacecraft's injection onto its trajectory to the comet and can be shielded only thereafter. A closure mechanism has therefore been designed which works by firing two pyrotechnic cable cutters to allow two hemispherical shell sections (of about 1 mm-thick aluminium-alloy) to rotate from their open launch and injection configuration into their closed configuration for cruise and encounter.

When the thin aluminium shield is impacted by a micrometeoroid, several different chains of events can occur, depending on the size of the meteoroid: either the shield absorbs the impact and a crater is formed in it, or the particle punches a hole in the shield and in doing so is vaporised and expands as a thin-walled cloud of vapour in a conical pattern behind the shield. Some slow,

Figure 2 – Light gas gun at the E. Mach Institute (Freiburg, Germany) used for the hypervelocity impact tests. The swivelling vacuum-chamber closure plate (extreme left) holds the specimens

small molten and solid particles will also be released by the shield from the edge of the hole left by the particle. The debris cloud, although still travelling at almost the same speed as the incoming micrometeoroid, is much less harmful than the original particle to any other obstacle in its path, because the initial momentum of the meteoroid is spread over a much larger surface (the larger the distance between the outer and inner shields, the smaller the impulse per unit area of the debris cloud on the impacted surface).

The rear shield

The above discussion explains why the Giotto dust protection system incorporates a relatively heavy (34 kg total) rear shield to absorb the effects of the debris cloud and protect the experiment platform. This rear shield is made of Kevlar-49 reinforced plastic (KRP) and polyurethane shock-absorbing foam in a sandwich configuration: 6.5 mm-thick KRP laminate impacted by the cloud, an intermediate 5 mm foam layer, and a 2 mm KRP laminate at the rear. The thicker front laminate will also stop the relatively slow, solid particles released by the bumper-shield perforation events.

The rear shield is split in two sections for integration purposes, and is fastened to the experiment platform through 12 honeycomb sandwich pads, which provide thermal and additional shock isolation.

The outer edge of the rear shield is shaped to provide local protection to a number of experiment sensors.

Testing and analysis

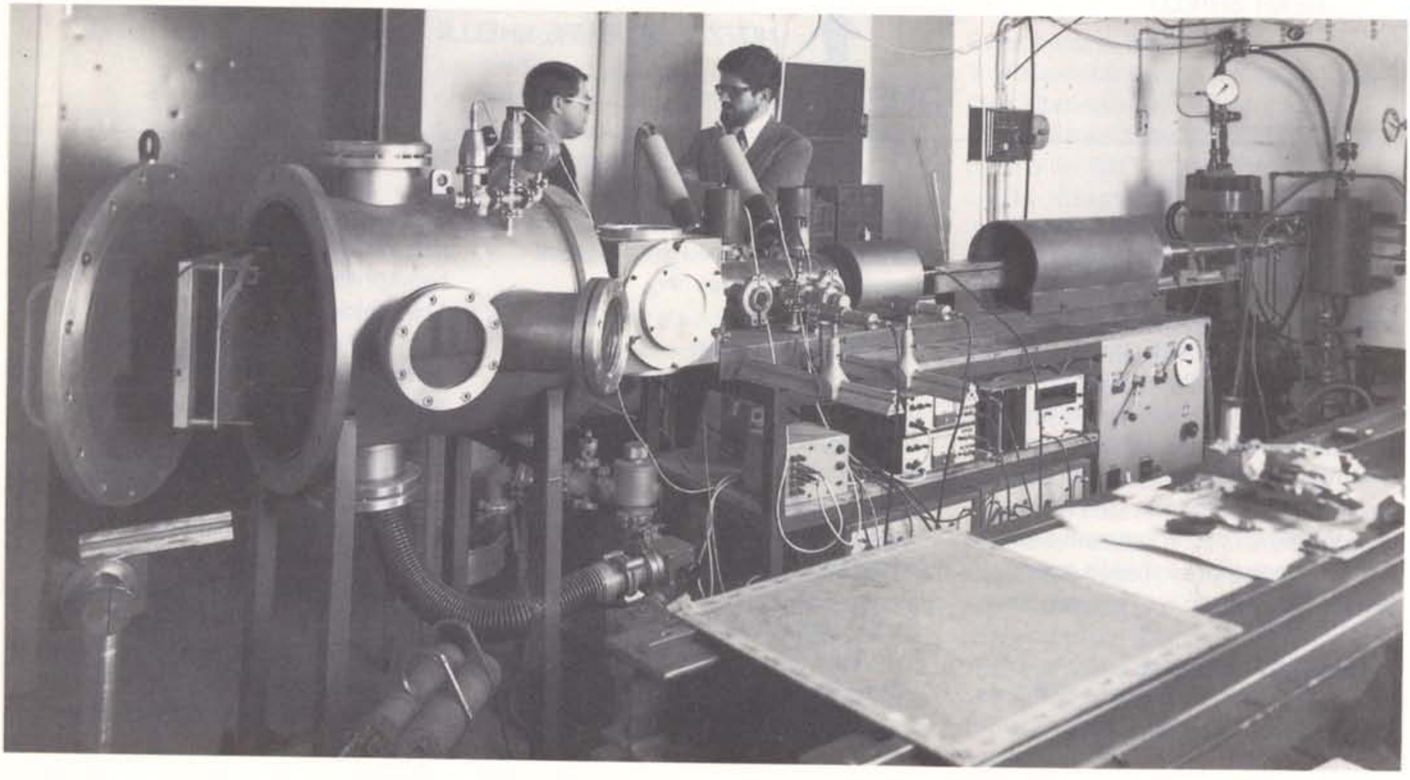
Hypervelocity meteoroid impacts of the type discussed here (68 km/s) have received very little attention in the past, compared with impacts in the 6–15 km/s range, which have been widely investigated by both analytical and experimental means.

The main questions posed by Giotto were principally:

(i) Is 1 mm of aluminium alloy sufficient to vaporise the largest dust particle that will probably be encountered during the Comet flyby?
(ii) What speeds will the small solid debris attain after perforation?
(iii) How will the energy and momentum of the incoming particle be partitioned?
(iv) How large will the holes left in the shield be?
(v) How much of the debris cloud's momentum will be thrown back by the rear shield?
(vi) What damage will there be to the rear shield?
(vii) Are there better shield materials than aluminium? (capabilities well known from Apollo-program experiences).

Light gas gun tests

A series of tests at the E. Mach Institute in Freiburg (Fig. 2) in January 1981 have provided interesting results to help answer the last of the above questions. A light gas gun was used to shoot small spheres of



aluminium (20–40 mg) into a wide choice of targets with impact speeds of about 6 km/s. Both the bumper-shield and rear-shield concepts were tested in 'Whipple shield' configurations, and direct shots were fired at several composite materials to check their impact-absorbing capabilities compared with aluminium alloys (Figs. 3a-c).

The conclusions of the tests were as follows:

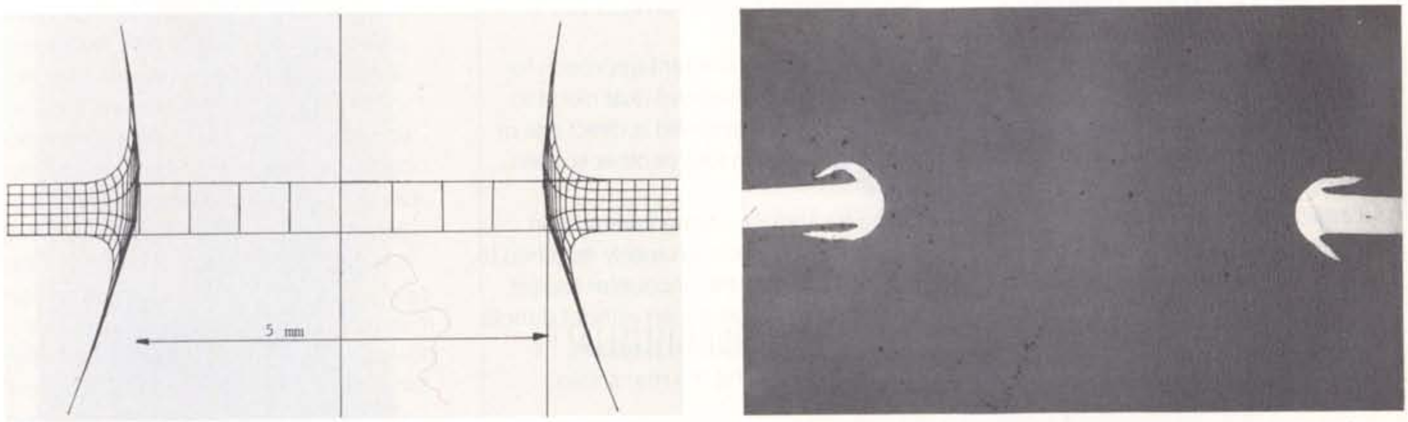
(i) Composite, laminated bumper shields did not show enough advantages to merit application on Giotto. In all cases the fragmentation of the impinging sphere was worse than that produced by a 1 mm aluminium-alloy shield, and only kevlar bumper shields showed a 'self healing' capability. (The kevlar cloth laminate is only partially disrupted at the edges of the perforation and therefore offers later impacting particles a smaller hole than that left in an equivalent shield of another material.)

(ii) Shields of kevlar-cloth-reinforced plastics were very effective in absorbing both direct and secondary impacts. Their capability was enhanced by using a sandwich configuration and by separating the rear shield from the element to be protected, to allow the shield to dissipate as much of the energy of the incoming meteoroid as possible by plastic deformation and damping.

(iii) Multilayer insulation blankets have to be kept away from the impinging debris cloud and therefore the rear shield has to protect also the experiment platform blanket called for in the thermal design.

One obvious limitation of these tests was the relatively low speed attainable with light gas guns available in Europe. This speed was, in particular, lower than that necessary to produce an impact energy sufficient to melt and substantially vaporise an aluminium meteroid (about 10 km/s). Given the good correlation between the results of testing and analysis (these are described later), the emphasis

Figure 3a – Comparison of the predicted and actual holes left in a 0.6 mm-thick aluminium-alloy bumper shield by a 2.5 mm-diameter aluminium sphere travelling at 5.5 km/s



a

Figure 3b – Effects of 2.5 mm-diameter aluminium spheres (22 mg) on composite and aluminium plates (direct shots)

b

6.6 km/s
12 mm thick kevlar-reinforced plastic

5.9 km/s
18.5 mm thick glass-fibre reinforced epoxy

5.6 km/s
10 mm thick aluminium alloy

Figure 3c – Comparison of the damage inflicted on two aluminium-honeycomb sandwiches by a 30 mg aluminium sphere travelling at 5.8 km/s. Test sample 514 has a 3 mm-thick kevlar-reinforced laminate on top, which weighs only half as much as the corresponding aluminium plate of sample 483

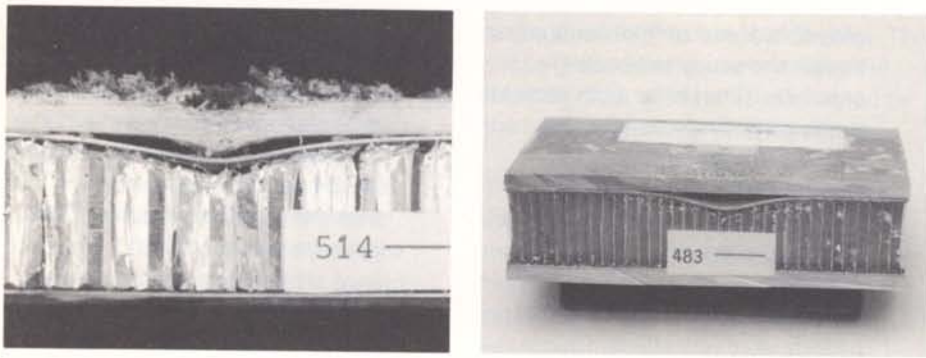


Figure 4 – A high-speed X-ray photograph of a shaped-charge experiment. The 'mushroom' projectile is travelling at 9.2 km/s

in testing had to be shifted to rear-shield testing, for which a sufficiently homogeneous and energetic cloud of molten, or preferably gaseous, material is necessary.

Tests with explosives

One means of trying to achieve impact speeds higher than 10 km/s and projectile masses greater than 0.1 g was to use explosive tubes and shaped charges*, and in late 1981 a feasibility study was initiated at Dornier under ESA contract.

The explosive tubes use the gases produced by high-energy explosives to accelerate small cylindrical pellets. Several configurations were tried (single and multiple tubes with and without a vacuum chamber at the end), but the best results achieved were about 6 km/s, with initial projectile masses of 0.1 g. Severe erosion was experienced which reduced the projectile's final mass.

Shaped charges are a known means of producing extremely fast jets of material by detonation of high explosives. In our case, the difficulty lies in the need to 'sweep away' most of the jet, leaving only its tip to impact on the target. Several techniques have been tried to produce the isolated projectile needed and the best results are very encouraging, in that they show speeds of about 9.5 km/s and main projectile masses greater than 1 g.

These larger projectiles are nevertheless still followed by a number of small secondary particles from the deflected jet. The mushroom-shape of the projectile poses serious problems in terms of complete melting/vaporisation on impact with the bumper shields and is difficult to simulate analytically (Fig. 4).

A second, rather different approach for generating a high-speed dust cloud to impact on the rear shield is direct use of high explosives in foils or other shapes.

Using a carefully planned detonation sequence, a gas cloud closely matched to that predicted by the encounter impact analysis can be produced without danger of later high-speed solid particles seriously damaging the rear shield.

Computer analysis

As part of the Giotto analysis, a computer-analysis study is being performed by Engineering Systems International (Paris) of the impact sequence using both a Lagrangian code (HEMP-ESI) and Eulerian codes. Lagrangian codes produce 'pictures' of the time history of an event deforming an initial network of zones which have been assigned appropriate characteristics to represent the materials and energies involved (reference system fixed to the configuration studied).
Eulerian codes produce the same type of pictures by setting up a fixed reference network and describing the flow of materials and energies involved (reference system fixed to the 'ground').

Some of the answers to the six initial questions posed at the beginning of the project have already been found. The first correlation attempted with one of the low-speed tests with the light gas gun proved very satisfactory, both in describing the physics of the impact and predicting the impact area of the debris cloud and the hole left in the aluminium test specimen by the aluminium sphere (Fig. 3a).

* A shaped charge is an explosive cylinder, the end of which has a concave cone shape and is lined with metal, in our case aluminium.

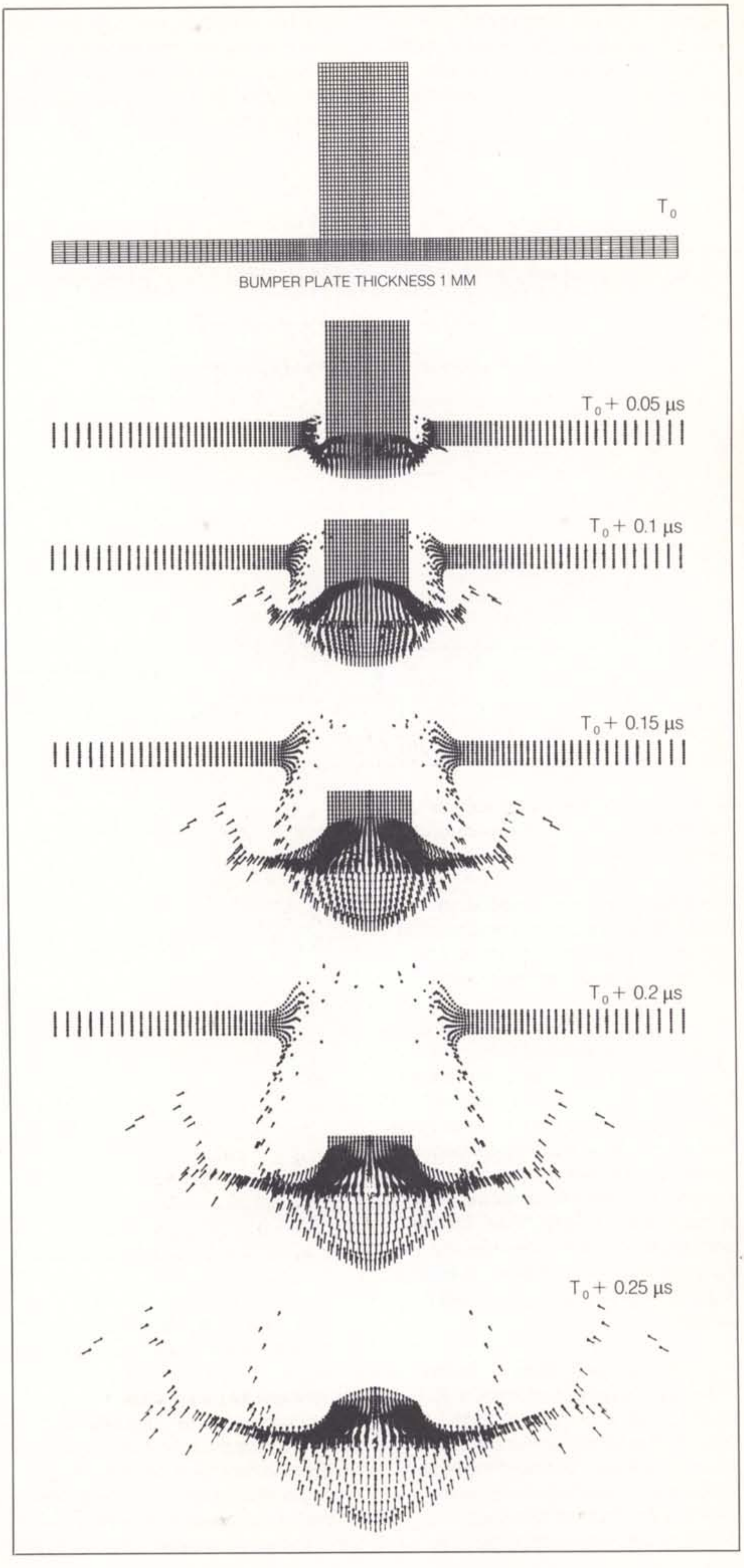


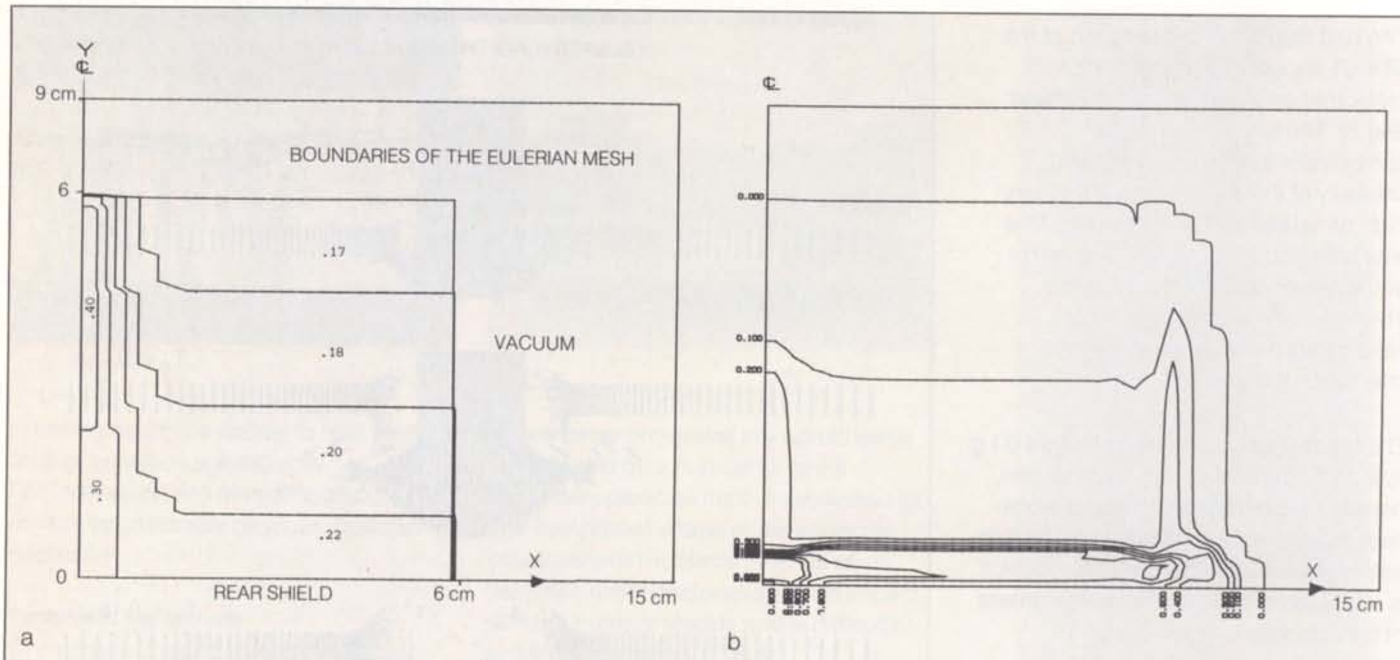
Figure 5 – Perforation sequence (velocity vectors) predicted by the Lagrangian code (HEMP-ESI) for a foamed-silica meteoroid (4 mm in diameter, 8 mm long, weight 0.1 g and density 1 g/cm³) impacting on an aluminium-alloy bumper shield at 68 km/s

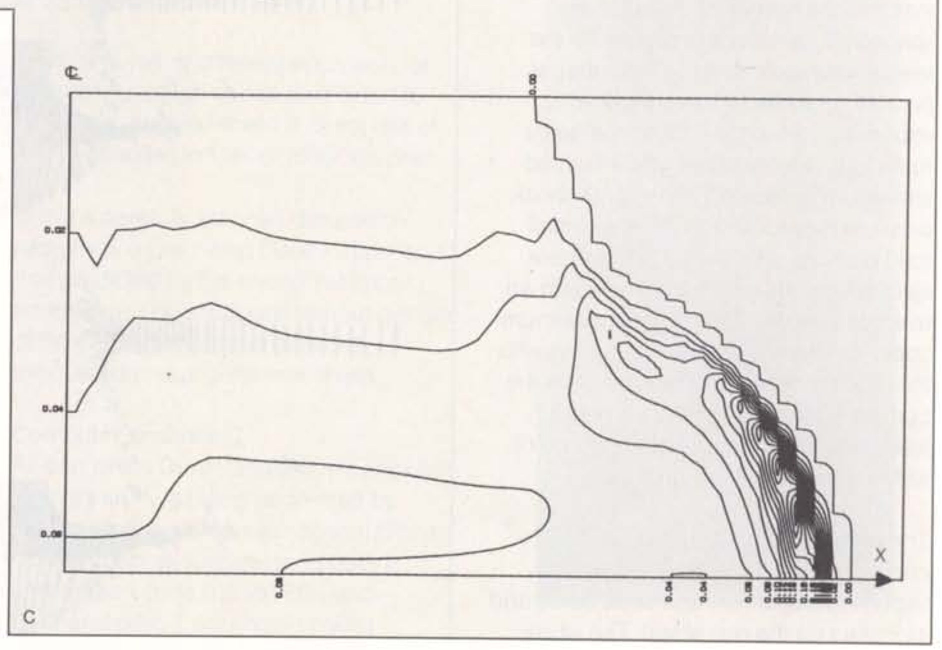
The next step was the prediction of the 68 km/s impact of a foamed-silica meteoroid on the 1 mm bumper shield (Fig. 5). The key point of these computations is the accuracy and reliability of the material models at very high pressures and temperatures. This was achieved by using sophisticated equations of state for the materials involved in the impact, and input parameters gathered from the best international literature.

The foamed-silica meteoroid (weight 0.1 g, cylindrical diameter 4 mm, length 8 mm, density 1 g/cm³) modelled was a worst-case estimate of a Brownlee-type particle as predicted by the latest comet model; it is also a worst case for the completeness of the vaporisation process, and it matches the maximum deviation in spacecraft spin axis acceptable for the telecommunications link. Silica gives a peculiar 'moustache' shape to the vaporising meteoroid (discriminated by running an identical test with a foamed-aluminium meteoroid): the impact shock pressure is predicted as 25 Mbar; small solid particles (less than 0.125 mm) are ejected from the edge of the hole with an average speed of 3.9 km/s and maximum speed of 10 km/s; the heat exchange with the shield is negligible; the hole left in the bumper shield has a diameter only 2.7 times larger than the meteoroid (a point widely debated in the workshops).

The second step in the analysis concentrated on the expansion of the vaporised aluminium and silica cloud and its impact on the rear shield. The whole process is very fast (a few microseconds), because the cloud travels almost as fast as the incoming meteoroid and its final effect on the rear shield is to transfer some of its momentum to it. The amount of 'rebound' of the cloud is critical and is determined by the gas characteristics and the formation of radial gas jets (Fig. 6). This part of the analysis was performed with both Lagrangian and Eulerian codes to cross-check results. Only about 40% of the cloud's momentum is rebounded

Figure 6 – Cloud-rebound plots from the SOLA-ESI program (axisymmetric model) showing the evolution in the cloud's density distribution on impact with the rear shield:
(a) Cloud at the instant of initial contact (T_0) with the rear shield
(b) At $T_0 + 0.4$ µs, the cloud is completely compressed against the rear shield
(c) At $T_0 + 2$ µs, the cloud is 'bouncing back', but radial expansion produces a 'ring' of higher density gas





back, thereby illustrating the substantial effect of the cloud's radial expansion at impact.

The pressure distribution on the rear shield has been computed as a function of time. The peak pressure at the centre of the impact area is about 12.3 kbar.

The third step in the impact analysis is prediction of the damage to the rear shield, of the shock transmission in the shield itself, and of the total response of the rear shield to the initial impulse. While the second area is still being investigated, a monodimensional analysis of the shield cross section has shown that the peak pressure is able to spall the front shield and partially compress the foam, but that the pressure-pulse attenuation is such that the second kevlar laminate is not spalled.

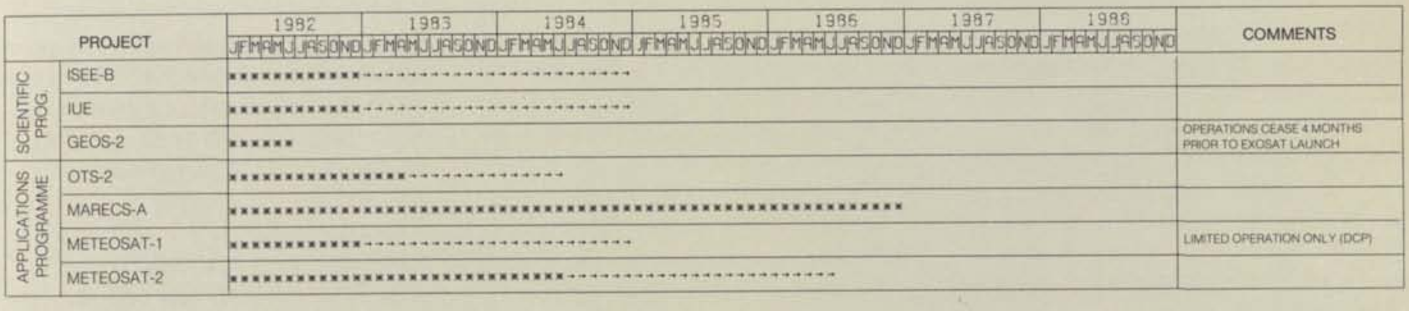
A global response analysis of the rear shield has also been performed at ESTEC using a linear finite-element model (ASKA). Both momentum and pressure-pulse inputs have been used to simulate two different impacts at points on the rear shield. The deflections and forces predicted are within acceptable limits, bearing in mind the conservative linear elastic assumption made.

Current and future activities

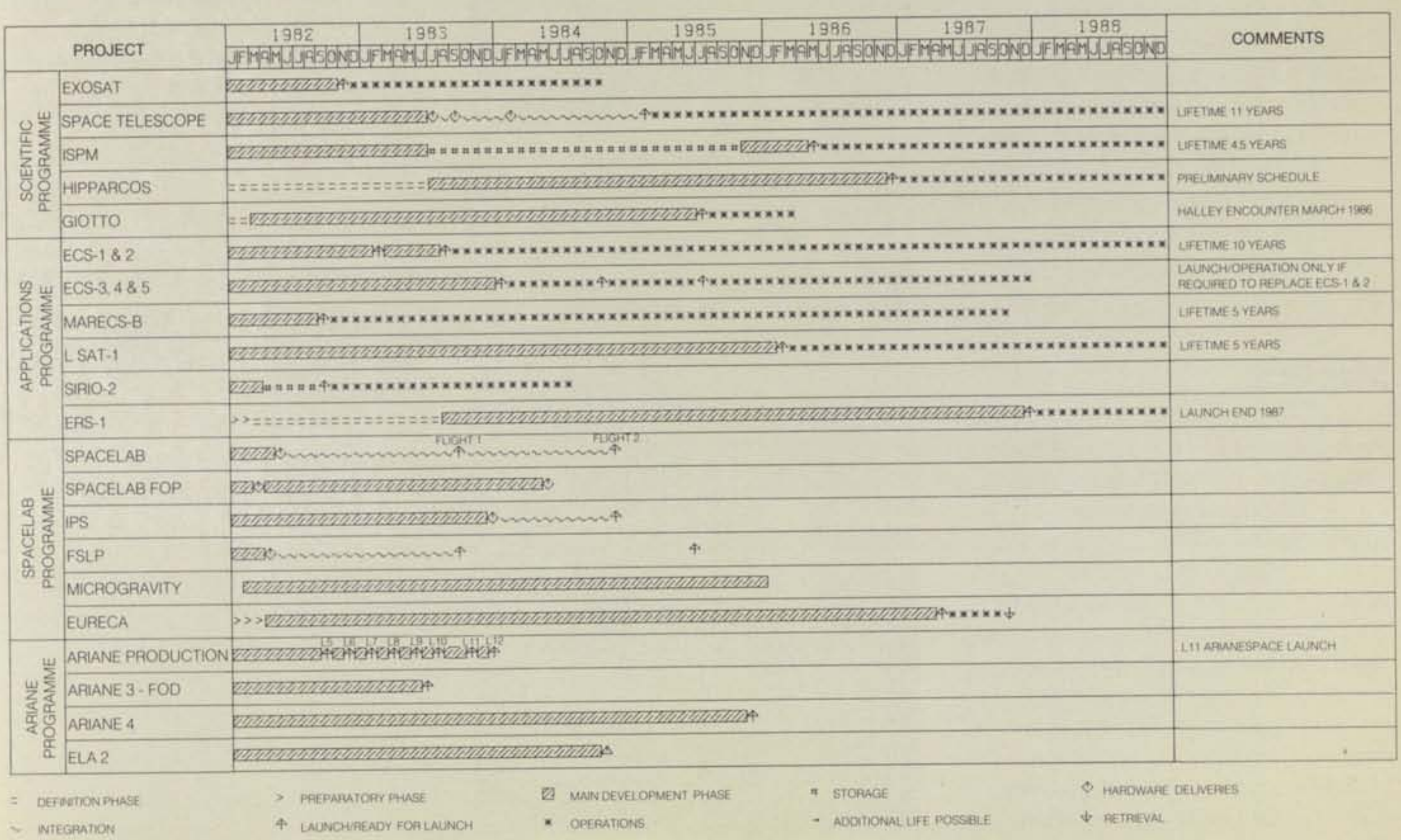
For completeness, the cloud rebound after impact on the rear shield is being analysed to determine the shape and characteristics of the gases re-impinging on the bumper shield from behind. Two other bumper-shield perforation analyses are also being completed, for a 5 mg and a 5×10^{-6} g meteoroid, (the latter should produce so-called 'marginal penetration', with a crater in the shield of about the same depth as the shield's thickness). Tests are continuing with fully representative Giotto materials; namely Kevlar-49 epoxy-resin laminates and high-density foams.

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

In Orbit / En orbite



Under Development / En cours de réalisation



OTS

Déjà bien engagé dans sa cinquième année d'exploitation, le satellite OTS poursuit son bon fonctionnement. Les essais thermiques exécutés lors du solstice d'été ont donné des résultats tout à fait conformes aux prévisions faites d'après les valeurs dont on disposait sur l'altération des surfaces. Ces essais thermiques à long terme, avec des moyens complets, apparaissent comme offrant le plus grand intérêt pour la conception des satellites futurs. Il reste encore selon les estimations actuelles assez d'hydrazine pour assurer une capacité de manoeuvre totalement normale pendant encore un an et demi. Des essais sont en cours pour déterminer la cause de la défaillance d'un amplificateur de tube à ondes progressives, qui reste toutefois sans incidence sur la mission en raison du haut degré de redondance des équipements du satellite. Les dernières mesures relevées dans le cadre du système d'intéressement ont permis d'établir que tous les canaux de répéteur qui fonctionnent dépassent les spécifications.

OTS est toujours très utilisé pour les expériences de transmission de données et de téléphonie ainsi que pour les transmissions de télévision. Par exemple, les matches de la Coupe du monde de football en Espagne ont été retransmis en Europe via OTS et lors de la Conférence Unispace 1982 qui s'est tenue à Vienne, une station de réception a permis de capter les transmissions régulières de données Spine (voir page 11). Les discussions se poursuivent avec Eutelsat au sujet de la prolongation des opérations après mai 1983.

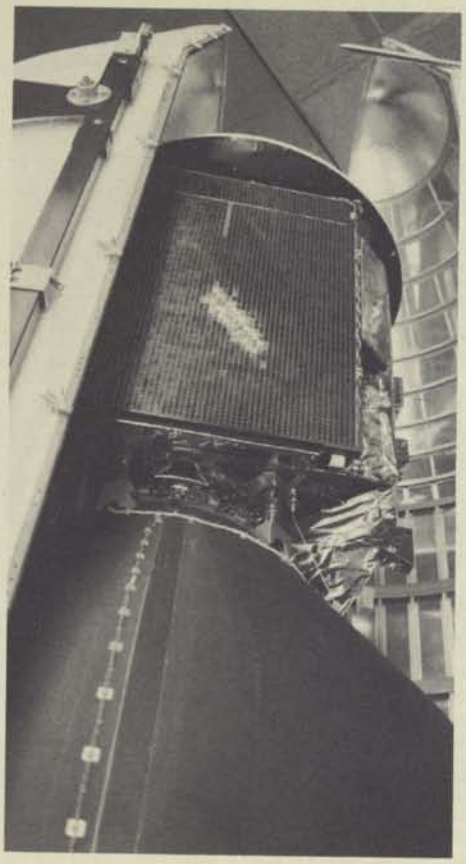
Marecs

Inmarsat utilise Marecs-A sur l'Atlantique depuis le 1er mai 1982. Les performances du satellite ont été entièrement satisfaisantes.

Après l'application et la mise à l'essai de modifications apportées au matériel en vue d'éliminer les décharges électrostatiques et perturbations connexes qui s'étaient produites sur Marecs-A en février, le satellite Marecs-B a subi avec succès des essais au niveau système. L'examen officiel de recette du modèle de vol a eu lieu le 26 juin à l'ESTEC, Noordwijk, et donné le feu vert pour l'embarquement du satellite à destination de Kourou le 2 juillet. La campagne de lancement a commencé aussitôt après, avec les préparatifs électriques et les contrôles fonctionnels qui ont abouti à l'examen d'aptitude au vol le 17 juillet, à l'issue duquel le satellite a été déclaré apte au vol. La campagne a été interrompue du 20 juillet au 10 août, le lancement n'étant pas prévu avant le 10 septembre (GMT). Après reprise de la campagne, les dernières opérations de chargement de carburant, de mise en place du moteur d'apogée et d'équilibrage ont été menées à bien, préalablement à l'intégration du satellite sur la structure spéciale Sylda destinée à permettre le lancement simultané de deux satellites sur orbite géostationnaire (le satellite Sirio-2 doit être lancé en même temps que Marecs-B). La charge utile composite (Sylda, Sirio-2 et Marecs-B) a ensuite été installée sur le lanceur et les activités de routine préalables au lancement suivent normalement leur cours.

Marecs-B integrated on top of Ariane's Sylda at Kourou, in September

Intégration de Marecs-B au système Sylda d'Ariane (Kourou, Septembre '82)



Météosat

Secteur spatial

Le fonctionnement des deux Météosat est resté satisfaisant au cours du dernier trimestre. Météosat-2 transmet toutes les trente minutes des images de la Terre dans les bandes visible, infrarouge et 'vapeur d'eau', Météosat-1 continuant pour sa part à assurer le soutien de la mission DCP.

Secteur sol

La configuration calcul complète a été mise en place en juillet et le système peut être maintenant considéré comme opérationnel. Il reste à effectuer certains travaux de développement sur le logiciel mais ces travaux n'affectent pas les utilisateurs. La nouvelle antenne destinée au système de collecte des données a été installée à la station de l'Odenwald et elle sera mise en service début septembre. Le coefficient de disponibilité du système a été élevé au cours de la période considérée.

Après la mi-septembre, les produits météorologiques feront l'objet d'une nouvelle diffusion opérationnelle qui aura lieu à minuit.

Programme opérationnel

Au mois de juillet, le gouvernement allemand a décidé de désigner des participants aux groupes de travail chargés du programme opérationnel Météosat. Cette décision a permis de reprendre les préparatifs qui avaient été interrompus en novembre 1981.

Exosat

Satellite

Au cours du trimestre écoulé, les essais du modèle de vol ont continué conformément aux prévisions. Avant le démarrage des essais sous vide thermique dans la chambre HBF3 de l'ESTEC, en avril, les performances fonctionnelles du satellite ont été revérifiées. Après avoir fait subir au satellite les essais d'exposition au vide et de cycle thermique et sur la base du résultat des vérifications fonctionnelles qui ont suivi, la commission d'examen des essais a conclu que tous les objectifs des essais avaient été atteints eu égard aux

OTS

With OTS operations well into the fifth year, the satellite continues to function successfully. Thermal tests conducted at summer solstice showed results closely in line with predictions based on previous surface-degradation values. These long-term, well-instrumented thermal tests are proving to be of the greatest value for future spacecraft design. Current estimates of remaining fuel indicate that another 1 $^1/_2$ years of completely normal manoeuvring capacity exists. Tests are currently being carried out to determine the cause of failure of a travelling-wave-tube amplifier, although the high degree of redundancy in the satellite means that this failure has no impact on the mission. The latest incentive-scheme measurements established that all operating repeater channels are above specification.

OTS is still being used very extensively for data and telephony experiments as well as television transmission. For instance, the World Cup football matches in Spain were transmitted in Europe via OTS and at the UNISPACE 1982 Conference in Vienna a receive-only station was used to pick up regular SPINE data transmissions (see article on page 11). Discussions are in progress with Eutelsat on the continuation of operations beyond May 1983.

Démonstration du système ESA de transmission/réception de données par satellite au cours de la Conférence UNISPACE '82

Part of ESA's satellite data-transmission/reception demonstrations at UNISPACE '82

Marecs

Inmarsat have been utilising Marecs-A over the Atlantic Ocean since 1 May 1982. Performance has been completely satisfactory.

After incorporation and testing of the hardware modifications aimed at eliminating the type of electrostatic discharges and associated interferences that occurred on Marecs-A in February, the Marecs-B spacecraft was successfully tested at system level. The formal Flight-Model Acceptance Review was held at ESTEC on 26 June and cleared the spacecraft for shipment to Kourou on 2 July.

The launch campaign started immediately thereafter with the electrical preparation and functional checks leading to the Flight-Readiness Review on 17 July, at which the spacecraft was declared flightworthy. The launch campaign was interrupted between 20 July and 10 August, in view of the planned 10 September (GMT) launch date. After resumption of the campaign, the final operations of fuel loading, apogee-motor installation and balancing were completed prior to integration of the satellite on the Sylda (the special housing used on Ariane when launching two satellites into geostationary orbit). (Late news: see page 83 re launch failure.)

Meteosat

Space segment

Meteosat-1 and 2 have continued to operate satisfactorily over the past three months, Meteosat-2 providing images of the Earth in the visible, infrared and water-vapour bands every thirty minutes, while Meteosat-1 continues to support the data-collection platform (DCP) mission.

Ground segment

During July the full computer configuration was implemented and the system can now be regarded as operational. Some software development is still outstanding, but it does not affect the users. The new antenna for the Data Collection System has been installed in the Odenwald and will be put into operation early in September. The availability of the system has been high during the last quarter.

After mid-September, the meteorological products will also be disseminated operationally at midnight.

Operational programme

In July the German Government decided to participate in the working groups on the Meteosat Operational Programme, making it possible to resume the preparatory work that was stopped in November 1981.

Exosat

Satellite

During the last quarter, flight-model tests have proceeded according to plan. Prior to the start of the thermal vacuum test at ESTEC (HBF3) in April, the satellite's functional performance had been rechecked and found to be satisfactory. Upon completion of the exposure to vacuum and thermal cycling, and as a result of the ensuing functional checkout, the test review board concluded that all test objectives had been met, given the limitations of some non-flight-standard hardware.

Reintegration and retest activities were initiated early in June to achieve the final-flight configuration. All payloads units have meanwhile been integrated and functional performance verification tests carried out. Completion of these tests early in July was followed by integration of *limitations concernant quelques éléments non conformes aux normes de vol.*

Les activités de réintégration et de reprise des essais ont commencé début juin en vue de parvenir à la configuration de vol finale. Tous les éléments de la charge utile ont entre-temps été intégrés et les essais destinés à vérifier leurs performances fonctionnelles exécutés. A l'issue de ces essais a commencé l'intégration de plusieurs éléments du modèle de vol du véhicule spatial, comme le suiveur stellaire, le mécanisme du réseau solaire et l'électronique du système de commande d'orientation et de correction d'orbite (AOCE).

Sous réserve du bon résultat des opérations de remise en état et des essais de recette du deuxième boîtier électronique de ce système aux normes de vol un échange pourrait être envisagé.

Charge utile
La totalité des équipements de la charge utile d'Exosat, soit huit détecteurs de l'expérience 'moyenne énergie', deux télescopes imageurs et l'expérience de scintillateur à gaz, a été intégrée dans le modèle de vol du véhicule spatial. Auparavant, on avait effectué l'étalonnage scientifique de tous les instruments, l'incorporation des systèmes 'suppresseurs de pings' et des déflecteurs de plasma sur les télescopes et les essais en vibration et sous vide thermique au niveau des unités. Parmi les travaux qui restent encore à faire sur la charge utile figurent les essais terminaux des unités de réserve et le remplacement d'un boîtier d'électronique de l'expérience 'moyenne énergie' par un autre doté de réglages du temps de montée optimisés.

Secteur sol
Les travaux progressent comme prévu pour un lancement en novembre. Le transfert de l'équipement de la station de Vilspa au Département Opérations de l'ESOC est prévu pour la seconde moitié de septembre. Un certain nombre de problèmes techniques ont retardé la deuxième série des essais de compatibilité qui ont cependant été finalement menés à bien.

Les travaux de mise au point sont bien avancés pour la plupart des logiciels d'opérations mais les problèmes rencontrés avec la nouvelle configuration de calculateur ont retardé les travaux concernant le logiciel de manoeuvre. Ce problème devrait être résolu au cours des essais de mise en service.

Le système d'analyse approfondie des données (Extended Data Analysis) a été installé à l'ESOC; il utilise certains des éléments de l'équipement d'essai au sol de la charge utile. L'équipe des observations Exosat a été transférée du Département Science spatiale de l'ESTEC à l'ESOC. Les préparatifs en vue de l'exploitation et de l'analyse des données par cette équipe ont avancé de façon satisfaisante et des mesures sont prises d'urgence pour parer aux incertitudes concernant la bonne disponibilité des paramètres de base provenant de l'étalonnage des télescopes imageurs.

Deux cents propositions d'observations, sur un total d'environ 500 soumises, ont été provisoirement acceptées en vue de leur exécution au cours des neuf premiers mois d'exploitation orbitale. On étudie actuellement la séquence détaillée des observations.

Lanceur
La situation des préparatifs du lancement a été réexaminée à deux reprises et un plan combiné des opérations de lancement a été établi pour préciser en particulier les services requis pour les opérations satellite/lanceur.

Le dossier d'analyse de la mission a fait l'objet d'un examen en juin. Toutefois, les prévision définitives de performances, tenant compte de diverses contraintes importantes du lanceur, devront faire l'objet d'un examen approfondi avant la Revue d'état de préparation au vol du lanceur.

The Exosat observatory facility at ESOC in Darmstadt

Installation de calcul et d'observation pour Exosat à l'ESOC, Darmstadt

Télescope spatiale

Générateur solaire
Les modifications apportées par le fabricant aux mâts bi-stem ont nécessité des essais additionnels de longévité et d'endurance. Ces essais ont été exécutés avec succès et les cassettes des matériels de vol sont en cours de préparation pour les essais de recette.

several flight-model spacecraft units, e.g. star tracker, solar-array mechanism, attitude and orbit control system electronics (AOCE).

Subject to satisfactory completion of refurbishment and unit acceptance testing of the second FM-AOCS-electronics box an exchange might be considered later.

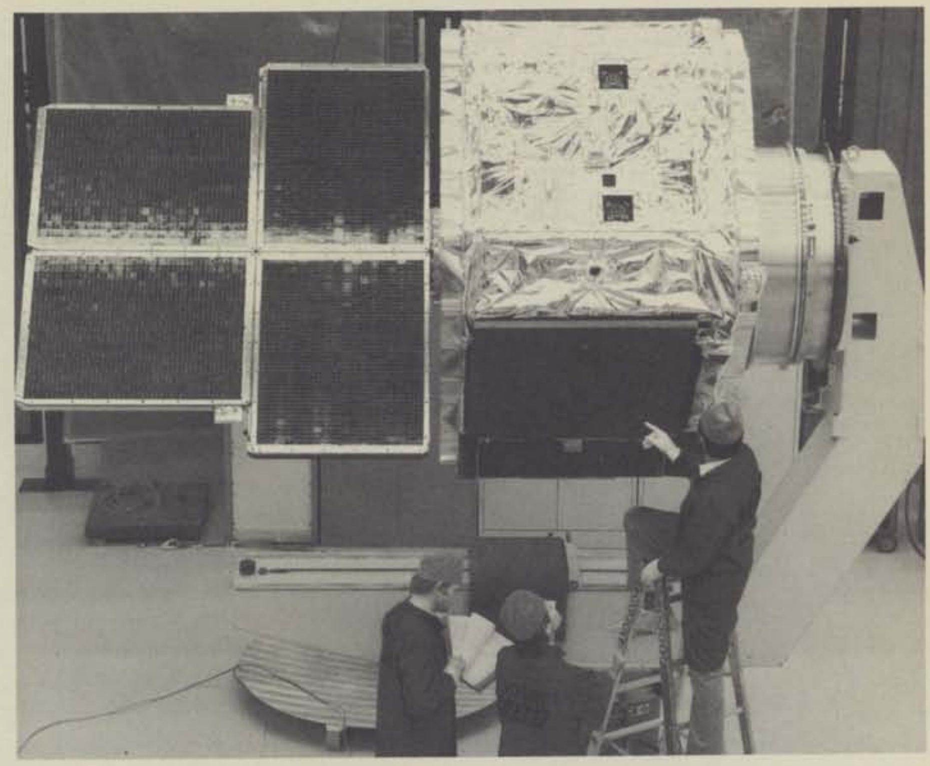
Payload
The complete Exosat payload complement of eight medium-energy experiment detectors, two imaging telescopes and the gas-scintillator experiment have been integrated with the flight-model spacecraft. This follows scientific calibration of all instruments, the incorporation of the 'ping-quencher' systems and plasma baffles on the telescopes and unit-level vibration and thermal vacuum testing. Work on the payload still to be undertaken includes final testing of spare units and the exchanging of a medium-energy experiment electronics box for one with optimised rise-time rejection settings. Final preparation of the low-energy telescopes (LEITS) will start in advance of the nominal launch campaign in order to allow re-integration into the flight-model satellite on time.

Ground segment
Work is on schedule for a launch in November. Handover of station equipment at Vilspa to ESOC's Operations Department is planned for the second half of September. Some technical problems delayed the second series of compatibility tests, but these were finally performed successfully.

Development of most of the operations software is well advanced, but problems with the new computer configuration have delayed work on the manoeuvre software. This problem should be remedied during the commissioning tests.

The Extended Data Analysis system has been installed at ESOC using some items of payload ground-test equipment. The Exosat observatory team has been transferred from ESA Space Science Department at ESTEC to ESOC.

Preparations for operations and analysis by the observatory team have proceeded satisfactorily and urgent action is underway to ensure timely availability of the basic parameters from the imaging-telescope calibrations.



Mesure de paramètres physiques d'Exosat chez MBB (début 1982)

Exosat physical-measurement work in progress at MBB in Germany earlier this year

Two hundred observation proposals have been provisionally accepted from about 500 submitted for execution in the first nine months of orbital operations. The detailed observation sequence is now being determined.

Launcher
Launch-preparation status has been reviewed twice and a combined launch/operations plan established identifying in particular those services required for satellite/launcher operations.

The mission-analysis file was the subject of a review in June. However, final performance predictions covering various important launcher constraints will have to be scrutinised prior to the Launcher-Readiness Review.

Space Telescope

Solar array
Some modifications introduced by the manufacturer in the bi-stem booms have necessitated additional life and fatigue testing. These tests have now been conducted satisfactorily and the flight-hardware cassettes are being prepared for acceptance testing.

During the last quarter, agreement has been reached between the contractor on all the modifications to the solar-array-drive electronics needed for a low interactive torque during slewing of the solar array. Progressive re-testing is starting and an overall system dynamic test is scheduled for November 1982.

The second thermal-cycling qualification run for blanket samples from −100°C to +100°C has successfully completed 30 000 cycles. Agreement has been reached with NASA on the basic principles for support at the NASA contractor's site during solar-array-related integration and verification activities. Delivery of the solar-array electronic boxes to NASA is foreseen by July 1983 and the flight arrays are scheduled for delivery in February 1984.

Faint-Object Camera
The large image instability observed in one direction of the f/96 optical chain during thermal vacuum tests has been isolated and is being corrected. Mass-

Au cours du dernier trimestre, toutes les modifications à apporter à l'électronique d'entraînement du réseau solaire pour réduire le couple d'interaction pendant les manoeuvres d'orientation du réseau solaire ont été arrêtées avec le contractant. La répétition progressive des essais commence et l'essai dynamique de l'ensemble du système est prévu pour novembre 1982.

La deuxième série d'essais de qualification d'échantillons de la nappe sous cycles thermiques de −100°C à +100°C a atteint avec succès les 30 000 cycles. Un accord est intervenu avec la NASA sur les principes de base d'un soutien chez le contractant NASA pendant les activités de vérification et d'intégration concernant le réseau solaire au niveau du Télescope spatial. La livraison des boîtiers électroniques du réseau solaire à la NASA est prévue pour juillet 1983 et celle des ailes aux normes de vol pour février 1984.

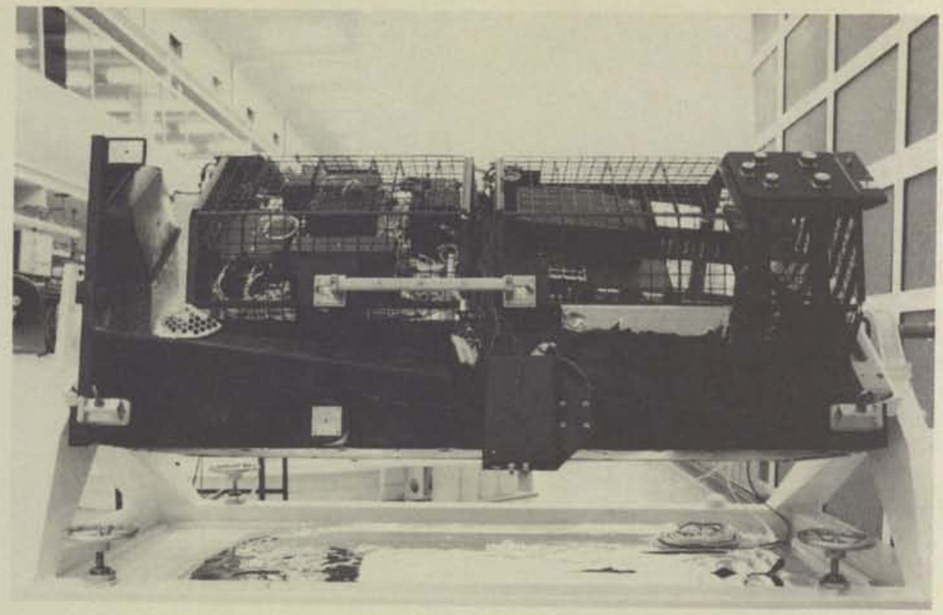
Chambre pour astres faibles

La grande instabilité constatée dans une direction de l'image sur le parcours optique à f/96 pendant les essais thermiques sous vide a été expliquée et sa correction est en cours. Les essais relatifs aux caractéristiques de masse et magnétiques ont été exécutés. Les essais de longévité de tous les mécanismes se sont déroulés de façon satisfaisante. Les cartes aux normes de vol de la mémoire de données scientifiques ont été fabriquées. L'électronique de rechange et une station de vérification ont été livrées au Goddard Space Flight Center pour des essais préliminaires d'interface avec le système de télécommande et de gestion des données de l'instrumentation scientifique de la NASA.

Détecteur de photons

Les essais exécutés sur le modèle d'identification du détecteur de photons dans les installations de Liège ont donné des résultats satisfaisants.

Les nouveaux tubes analyseurs aux normes de vol ont été livrés par Westinghouse et les travaux de développement portant sur l'habillage destiné à protéger ces tubes contre les effluves en couronne ont été repris. Une autre tête de détecteur reposant sur une section 'chambre' sans enrobage a été montée en vue de travaux de développement complémentaires. L'association de cette tête de détecteur et du modèle d'identification amélioré servira de modèle électrique du détecteur de photons, représentatif du modèle de vol, pour une vérification complète des interfaces à l'intérieur de la chambre pour astres faibles. Le retard de 9 mois prévu pour la disponibilité des tubes analyseurs aux normes de vol peut ainsi être ramené à 5 mois en ce qui concerne la livraison de la FOC à la NASA actuellement prévue pour la mi-septembre 1983.



Space Telescope Faint-Object Camera (FOC) during test activities at ESTEC in June

Essais de la Chambre pour astres faibles du Télescope spatial à l'ESTEC (juin '82)

Hipparcos

L'examen de définition de système, qui a eu lieu comme prévu début juillet, a permis d'identifier un certain nombre de secteurs de difficultés mais aucun d'eux n'est apparu critique pour le projet ou comme nécessitant des modifications de la conception de base qui s'est précisée au cours de la période initiale de 6 mois de la phase de définition du système. Le passage à une phase de définition de système non concurrentielle a permis d'ajuster la planification du reste de cette phase pour pousser au maximum la définition au niveau système et sous-système, tout en maintenant la date initialement prévue pour le démarrage de la phase de réalisation (milieu de 1983). Les travaux progressent en ce qui concerne la définition plus détaillée; la remise préliminaire, aux sous-traitants, des lots de travaux relatifs à la soumission concernant les sous-systèmes est prévue pour début octobre et l'examen de définition des sous-systèmes pour la mi-novembre 1982.

Giotto

La phase principale de réalisation (phase C/D) progresse conformément au calendrier; les instruments scientifiques qui procèderont à des mesures in situ à proximité de la comète de Halley en sont au stade de la mise au point dans les différents instituts scientifiques participants.

Le premier modèle de développement du véhicule spatial sera la maquette électrique, qui doit être intégrée et essayée chez British Aerospace début 1983. Ce sera la représentation électrique complète des sous-systèmes et instruments scientifiques du véhicule spatial. Outre les données utiles qu'elle fournira en termes d'essais et de préparation à la mission, cette maquette servira à mettre en évidence les modifications qui devront être apportées au modèle de vol. Les délais étant très courts avant le lancement, les travaux sur le modèle de vol suivront immédiatement les essais sur la maquette électrique;

property and magnetic tests have been carried out. The life testing of all mechanisms has been completed successfully. The flight boards of the scientific data store have been manufactured. The spare electronics-bay assembly and a checkout station have been delivered to Goddard Space Flight Center for early interface testing with the NASA scientific instrument command and data-handling system.

Photon Detector Assembly

Tests with the engineering-model PDA have been carried out satisfactorily at Liege.

The new flight camera tubes have been delivered by Westinghouse and the development work for packaging these tubes into a corona-free tube assembly has been resumed. Another detector-head unit based on a non-potted camera section has been assembled for further development work. This detector-head unit, plus the upgraded engineering model, will be used as a flight-representative PDA electrical model for complete interface verification within the Faint-Object Camera. In this way the 9 month delay in availability of the flight camera tubes can be contained to a 5 month delay in FOC delivery to NASA, which is currently forecast for mid-September 1983.

Hipparcos

The System Definition Review, which took place in early July as planned, identified some problem areas, but none of a project-critical nature or requiring changes to the basic design that has emerged during the initial six-month period of the System Definition Phase. The change to a noncompetitive System Definition Phase has allowed the planning for the remainder of the phase to be adjusted to permit maximum definition at system and subsystem level, while retaining the originally planned date for the commencement of the Development Phase (mid-1983). Work is proceeding on the more detailed definition, with the preliminary issue of subsystem bid packages to subcontractors anticipated for the beginning of October and the Subsystem Definition Review planned for mid-November 1982.

Giotto

The main development phase (C/D) is proceeding on schedule, and the scientific instruments for performing in-situ measurements at comet Halley are already under development at the various participating scientific institutes.

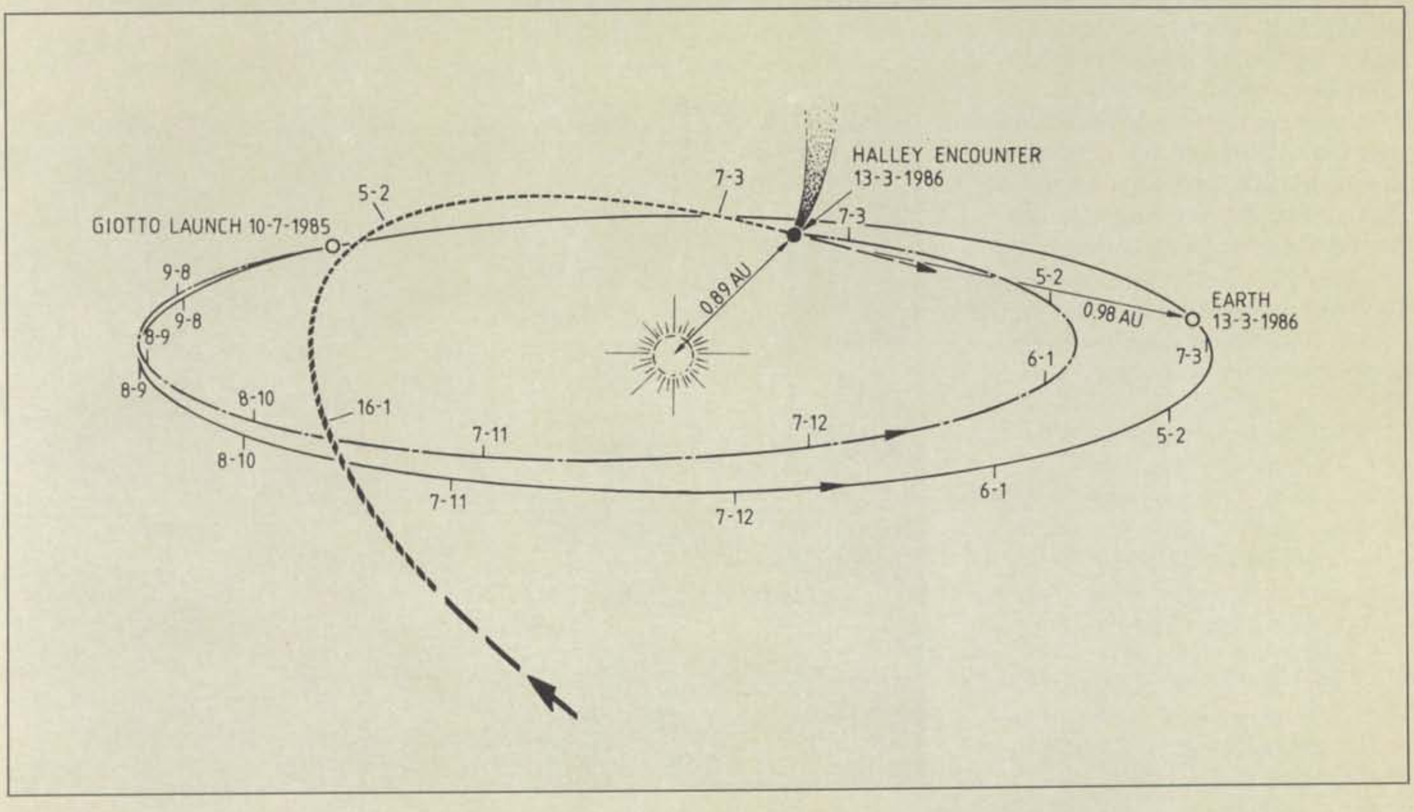
The first spacecraft development model will be the electrical model, to be integrated and tested at British Aerospace early in 1983. It will be a complete electrical representation of the spacecraft subsystems and scientific instruments. This model will not only provide useful test and training data, but will also serve to identify any design changes that may have to be made to the flight spacecraft.

Due to the somewhat restricted time available before launch, work on the flight-model spacecraft follows closely behind that on the electrical model, with integration starting in January 1984 and completion of integration/testing scheduled for early 1985.

Giotto will be launched by an Ariane-3 vehicle in July 1985, with a companion spacecraft known as Brazilsat. Negotiations with Arianespace, the launching Authority, are nearing completion, and detailed engineering

Trajectoire type de Giotto depuis le lancement (10.7.1985) jusqu'au rendez-vous avec la comète de Halley (13.3.1986)

Reference trajectory for Giotto from launch on 10 July 1985 to post-perihelion Halley encounter on 13 March 1986



l'intégration démarrera en janvier 1984; l'achèvement de l'intégration et des essais est fixé au début de 1985.

Giotto sera lancé par un lanceur du type Ariane 3 en juillet 1985 en même temps qu'un satellite appelé Brazilsat. Les négociations avec Arianespace, responsable du lancement, sont en voie d'achèvement et l'on travaille au détail des interfaces techniques avec le lanceur.

La trajectoire de la comète étant affectée non seulement par l'attraction du soleil et des planètes, mais aussi par son activité propre, les opérations de navigation et de visée seront une tâche relativement complexe pour Giotto comme pour les véhicules spatiaux russe et japonais. C'est pourquoi l'Europe, l'URSS, le Japon et les Etats-Unis (la NASA est chargée de la Veille internationale de la comète de Halley et établit la modélisation de ses éphémérides) travailleront en coopération internationale afin de tirer un profit scientifique optimal de ces trois missions.

ECS

Le programme ECS en est à la phase finale de développement et d'essais qui doit aboutir au lancement du premier satellite de la série fournie à Eutelsat. Le programme a subi un léger retard, car des modifications ont dû être apportées au satellite par suite des anomalies constatées dans le fonctionnement en orbite de Marecs-A. Ces modifications découlaient pour l'essentiel de la nécessité d'assurer une protection contre les effets de phénomènes de décharges électrostatiques. En outre, les problèmes rencontrés dans la mise au point des amplificateurs de tube à ondes progressives (décommutations inopinées) ont entraîné des travaux d'analyse et d'essai supplémentaires, toujours en cours.

A l'heure actuelle, ECS-1 se trouve chez IABG, Munich, pour y subir des essais acoustiques avant de retourner à Toulouse pour ses derniers essais au niveau système et son expédition à Kourou. Le satellite doit normalement être prêt à être lancé dès novembre 1982.

Le module de servitude d'ECS-2 se trouve à un stade avancé de son intégration, à Toulouse. Le module de télécommunications est chez le contractant responsable de la charge utile (AEG Backnang) en attendant qu'aboutissent les investigations relatives aux amplificateurs de tube à ondes progressives; il sera ensuite couplé au module de servitude et subira les préparatifs nécessaires en vue de son programme d'essais au niveau système. Il sera en principe prêt à être lancé en juillet 1983. La station d'essais et de surveillance de Redu est pratiquement prête à fonctionner pour les satellites ECS.

Sirio-2

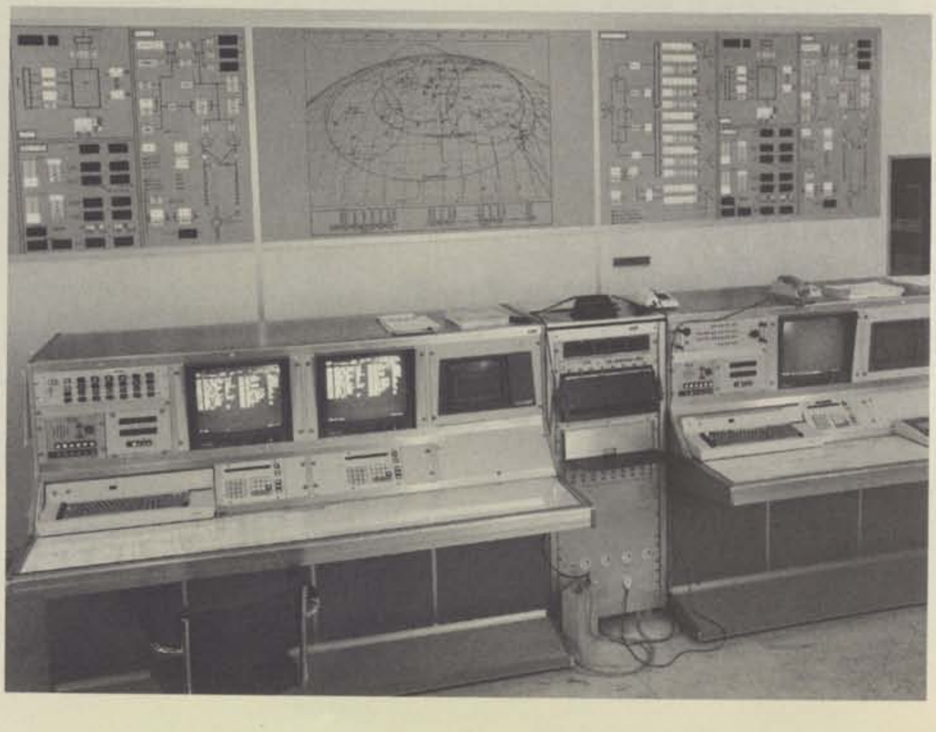
Après l'interruption de la campagne de lancement en mars 1982, le satellite Sirio-2 est resté dans son conteneur à Kourou jusqu'à la reprise de la campagne, en juillet. Certaines améliorations ont été apportées à l'équipement de vérification au cours de la période 'd'attente'. A l'heure où nous mettons sous presse, la préparation de la campagne de lancement est presque terminée. Le satellite a été préparé pour le lancement et le composite Sirio-2/Marecs-B/Sylda est prêt à être transporté sur le site Ariane.

Il a été procédé à l'ESOC et sur les moyens sol de Sirio-2 à Fucino à de très nombreuses simulations. Celles-ci ont permis d'éliminer de petits défauts dans la conception du système et donné au personnel l'occasion d'acquérir un entraînement utile en prévision des opérations des premières orbites et de la mise en service, ainsi que des opérations relatives à la mission MDD et à l'expérience Lasso (voir dernières nouvelles page 83).

Télédétection

Campagne SAR-580
Le traitement optique des données est maintenant terminé et les dernières scènes seront distribuées courant septembre. Le traitement digital a été perturbé par le déménagement des calculateurs du DFVLR, et par la nécessité de corriger le logiciel de traitement mis en évidence par le contrôle de qualité sur les produits de sortie. Plusieurs solutions pour pallier ce défaut sont en cours d'examen.

ERS-1
La Déclaration relative à la phase B



The ECS ground-station control console at Redu in Belgium

Console de commande de la station vol d'ECS à Redu, Belgique interfaces with the launch vehicle are being worked out.

As the comet's path is affected not only by the gravitational effects of the Sun and planets, but also by its inherent activity, navigation and targetting will be a comparatively complex task for Giotto and for the Russian and Japanese spacecraft. An international cooperative effort by Europe, the USSR, Japan and the USA (NASA is managing the International Halley Watch and providing comet-ephemeris modelling) has therefore been established with the intention of optimising the scientific return from the three missions.

ECS

The ECS programme is in the final development and test phase leading to the launch of the first satellite in the series being provided for Eutelsat. The programme was delayed slightly owing to the need to introduce modifications to the spacecraft as a result of anomalies seen in the in-orbit performance of Marecs-A. These modifications were necessary to protect against the effect of electrostatic-discharge phenomena. In addition, development problems with the travelling-wave-tube amplifiers (spurious switch-offs) have required extra analysis and testing, which is still in process.

At present, ECS-1 is at IABG Munich for acoustic testing prior to returning to Toulouse for its final system-level tests and shipment to Kourou. The satellite should be ready for launch in November 1982.

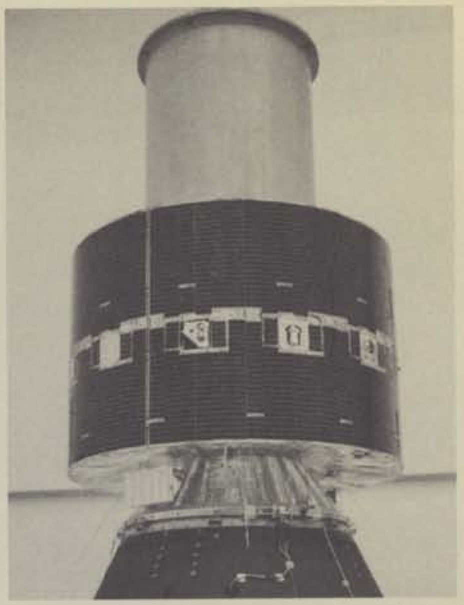
The ECS-2 service module is in an advanced stage of integration in Toulouse. The communications module is at the payload contractor's plant (AEG, Backnang) awaiting resolution of the travelling-wave-tube amplifier investigations, after which it will be mated with the service module and prepared for its system-level test programme. It is expected to be ready for launch by July 1983.

The Test and Monitoring Station at Redu is virtually ready for use with the ECS satellites.

Sirio-2

Following the aborted launch campaign in March 1982, the Sirio-2 spacecraft was stored in its container in Kourou until the resumption of the campaign in July. Certain improvements were made to the check-out equipment during the standby period. At the time of writing (end August), the launch campaign is nearing completion. The satellite has been prepared for launch, and the Sirio-2/ Marecs-B/Sylda assembly is ready for transport to Ariane.

Intensive pre-launch simulations have been carried out at ESOC and at the Sirio-2 ground facilities in Fucino. The simulations have served to remove minor system design faults and provide adequate personnel training in preparation for early-orbit, commissioning, MDD and Lasso operations (late news: see page 83 re launch failure).



Intégration de Sirio-2 sur la base de lancement de l'ESA à Kourou (septembre 1982)

Sirio-2 during integration at the Agency's Kourou launch base in September

Remote Sensing

SAR 580 campaign

The optical processing of data has now been completed and the last images will be distributed in September. Digital processing was upset by the move of the DFVLR computers and by the need to correct the processing software revealed by output-product quality control. Various ways of overcoming this deficiency are under study.

ERS-1

The Declaration on Phase-B (definition phase) of ERS-1 has been subscribed to by 12 Member States, representing 95.17% of the contributions; the only country not participating is Ireland.

The industrial Phase-B began on 4 August at Dornier, after the Agency's Industrial Policy Committee (IPC) had approved the contract proposal submitted on 30 July. It will end in June 1983, with a cost proposal for the subsequent phases (detailed definition and development).

The Executive is arranging an experimental campaign with a C-band scatterometer in order to obtain a model of the sea in this band, and to demonstrate its belief that the wind parameter can be extracted with the performances stipulated in the mission objectives. This campaign will take place in 1983.

Remote sensing experiments for FSLP

A meeting of the Investigators Working Group is being held in the USA from 30 August to 3 September 1982; representatives of the Executive are attending.

Spacelab

Following the delivery of Spacelab Flight Unit Configuration-I (FU-I) to the Kennedy Space Center (KSC), two assemblies have now been completed: the 'Long Core Module' and the 'Long Experiment Train'. The former consists of the Forward End Cone, the Core Module, the Experiment Segment, the Work Bench Rack, the Control Centre Rack and the Subfloor. Subsystem checkout of this assembly has been completed, so that the system is now ready to accept the payload. So far very few problems have been encountered during the assembly and checkout activities which, bearing in mind the complexity of the system, is indicative of high hardware and software quality. The Long Experiment Train has been hooked up to the integrated pallet and the ESA/NASA payload for Spacelab Mission-d'ERS-1 a été souscrite par 12 Etats représentant 95,17% des contributions; seule l'Irlande ne participe pas.

La phase B industrielle a commencé le 4 août chez Dornier, après accord de l'IPC sur la proposition de contrat presentée le 30 juillet. Elle se terminera en juin 1983 par la remise d'une proposition de prix pour les phases ultérieures (définition précise et développement).

L'Exécutif met sur pied une campagne expérimentale avec un diffusiomètre en bande-C pour obtenir un modèle de mer dans cette bande, et renforcer la confiance de l'Exécutif dans la possibilité d'extraire le paramètre vent avec les performances mentionnées dans les objectifs de mission. Cette campagne se déroulera en 1983.

Expériences de Télédétection de la FSLP

Une réunion de l'IWG (Investigators Working Group) à laquelle participaient des représentants de l'Exécutif s'est tenue aux Etats-Unis du 30 août au 3 septembre 1982.

Spacelab

Après la livraison de la configuration de vol Spacelab no 1 (FU-I) au Centre spatial Kennedy (KSC), deux ensembles viennent d'être terminés: le 'module central long' et le 'train d'expériences long'. Le premier comprend le cône avant, le module central, le segment 'expériences', le bâti 'établi', le bâti 'centre de contrôle' et les équipements sous plancher. La vérification des sous-systèmes de cet ensemble est terminée et le système est maintenant prêt à recevoir la charge utile. Très peu de problèmes ont été rencontrés jusqu'ici dans les activités d'assemblage et de vérification ce qui, compte tenu de la complexité du système, témoigne de la haute qualité des matériels et des logiciels. Le train d'expériences long a été accroché au porte-instruments intégré et subit maintenant les opérations de vérification de la charge utile ASE/NASA de la mission Spacelab no. 1, de façon à pouvoir être couplé au Spacelab.

Le modèle de qualification de l'enregistreur de données à haut débit (HDRR) a très bien fonctionné durant les essais au KSG et la livraison du modèle de vol de l'HDRR en temps utile pour l'exécution de la mission SL-1 en septembre 1983 semble désormais assurée.

En ce qui concerne la configuration de vol no. 2 (FU-II), les activités d'intégration et d'essais chez ERNO à Brême ont été achevées et la commission réunie le 2 juillet 1982 a conclu positivement l'examen de recette définitive. Le transport à destination du KSC, assuré par deux avions, a suivi les 26 et 29 juillet respectivement. Ces matériels, dont l'inspection est en cours, seront entreposés jusqu'à la fin du premier trimestre en 1983. Ces systèmes ne sont requis que pour la mission Spacelab no. 2 actuellement prévue pour novembre 1984.

Le système de pointage d'instruments (IPS) a fait l'objet d'un examen critique de conception (CDR) en août 1982. Cet examen ayant été passé avec succès, la NASA a donné le feu vert pour la production du deuxième IPS à approvisionner dans le cadre du programme de production ultérieure. Les points encore en suspens concernent la confirmation des performances en cas de perturbations dues à la présence de l'homme et l'analyse détaillée de la sécurité offerte par l'ensemble de fixation de la charge utile (PCA).

Le programme de production ultérieure du Spacelab (FOP) dans le cadre duquel la NASA achète un deuxième Spacelab avance selon le calendrier prévu.

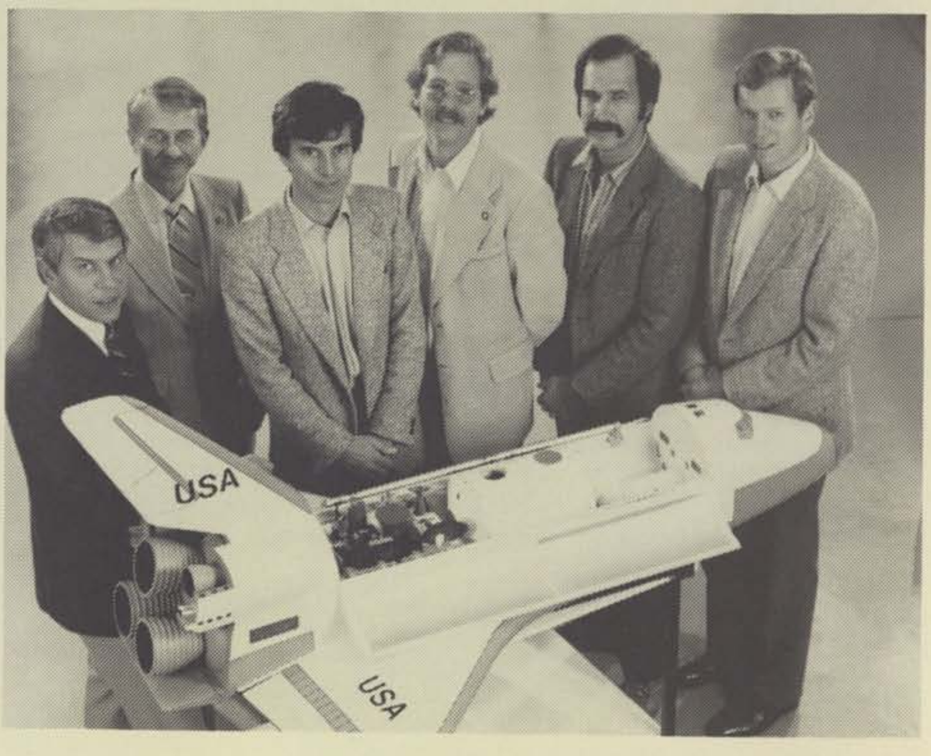
FSLP

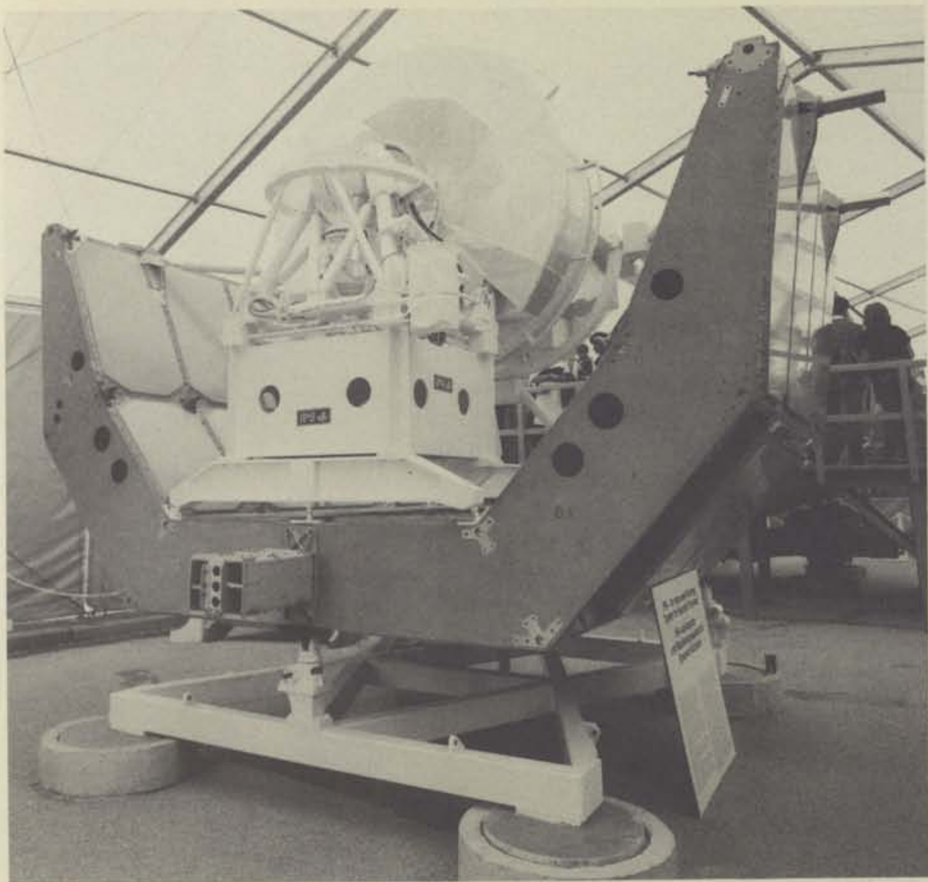
A l'issue de la remise en état et des essais qui se sont déroulés chez MBB, le bâti double de sciences des matériaux a été livré au KSG de la NASA le 6 juillet, comme prévu. Il y a rejoint le reste de la charge utile pour participer aux activités d'intégration de niveau IV. Les activités parallèles, telles que vérification d'ajustage, étalonnage, procédure de clôture des bâtis, se sont poursuivies conformément aux prévisions. En juillet, le matériel européen et la documentation correspondante ont été officiellement remis à la NASA.

Le pont intermédiaire européen (EBA) a ensuite été intégré au porte-instruments, à côté de l''orthogrid' de la NASA, et les bâtis ont été installés sur le plancher du compartiment de vol. Les équipements de vérification des expériences ont été mis en place et testés en vue des essais fonctionnels qui doivent commencer en septembre.

European Spacelab-1 Payload Specialists Ulf Merbold (flight) and Wubbo Ockels (reserve) with their American counterparts Byron Lichtenburg (flight) and Michael Lampton (reserve), and US Mission Specialists Owen Garriott and Bob Parker

Les spécialistes européens de charge utile Spacelab – Ulf Merbold (sélectionné pour le vol) et Wubbo Ockels (en réserve) avec leurs collègues américains Byron Lichtenberg (sélectionné pour le vol) et Michael Lampton (reserve), en compagnie des spécialistes mission américains Owen Garriott et Bob Parker





Modèle d'IPS exposé à l'UNISPACE '82

Model of IPS on display at UNISPACE '82

One is now being checked out so that it can be mated to the Spacelab.

The High-Data-Rate Recorder (HDRR) qualification model has performed very well during tests at KSC and delivery of the flight model for a September 1983 launch now seems assured.

Integration and test activities at ERNO (Bremen) on Flight Unit Configuration-II (FU-II) have been completed and the Final Acceptance Review held successfully on 2 July 1982. Transport to KSC by two aircraft followed on 26 and 29 July. This hardware is now being inspected and will be stored until the end of the first quarter of 1983. These systems are needed for Spacelab Mission-Two, currently scheduled for November 1984.

The Instrument Pointing System (IPS) underwent a successful Critical Design Review (CDR) in August 1982, and NASA gave the go-ahead for the production of the second IPS to be procured under the Follow-On Production programme. Remaining tasks include confirmation of performance for the 'man-disturbed mode' and detailed analysis of the safety of the Payload Clamp Assembly (PCA).

The Spacelab Follow-On Production (FOP) programme, under which NASA is purchasing a second Spacelab, is proceeding on schedule.

FSLP

After finalisation of refurbishment and testing at MBB, the Material Science Double Rack was delivered to NASA/KSC on 6 July on schedule. There it joined the rest of the payload in the Level-IV integration flow. Off-line activities, such as fit-checks, calibration, close-out of racks, was continued as planned. In July the European hardware and accompanying documentation was officially handed over to NASA.

The European Bridge Assembly (EBA) was subsequently integrated into the pallet, next to the NASA orthogrid, and the racks were installed on the flight floor. The experiment check-out equipment was set up and verified, in preparation for the functional tests scheduled to start in September.

A SPICE office has been opened at NASA/KSC, since the end of May, to manage the ground operation activities.

At NASA/MSFC, the SPICE group and contractors continued preparation of the mission operations, and flight timeline analysis.

The crew continued training in the Payload Crew Training Complex at NASA/MSFC, as well as receiving classroom training on the use of the Experiment Computer Application Software.

A procurement action has been initiated for a single Spacelab rack for the Sled payload element on the German Spacelab D1, and preparations have been made to issue an RFQ for the payload-element integration activities.

Microgravity

The Microgravity Research Programme consists of three elements: the Biorack, the Improved Fluid Physics Module (IFPM) and the Sounding-Rockets Programme.

Biorack

The formal System Definition Review was held at the end of June 1982. The Review Board and the Biorack Science Team considered the system 'healthy', though it recognised that the proposed solution of controlling the temperature of biological specimens during launch and landing with passive thermal canisters is critical and is still to be proved by testing.

Tests on the full-scale model of the freezer/cooler combination unit have shown its performance to be near nominal and that only minor modifications would be required to give the assurance that specification requirements will be met. Testing of a first thermal-control canister is about to be started.

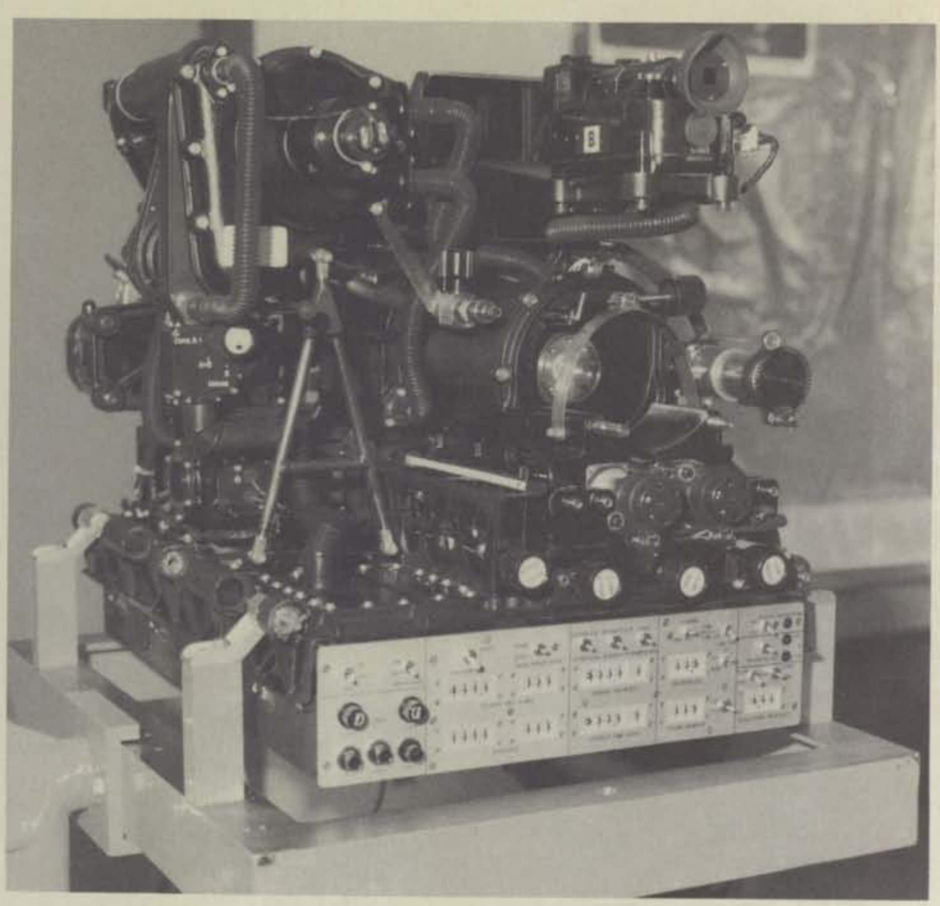
Other activities have been:
- to place a contract with ERNO (D) for the supply of a Spacelab single rack and standard equipment (procured by SPICE)
- to start Phase-B in industry for the thermal-conditioning units and

Depuis fin mai, un bureau du SPICE est ouvert au KSG de la NASA pour assurer la gestion des activités relatives aux opérations au sol.

Au MSFC de la NASA, le groupe SPICE et les contractants ont poursuivi les préparatifs des opérations de mission et l'analyse de la séquence opératoire en vol.

L'équipage a poursuivi son entraînement au centre de formation des équipages de la charge utile, au MSFC de la NASA, ainsi que sa formation théorique pour l'utilisation du logiciel d'application des ordinateurs des expériences.

L'approvisionnement d'un bâti simple du Spacelab a été décidé pour l'élément de charge utile Sled qui sera embarqué sur la mission allemande D1, et on a préparé l'envoi d'une demande de prix couvrant les activités d'intégration de l'élément de charge utile.



The Fluid Physics Module which will form part of the First Spacelab Payload (FSLP)

Le Module de Physique des Fluides, un des éléments de la Première Charge utile Spacelab

Microgravité

Le programme de recherche en microgravité comporte trois éléments: le Biorack, le module de physique des fluides amélioré (IFPM) et le programme d'expériences à bord de fusées-sondes.

Biorack

L'examen officiel de définition de système a eu lieu à la fin de juin 1982. La Commission d'examen ainsi que l'Equipe scientifique du Biorack ont estimé que le système était sain; elles ont cependant indiqué que la solution proposée pour assurer la régulation de température des substances biologiques au cours des phases de lancement et l'atterrissage à l'aide d'enceintes thermiques passives était critique et que l'on devait encore faire preuve de sa validité par des essais.

Les essais effectués sur la maquette en vraie grandeur de la combinaison congélateur/réfrigérateur ont montré que les performances de cet ensemble étaient voisines des caractéristiques nominales; seules des modifications mineures seraient nécessaires pour avoir l'assurance que les impératifs de la spécification sont respectés. L'essai d'une première enceinte de régulation thermique est sur le point de commencer.

Les autres activités ont été les suivantes:

- *passation avec ERNO (D) d'un contrat pour la fourniture d'un bâti simple du Spacelab et d'un équipement normalisé (approvisionné par le SPICE);*
- *démarrage de la phase B dans l'industrie pour les dispositifs de conditionnement thermique et les dispositifs expérimentaux associés [Matra (F) choisi avec BTM (B) et Dornier (D) comme sous-traitant(s)];*
- *lancement de l'appel d'offres concurrentiel restreint pour la boîte à gants;*
- *poursuite de l'étude des expériences proposées dans le cadre de la préparation du choix officiel de la charge utile de la première mission qui doit être fait par le Conseil directeur du programme Spacelab au mois d'octobre.*

Les études de phase B du **module de physique des fluides amélioré** *(IFPM) ont commencé fin juin 1982. Cette phase durera sept mois, après quoi on examinera si l'IFPM est compatible avec le calendrier de la mission Spacelab D1 allemande ou si son embarquement doit être reporté à une mission Spacelab ultérieure, le module de physique des fluides de la première mission Spacelab devant alors, dans ce cas, être remis en état et embarqué sur la mission D1.*

Un appel de propositions d'expériences pour l'emport prévu de l'IFPM sur la mission D-1 a été lancé le 9 juillet 1982.

En ce qui concerne le **programme d'expériences à bord de fusées-sondes**, *les résultats du vol TEXUS-VI sont en cours d'évaluation. L'ESA a participé pour la première fois à ces activités à bord de fusées-sondes en assurant le financement de 60% de la charge utile de 240 kg, composée de expériences différentes dont 6 conçues dans le cadre du programme de l'ESA.*

L'Exécutif a reçu 22 propositions en réponse à l'avis de possibilité de vol sur TEXUS-VII/VIII en avril/mai 1983.

Eureca

Les études de pré-phase A concernant le porte-instruments récupérable européen (Eureca) se sont achevées en juin 1982 et ont démontré la faisabilité technique du concept Eureca. Pour la définition de la

associated experiment provisions [Matra (F) selected, with BTM (B) and Dornier (D) as subcontractor(s)]
- to release the request for tender for the glovebox under a restricted, competitive tender action
- to continue candidate-experiment studies in preparation for the formal selection, to be made by the Spacelab Programme Board in October, of payloads for the first mission.

For the **Improved Fluid Physics Module** (IFPM), the Phase-B studies started at the end of June 1982. This phase will last seven months, after which the question of whether the IFPM can meet the German D-1 Spacelab mission schedule or has to be flown on a later Spacelab mission will be reviewed. In the latter case, the Fluid-Physics Model of the first Spacelab mission will be refurbished and flown on Spacelab D-1.

A call for experiments for the planned IFPM flight on D-1 was issued on 9 July 1982.

In the **Sounding-Rockets Programme,** the results of the Texus-VI flight are now being evaluated. ESA participated in this sounding-rocket activity for the first time by providing the funding for 60% of the 240 kg payload, which consisted of eleven different experiments, of which six were designated through the ESA programme.

Twenty-two proposals have been received in response to the Announcement of Opportunity for the Texus VII/VIII flights in April/May 1983.

Eureca

The pre Phase-A studies for the European Retrievable Carrier (Eureca) were completed in June 1982 and have confirmed the technical feasibility of Eureca at a conceptual level. Two groups were set up for payload definition: the Eureca Payload Working Group to define the payload for the first Eureca mission, and the Experimenter Review Panel for future Eureca payloads.

Aside from the first mission, dedicated primarily to microgravity experiments, considerable interest has been shown in the use of Eureca for follow-on missions.

Modèle de travail de l'unité réfrigérateur/congélateur du Biorack

Breadboard model of the Biorack cooler/freezer unit

On 17 June 1982, the first Eureca mission was booked with NASA for a launch in April 1987, followed by retrieval in October 1987, approximately.

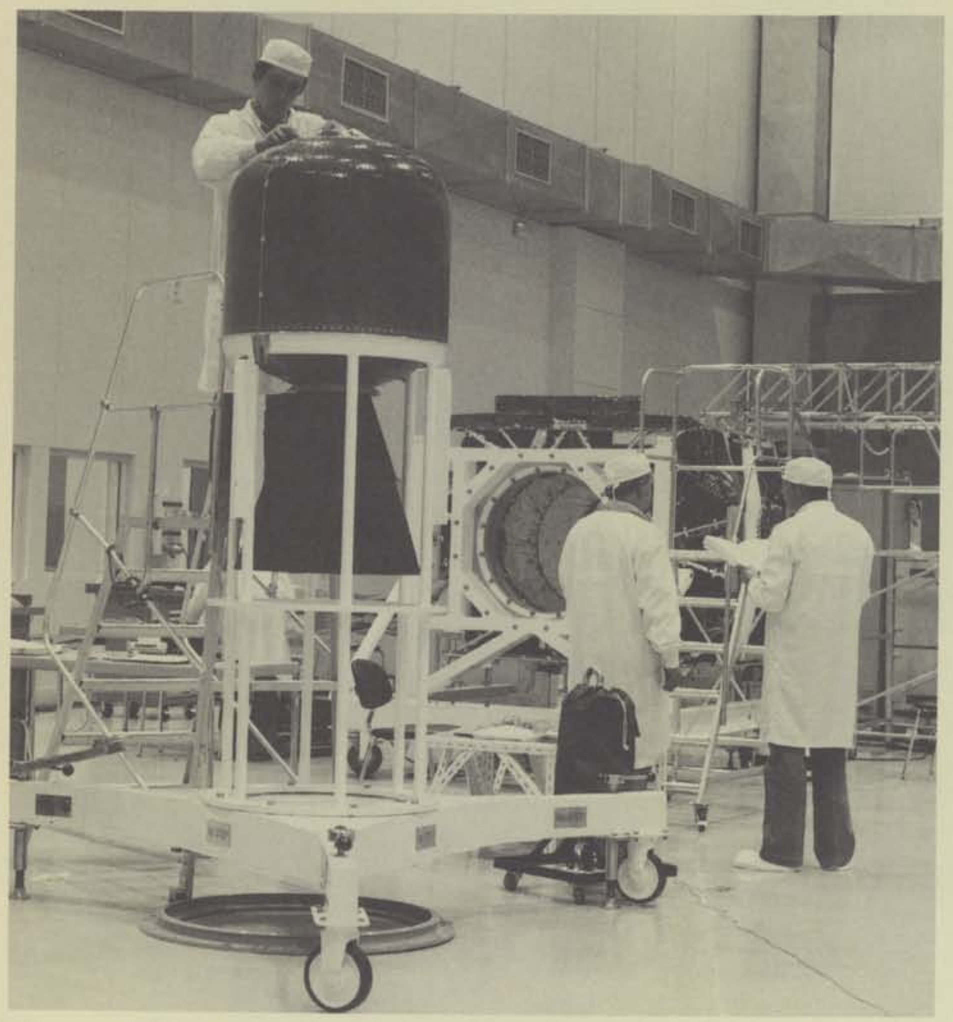
The Phase-A study activities for Eureca commenced on 12 August 1982, and will last about six months.

MAGE

The MAGE-II flight and spare motors for ECS-1 have been built. Some minor finishing and a final inspection still remain to be done prior to their planned transport to the Kourou launch site in early October 1982. These motors will be stored in Kourou until needed for the ECS-1 launch.

A request for quotation is being sent to the contractors for the supply of MAGE-II motors for the follow-on series of ECS-2 to ECS-5 satellites. MAGE-II motors for the French TC1 telecommunications satellites and MAGE-IS motors for the Giotto scientific satellite are being procured directly from the motor contractors by the respective satellite prime contractors.

The status of MAGE will not be reported separately in this section of future Bulletin issues, as the planned development of MAGE-I, IS and II motors is now complete.



The MAGE-II motor for ECS-1 during testing at Matra in Toulouse

Essai du moteur MAGE-II d'ECS-I chez Matra à Toulouse

charge utile, deux groupes avaient été constitués: le groupe de travail sur la charge utile Eureca, chargé de définir la charge utile de la première mission et le groupe d'expérimentateurs pour les futures charges utiles.

En dehors de la première mission essentiellement consacrée aux expériences de recherche en microgravité, l'utilisation d'Eureca pour des missions ultérieures a suscité un intérêt considérable.

Le 17 juin 1982, la première mission Eureca a fait l'objet d'une réservation auprès de la NASA, pour un lancement en avril 1987 suivi d'une récupération vers le mois d'octobre suivant. Une proposition de phase A Eureca a été présentée et acceptée. Le lancement des activités d'étude a eu lieu le 12 août 1982. La durée en sera d'environ six mois.

MAGE

La fabrication des exemplaires de vol et de rechange des moteurs MAGE-II destinés à ECS-1 s'est achevée. Certains travaux mineurs de finition, ainsi qu'une inspection finale, doivent encore avoir lieu avant le transport des moteurs à Kourou au début d'octobre 1982. Ces moteurs seront stockés à Kourou jusqu'au lancement d'ECS-1.

Une demande de prix a été envoyée aux contractants pour la fourniture de moteurs MAGE-II destinés à la série des satellites ECS-2 à ECS-5. Les moteurs MAGE-II pour les satellites français de télécommunications TC1 et les moteurs MAGE-IS pour le satellite scientifique Giotto sont approvisionnés directement près des constructeurs par les maîtres d'oeuvre respectifs des satellites.

Il ne sera plus fait mention de la situation du moteur MAGE dans cette partie des éditions ultérieures du Bulletin, car la réalisation des moteurs MAGE-I, IS et II est maintenant achevée.

Financial Control in International Organisations

H. Schullze, Financial Controller, ESA, Paris

The nature and organisation of financial controls in international organisations are largely determined by the fact that most such organisations are financed by contributions from a number of different Member States. As the contributions represent national budgetary funds, these Member States are particularly interested in guaranteeing their correct and efficient utilisation. Moreover, international organisations differ from private industrial enterprises insofar as they are non-profit-making bodies. Profit, the most important yardstick for the efficiency and success of a private firm, cannot therefore be used as a measure of the economic use of the resources of an international organisation; those funding them therefore seek 'a replacement' in the form of stringent financial-control mechanisms.

General principles of financial control

Control bodies

Financial control in international organisations is exercised at different levels by the:

- Delegate Bodies of the organisation
- Financial Administration of the Executive
- Internal Financial Control Service
- External Audit Commission.

The tasks of these bodies are primarily determined by the control system applied by the organisation concerned through financial rules or regulations. Although the systems differ substantially from one international organisation to another, there are certain features and problems that are common to all the control bodies, independent of the specific nature of their organisation's work, and these common elements will be discussed below.

The role of the 'Delegate Bodies' (i.e. of Councils, Finance Committees, etc.) is normally restricted to the approval of budgets and a general overseeing of the financial operations of the organisation. In this area of activities, management and control tasks are amalgamated such that it is difficult to attribute the various tasks to one category or the other. As a rule, Delegate Bodies scrutinise budget proposals and approve or reject them, decide upon major issues such as important budget transfers, anticipated calls for contributions, verify – on the basis of the Audit Commission's report – the yearly accounts, and give discharge to the Head of the Executive for the financial management in a given financial year.

The Financial Administration of the Executive is responsible for the day-to-day management of financial activities, i.e. the preparation and implementation of the budgets, the keeping of treasury and accounts, the preparation of financial regulations, instructions, etc. The extent to which the Financial Administration also carries responsibilities in the field of controls, in particular verifications of the correctness of financial commitments and payments before their execution, depends on the financial control system of the organisation concerned.

The Internal Financial Control Service has to verify the financial transactions of the organisation, and in particular commitments and payments, for conformity with the provisions of the budget and all the rules and regulations relating to those transactions. Whether the verifications have to be executed before or after the transaction depends, again, on the organisation's financial control system; the same service may be charged with both types of verification. If financial control is executed a posteriori, the service has also, as a rule, to carry out audits of the cash accounts, to inspect stores, stocks and inventories, and to monitor continuously the economic use of resources.

The hierarchical position of internal financial control services is often a point of contention. The Financial Administrations, on the one hand, claim that they need an instrument for controlling the different branches of their departments, the more so if these branches are de-centralised and in

Figure 1 — Three sets of Dutch financial instructions from the past:
- *Organic decisions, starting in 1799*
- *Instructions for the superintendents of the National Exchequer of the Batavian Commonwealth (1799)*
- *Bound volume 'Archive 1810-1823', open to show the text, hand written with a quill pen: '25 December 1817. N.50. We William etc., considering the report of the Dutch National Exchequer, dated the 11th day of August of this year...'*

different cities and/or countries. On the other hand, the national audit bodies argue that the heads of the finance departments should also be controlled by the internal financial control services. Today, this latter view predominates and therefore in most organisations the heads of the internal financial control services (financial controllers) report directly to the Head of the Executive (e.g. the Director General or Secretary General).

As a rule, the Financial Controller is also liaison officer to the Audit Commission. As in industry, there are certain elements of co-operation between Internal and External Control Services. For example, the yearly verification plan of the Internal Control Service, once approved by the Head of the Executive (or the Director of Administration to whom day-to-day management tasks concerning the Service may be delegated), is conveyed to the Audit Commission which also receives copies of the Internal Control Service reports. This co-operation avoids duplications and overlaps which would otherwise be inevitable because the tasks of the two services coincide in many areas.

Leaving aside, for the moment, the institution of the permanent Audit Court of the European Community, it can be said that External Audit Commissions are, as a rule, composed of senior officials of the national audit authorities of Member States; they may be assisted by agents who are normally of the same nationality as the senior auditors. The External Audit Commission, similar to certified public accountants in industry, spends a certain number of weeks or months together with the agents each year on the premises of the organisation to conduct their verifications. Exceptionally, the agents may be permanently based on the premises of the organisation, which then have also to shoulder their salaries and other emoluments.

The activities of the External Audit Commission are governed by three principles:
- independance from national authorities
- rotation of its members
- execution of verifications a posteriori.

When acting as international auditors, the members of the Commission are responsible only to the organisation's supreme delegate body (generally called the 'Council').

Equitable rotation of the members of the Commission gives each Member State the opportunity to obtain assurance through the reports of its own senior officials that the public funds involved are, in fact, being correctly and economically used for the agreed purposes of the organisation.

The Audit Commission has to examine a posteriori the budgets, budgetary accounts, the financial management and any measures having financial implications; it must verify that expenditure has conformed with the budget estimates and that the records are lawful and correct; the Commission must also report on the economic use of the organisation's financial resources.

At the end of each financial year, the Commission draws up a report which must be approved by the Council and which forms the basis of the discharge to be given to the Head of the Executive.

Aspects of internal audit

If internal financial control is carried out a posteriori, it is also called 'internal audit'. In this case, the verifications have some particular features, two of which will be outlined below.

Today there is a general trend in industry, and in international organisations, to extend the responsibilities of the internal audit beyond the purely financial auditing to so-called 'operational auditing'. Whilst 'a financial audit is a historically oriented, independent evaluation performed... for the purpose of attesting to the fairness, accuracy and reliability of the financial data... operational audit is a future-oriented, independent and systematic evaluation performed... for the purposes of improving organisational profitability and increasing the attainment of the other organisational objectives.'*

* Institute of Internal Auditors (New York) Research Report No. 19, page 51f.

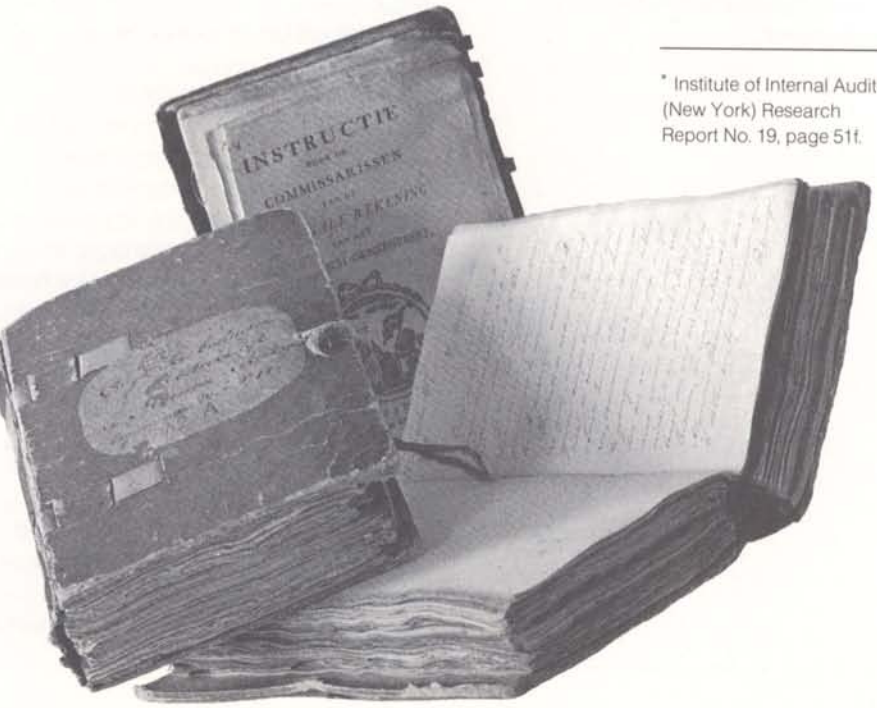


photo: sjaak ramakers, utrecht

As far as the daily work of internal auditors is concerned, their verifications are not without human problems. Sometimes, their control activities are met with mistrust and resistance. In the recent past, behavioural patterns in internal-audit relationships have therefore undergone thorough changes. The once 'traditional audit approach or style' whereby the auditor considers the protection of his employer against loss his primary task, is falling from favour. In this role the auditor treats those he audits as strangers with whom he does not discuss the results of his findings, merely reporting violations of regulations. Nowadays, this traditional approach is being replaced by the 'participative teamwork approach', which is considerably improving relations between the auditor and his clients. With this approach, the auditor considers support to management for the achievement of its goals his primary task. The purpose of his verifications and his findings are discussed with those audited, who are then asked to confirm the correctness of the facts given in the audit report. Deviations in opinion are then added to the report.

Control systems
The financial control systems of international organisations are influenced to a large extent by the audit systems in force in the Government departments of their Member States. The most important distinguishing criterion is provided by the stage at which the audit is made:

- a priori controls are carried out before commitment of the funds or payment of the expense. This usually gives rise to the endorsement of the corresponding vouchers, a refusal of this endorsement blocking the whole procedure;
- a posteriori controls are made of operations already carried out, and are either applied continuously or at the end of the financial exercise.

Using this criterion, the audit systems of Member States can be classed into two major groups:

- the group of countries that prefer a posteriori verification: Denmark, Germany, the Netherlands, and the United Kingdom;
- the group of countries that put the emphasis on a priori verification: Belgium, France, Italy and Switzerland.

A priori controls should be exclusively concerned with the regularity ('good order') of the planned commitment or payment. Experience shows, however, that the officers authorised to carry out those control activities tend to go beyond the checking of 'good order', commenting also on its advisability. This tendency leads to a somewhat cumbersome procedure, which in an extreme case can paralyse management. As a consequence, countries that practise a priori controls usually either exempt from that control most public bodies that have an industrial or commercial activity, or 'relax' their audit system for such bodies.

In international organisations both systems exist. Although it is not possible to establish firm rules in this context, it can be said that in ESA and those organisations that may be considered 'sister organisations', systems based primarily on a priori controls have not been introduced, due in the main to the scientific/technical character of these organisations.

Financial control in international organisations
As there are about 200 major international organisations, i.e. entities emanating from interstate agreements and set up for the achievement of common aims, it is obviously not possible within the framework of this article to consider the financial control systems that all of them have introduced. The situations existing in five of these organisations – the EEC, UNESCO, OECD, CERN and ESO – will be summarised here as representative examples.

European Economic Community (EEC)*
Council and Parliament are the budgetary authorities. The Executive (Commission) is, in principle, responsible for the implementation of budgets and internal financial control, whilst a Court of Auditors is charged with external audits.

The Financial Regulations foresee that, in implementing and internally controlling the budgets, three functions have to be strictly separated: those of the authorising officer, the financial controller and the accounting officer.

The control system is based on a priori controls by the Financial Controller, whose 'visa préalable' is required before any measures are taken that may give rise to expenditure chargeable to the budget. In the Commission, the post of Controller is held by a Director General, who is responsible only to the appointing institution.

To reinforce the monitoring of financial management, the Commission sees the role of the Financial Controller developing also in the field of internal audit, i.e. in the direction of a posteriori controls. However, the Court of Auditors has drawn attention to the danger of conflict that may result from that tendency because the 'visa préalable' commits the Financial Controller, which must restrict his ability to question decisions subsequently.

United Nations Educational, Scientific & Cultural Organisation (UNESCO)
Delegate Bodies and external auditors assume the functions described above under 'General principles'.

One external auditor – the Auditor General of a Member State (or one who exercises a comparable function) – is appointed for a period decided by the General Conference (in practice 5 years).

* Special provisions applicable to the funds and certain other sectors are not taken into account here.

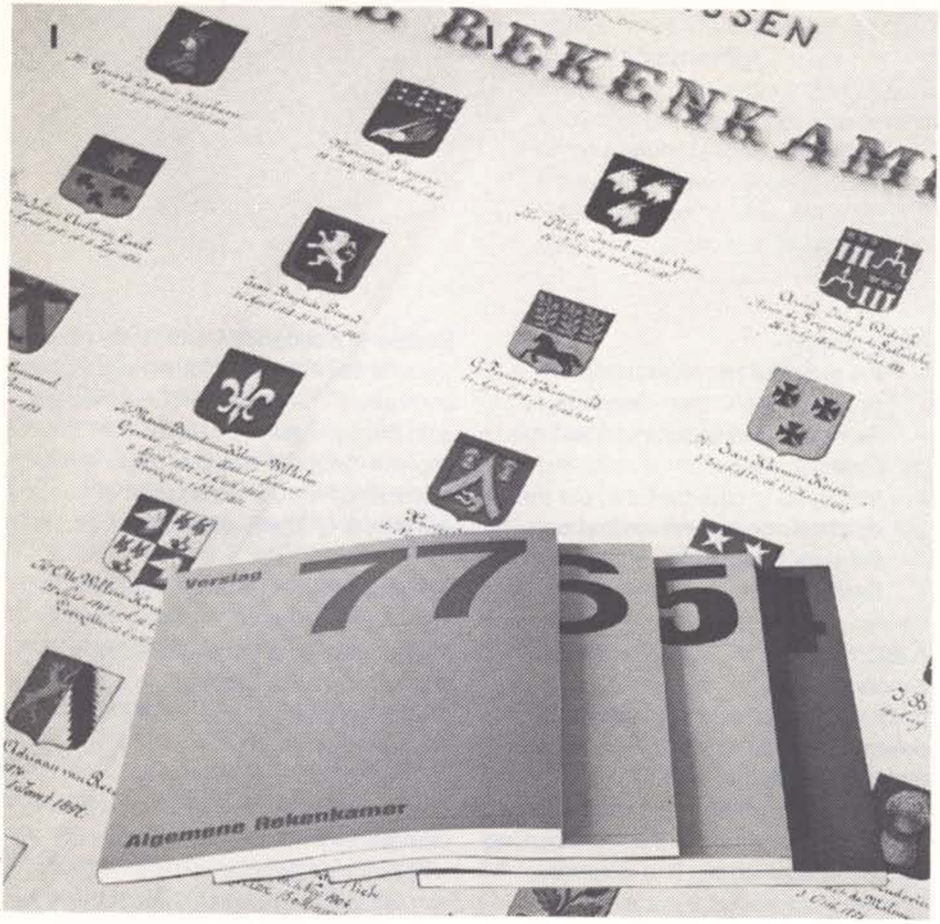


photo: sjaak ramakers, utrecht

Figure 2 – The Annual Reports of the Dutch National Exchequer, published as Second-Chamber documents, for the years 1974 to 1977. In the background, The Coats of Arms of Members and Secretaries of the Dutch National Exchequer (period: 1814-1933)

For the purpose of making local or special examinations, the external auditor may engage the services of any national Auditor General (or equivalent title) or commercial public auditors of known repute or any other person who is technically qualified. The incumbent external auditor is the UK Auditor General who uses 4-5 members of his own staff for the execution of the necessary verifications. With the exception of one auditor permanently residing in Paris, the team works for UNESCO on a temporary basis.

Internal financial control is exercised on the one hand by a Comptroller who reports to the Assistant Director General for Administration. The Comptroller has been given important powers in the field of a priori controls and financial management. All proposed obligations must, in principle, be submitted to the Comptroller or officers designated by him for prior approval; corresponding a priori controls are exercised in respect of payments. In addition, the Comptroller is responsible for the management of all funds of the organisation, the establishing and maintaining of all official accounting records (with the exception of records of budget appropriations) and the establishment of the periodic financial statements required by the Financial Regulations.

The a posteriori verifications, on the other hand, are effected by an Internal Audit Division whose head, the Inspector General, reports directly to the Director General.

Organisation for Economic Cooperation & Development (OECD)
Council is the budgetary authority: the external audit is carried out by a Board of four auditors, whose term of office is four years, except for the French auditor whose appointment is for an indefinite period.

The internal financial control is exercised by a Financial Controller appointed by the Secretary-General, subject to approval by Council. The Financial Controller has an important advisory role since he has to express his views to the Secretary-General on draft budgets, draft rules and other proposals having financial implications. Requests to enter into commitment must be submitted for countersignature to the Financial Controller, who is also an ex-officio member of the Contracts Committee and other boards and keeps the budgetary accounts of income as well as the general accounts of the organisation. The Financial Controller may also carry out a posteriori verifications.

Organisation européenne pour la recherche nucléaire (CERN)
Delegate Bodies and external auditors are responsible for the usual tasks.

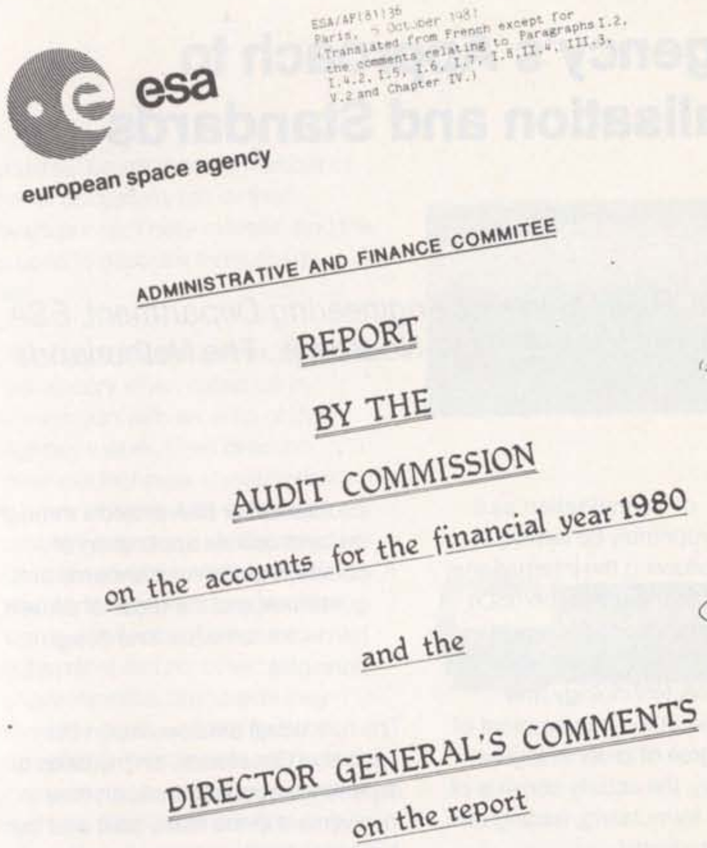
Until 1972, the functions of the Financial Controller were exercised by the Head of the Finance Division who, in this capacity, came directly under the Director General. The controls essentially concentrated on the execution of the budget.

In 1972, the Internal Audit Service was separated from the Finance Division and placed directly under the Director General. Verifications are, in principle, carried out a posteriori: however, contracts exceeding 200 000 Swiss Francs, directly negotiated contracts exceeding 50 000 Swiss Francs, and service contracts also require the 'visa préalable' of the Service. In this way, the utilisation of about 20% of the total CERN appropriations undergoes a priori and a posteriori controls by the same control body.

European Southern Observatory (ESO)
The Delegate Bodies assume the usual tasks. In accordance with the Financial Protocol, the Council appoints external auditors who serve for a period of three years, and may be re-appointed.

Internal financial control is exercised by an Internal Auditor who is directly responsible to the Director General and who carries out a posteriori verifications.

Financial control in ESA
The Delegate Bodies of the Agency assume the usual tasks described above under 'General principles'. The following controls are carried out by the Agency's Finance Department within the Directorate of Administration:
– the a priori verification – and



ESA/AF(81)36
Paris, 5 October 1981
(Translated from French except for the comments relating to Paragraphs I.2, I.4.2, I.5, I.6, I.7, I.8, II.4, III.3, V.2 and Chapter IV.)

esa
european space agency

ADMINISTRATIVE AND FINANCE COMMITEE

REPORT

BY THE

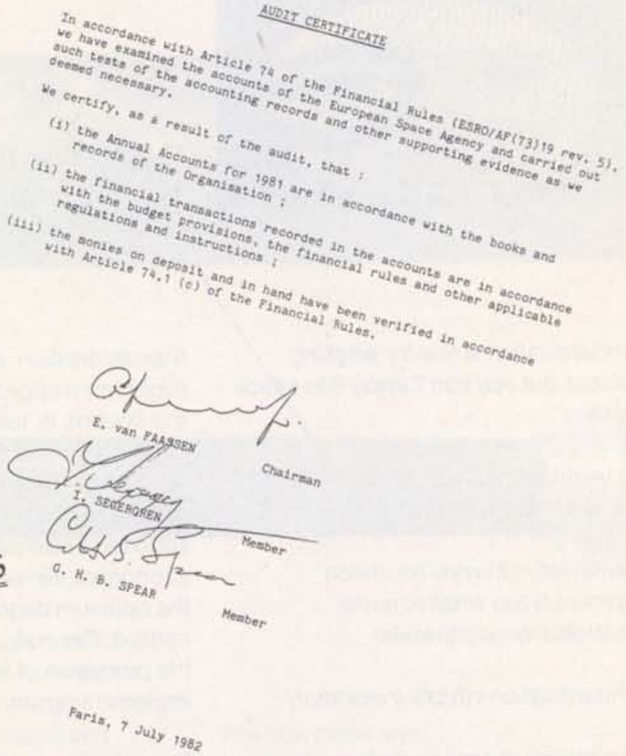
AUDIT COMMISSION

on the accounts for the financial year 1980

and the

DIRECTOR GENERAL'S COMMENTS

on the report



AUDIT CERTIFICATE

In accordance with Article 74 of the Financial Rules (ESRO/AF(73)19 rev. 5), we have examined the accounts of the European Space Agency and carried out such tests of the accounting records and other supporting evidence as we deemed necessary.

We certify, as a result of the audit, that :

(i) the Annual Accounts for 1981 are in accordance with the books and records of the Organisation ;

(ii) the financial transactions recorded in the accounts are in accordance with the budget provisions, the financial rules and other applicable regulations and instructions ;

(iii) the monies on deposit and in hand have been verified in accordance with Article 74.1 (c) of the Financial Rules.

E. van FAASSEN — Chairman

I. SEGERGREN — Member

C. H. B. SPEAR — Member

Paris, 7 July 1982

Figure 3 – The Audit Commission's Report on ESA's accounts for the financial year 1980

Figure 4 – Audit Certificate for ESA's financial transactions in 1981

approval – of proposals concerning the use of contract authority and payment appropriations. This activity is carried out by budget controllers under the Head of the Budget Planning and Management Division

- the a priori verification – and approval – of payments; this payment control is carried out by the finance officers responsible for the verification of expenditure.

The Financial Controller is responsible for:

- a posteriori control of the use of Contract Authority and Payment appropriations
- a posteriori control of receipts and expenditure
- continuous examination of the economic use of the resources of the Agency.

The Financial Controller is responsible to the Director General, who has delegated the day-to-day management of the Service to the Director of Administration. The Financial Controller is also the liaison officer to the Audit Commission.

The Audit Commission is composed of three auditors, who report to the Council of the Agency. The tasks of the Commission correspond to those described under 'General principles'. The ESA Commission is supported by three agents who work permanently on the premises of the Agency and who are authorised to convey their comments directly to the Director General or the Financial Controller. This support allows the Audit Commission to carry out its audits throughout the year and not just periodically, as is usual in other international organisations.

Final remark

The examples described above show that internal financial control is a controversial area in international organisations. There are considerable variations in the size, timing and type of control exercised. There are in fact as many systems as there are organisations, due to some extent to the different tasks of the organisations, the varying volumes of their budgets and also the various national and international sources on which the authors of the relevant financial rules or regulations have drawn.

Moreover, the control systems are constantly undergoing a process of further development. One may therefore conclude that, at present, there is no single control mechanism that offers a panacea for financial errors. In addition, whatever type of control an international organisation may choose, ultimately cost-conscious management and good cooperation between all bodies responsible for financial control are the determining factors in achieving the aims in view: namely, economic and efficient use of the organisation's resources.

The Agency's Approach to Normalisation and Standards

H. Stoewer & P. Hill, Systems Engineering Department, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

'Standardisation is fine for washing machines but you can't apply it to space hardware'

'The technology in space moves too fast to allow any standardisation'

'The market in Europe for space equipment is too small to make standardisation worthwhile'

'Standardisation inhibits innovation'

'Every project in space needs newly developed equipment in order to meet the demands of new mission requirements'

Whenever the topic of normalisation or standardisation in relation to space equipment comes up for discussion, some variant on one or other of the above comments is usually heard. What is the real situation in Europe, and what are ESA's objectives and activities? This article is intended to answer these questions, at least in part, for the lower levels of standardisation (the re-use of platforms or complete satellite systems is not discussed) and to stimulate new ideas on the relevance of standardisation in European space activities.

Standardisation, or normalisation as it might more appropriately be termed in this context, is, following the International Organisation for Standardisation (ISO), 'an activity giving solutions for repetitive application, to problems essentially in the spheres of science, technology and economics, aimed at the achievement of the optimum degree of order in a given context. Generally, the activity consists of the processes of formulating, issuing and implementing standards'.

The role of standardisation within an organisation is conditioned primarily by the technological status and rate of change of the work involved, and the size of the potential area of application for each possible aspect of standardisation. In economic terms space engineering in Europe is a rather small-scale activity, which means that the potential for hardware standardisation in the normal sense is limited. The technologies involved are often advanced and in a state of rapid change – a situation also unfavourable to the gaining of economic advantage by standardisation. Careful attention is therefore paid to the selection of areas of technology that do offer scope for useful standards, and to the assessment of the economic usefulness of those standards that are developed and applied.

The goals and the means

The overall objective of the Agency's standardisation activities is to:

> 'ensure technical compatibility between different parts of the Agency's infrastructure and operational systems, and to provide cost reductions or cost avoidance for ESA projects through the appropriate application of common technical standards and guidelines and the reuse of proven hardware, software and design principles.'

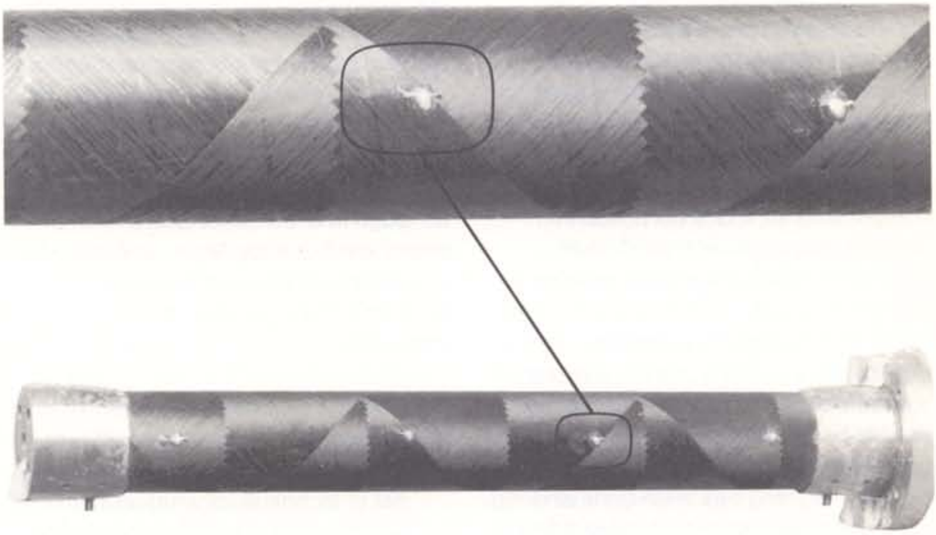
The functional divisions within the Technical Directorate, on the basis of experience acquired through their involvement in the many past and current Agency projects, develop and maintain certain technical standards, guidelines and engineering handbooks, and identify hardware and software items which should continue to be used for new projects. They let contracts with industry for those parts of the work that can be done most effectively externally or when in-house resources are insufficient.

Standardisation measures are primarily applied through transfer of experience by involvement of the functional divisions in studies for new projects, project-definition work and the technical review process. Standards and guidelines are included in the Agency's Invitations to Tender (ITTs), but normally only after they have been tested by exposure to the Agency's project teams, to industry and to experts from national space centres. Implementation progresses from first drafts to firm standards or approved Agency documents.

Coordination with ESA Member States is maintained to ensure successive Europeanisation of all appropriate measures.

The principal outputs of the

Figure 1 – Guidelines for composite structural parts require detailed tests and analyses before they can be released for general use



standardisation effort are a number of classes of document, rather than hardware per se. These classes, and the terms used to describe them are as follows:

- *Standards* are documents which are mandatory when called up in connection with an area of the Agency's work. They describe essential technical characteristics of a piece of hardware, software, process or procedure, but need not describe all of those characteristics. A standard may perhaps describe signal interfaces of a box or subsystem, but no other characteristics. Standards may describe items with any level of complexity, from individual parts or components to complete operational systems. Standards contain only characteristics that are verifiable by some form of test or inspection.

- *Guidelines* describe desirable technical characteristics of equipment or recommended processes or procedures associated with a design stage or activity, and represent a codification of 'good space engineering practice'. Although guidelines are not by nature mandatory, departure from the practices recommended in a guideline will imply a need for justification at reviews and during monitoring activities. They may be compared with the 'Codes of Practice' published by some national standardisation organisations.

- *Handbooks* are documents that bring together in one convenient format useful facts associated with some aspect of space engineering, and which may not be conveniently available in collected form elsewhere. They therefore include catalogues of available or preferred space equipment, and the technical characteristics of such equipment, parts, components, etc. They can equally include processes and materials.

- *Specification Formats* are model technical specifications, in skeleton form and containing introductory, descriptive and specifying text, but not actual technical quantities. They are intended to facilitate the production of complete and unambiguous specifications by provision of a format containing all normally necessary features of a specification for a particular purpose, e.g. a power-supply subsystem for a satellite.

Analysis and application

This activity is concerned with the system and management aspects of standardisation which are relevant to most or all of the Agency's activities, including general co-ordination with Member States and other organisations concerned with standardisation. It also includes evaluation of the potential or actual effectiveness of standardisation methods, applied or proposed, in order to permit informed decision-taking on future activities.

The objectives are:
- to agree on the use of common standards and guidelines with national space authorities and industry
- to provide an economic assessment and a common technical basis for selecting areas for standardisation
- to ensure technical consistency within, and effective and appropriate application of ESA standardisation activities
- to ensure that user interests, in particular those of current and planned projects, are properly recognised
- to simplify the preparation of technical specifications and similar documents which state technical requirements.

There are three essential elements to be considered when implementing these objectives, namely:
- solutions to real problems
- repetitive application
- optimum degree of order

to quote from the ISO definition.

If we look on the one hand at the range of

Figure 2 – Standardisation-activity matrix

MATRIX: HARDWARE (INC. SOFTWARE) VS CHARACTERISTICS

•	STAGE OF NORMAL APPLICATION
*	ACTIVITY IS IN PROGRESS (STUDY CONT.)
+	ACTIVITY IS STUDIED (INTERNAL)
?	ACTIVITY SHOULD BE EXAMINED
??	SHOULD BE EXAMINED BUT UNLIKELY
–	PRIMA FACIE NOT A CANDIDATE
ISO	USE OF EXISTING STANDARDS MOST LIKELY

TYPE OF STANDARD / HARDWARE / SOFTWARE LEVELS	CHARACTERISTICS					INTERFACES										
	FORM FIT FUNC'N	APPL'N, USAGE PROC.	ENV'T LEVELS	QUAL., ACC	LIFE TIME TESTING	I/F THERMAL	I/F MECH.	I/F EMC	I/F POWER	I/F TEST	I/F SOFTWARE	I/F TELEM	I/F TELEC.	I/F AOCS	I/F R/F	I/F PARTICLES, CONTAM.
1 PARTS	* ISO	* ?	?	?	?	–	+	–	–	–	–	–	–	–	–	?
2 MATERIALS	* ISO	• ISO	*	?	*	+	–	–	–	–	–	–	–	–	?	*
3 COMPONENTS	•	•	•	•	•	+	• ISO	+	•	• ISO	–	–	–	–	*	*
4 MODULES (CARDS)	–	??	??	??	?	?	?	?	?	–	–	–	–	–	??	?
5 SUB ASSEMBLIES	–	?	??	?	?	?	?	?	?	?	?	?	?	?	?	?
6 EQUIPMENTS	–	–	+	+	+	+	?	•	*	+	?	•	•	*	* •	?
7 SUB-SYSTEMS	–	–	?	?	?	–	–	?	?	?	?	•	•	+	+	?
8 PLATFORM, PAYLOAD	+	+	+	+	+	+	+	•	+	+	+	+	+	+	+	+
9 SPACECRAFT, VEHICLE	–	*	•	*	–	–	–	+	–	–	+	•	•	•	•	–
10 COMPLETE SYSTEM	–	–	–	–	–	–	–	??	–	–	–	–	–	–	ISO	–

hardware or software items which are candidates for some form of standardisation and on the other hand at the range of types of standards, a diagram or matrix for standardisation emerges (Fig. 2). This matrix shows for example that a lot of work is already in progress on standardisation of electrical components for space purposes. In another area, such as that of small mechanical parts like screws, reliance for standards and guidelines is more strongly based on existing and available documents and parts used in, say, the aircraft industry. In some areas such as printed-circuit modules – the next level of assembly up from components and boards – nothing has been done and preliminary assessments suggest that it is probably not a suitable area. This matrix can be used to focus our analysis on what needs to be done, i.e. in which area to invest x resources for y benefits.

Standards and guidelines

This area of activity covers the work necessary to perform preliminary studies on possible standards in the various technical areas concerned, the detailed preparation of the standards, the negotiation, discussions and other forms of work needed prior to formal issue, and the final issue and usage of appropriate documents, and supporting services.

All types of documents discussed under 'goals and means' above are in fact included here, i.e. standards, guidelines, handbooks and format documents. Hardware development is not included, although in a few cases actual tests at breadboard or early development model level may form an essential part of the establishment or verification of a standard.

The objectives of standards and guidelines are:

- to provide a commonly recognised set of technical information which, when followed, will allow compatible inter-operation between satellite systems and ground infrastructures, between subsystems of a satellite, and between lower level elements used to form subsystems
- to provide a commonly recognised information set which may allow economies to be made in space-project developments by avoiding unnecessary repetitive design effort
- to provide reference information which may be used to assess the technical performance of space projects, at all levels of complexity, i.e. overall system down to component or part level
- to permit industry to work to one standard for all projects and avoid expenditure of unnecessary effort in meeting more than one set of requirements.

Telemetry, tracking and command and data handling

In this domain, an extensive ground infrastructure is used by ESA, NASA and the national agencies for communication with satellites and exploitation of the data.

Because of the common use of this ground infrastructure a second level of standardisation is possible by adopting standard on-board TTC and DH system architecture, hardware and software concepts common to different satellite projects.

The approach consists of providing TTC and DH standards at the following levels:

- Level A, which is the top level and deals with the spacecraft-to-ground interfaces. It includes documents such as the telemetry and telecommand standards.
- Level B, which deals with the internal

spacecraft interfaces. At present only the 'hardware' signal interfaces such as data bus and channel interfaces are defined. It is intended to extend the scheme to include guidelines on the production, operation and maintenance of on-board software.
- Level C, which covers the specification of the interfaces and performance of an on-board data-handling subsystem and the various units which can be combined to form a subsystem, such as the remote and central terminal units.

Documents at levels A and B are essentially sufficient to define both the operational and testing requirements with the ground infrastructure, and also the data interfaces on-board the spacecraft. As such they are independent of the exact configuration of the on-board data-handling hardware. The documents at level C define a particular set of configurations of the spacecraft data-handling system.

For all these levels of standards there is a necessity for consultation with other bodies outside ESA, e.g. with NASA, national agencies and industry. To formalise these contacts a series of working groups has been established with overall responsibility for formalising agreements for TTC and DH standards.

These groups are:
- the NEWG (NASA/ESA Working Group), to establish compatibility between the two agencies in the TTC and DH domain
- the STAB (TTC and DH Standard Approval Board), to establish, in close collaboration between ESOC and ESTEC, a set of ESA standards in this area
- the ESA/Eurospace On-Board Data Handling Working Group, which serves as a forum for discussion with industry, especially for the level-B and level-C standards.

These Working Groups are helped both by in-house studies and external contracts, either to produce standards or to study particular technical issues that need to be resolved prior to standard approval.

Telecommunications

The general approach here is similar to that outlined above for TTC and data handling. A large proportion of the work is done by in-house study effort. Liaison with NASA, CCIR, and the SFCG (Space Frequency Co-ordination Group) plays an important role. Particular technical aims within this domain are improved bandwidth utilisation, greater accuracy in ranging, and easing of the process of antenna design and testing.

The existing and projected ESA standards are comprised of:
- the RF and Modulation Standard
- the S-Band Omni-directional Antenna Standard
- the S/X Bands Coherent Transponder Standard
- the Antenna Standard
- the S/X Bands Transponder Standard
- the Highly Accurate Positioning Systems Standard, and
- a Bandwidth Allocation Standard for TTC of TV Satellites.

Attitude and orbit control

The basic approach here is to provide background information and guidance rather than standards of the kind defined above.

Existing and projected guidelines consist of:
- an attitude performance requirement definition handbook, including error sources, error budgeting and partitioning
- design guidelines for AOCS of satellites in the spinning phase
- guideline and format interface specification for the dynamic interaction of nonrigid satellite parts with the control system
- handbook of methods of performance analysis for attitude measurement for spinning satellites
- guidelines and format specifications for control-subsystem dynamic testing methods and techniques
- handbook of AOCS on-board control algorithms/software, and
- guidelines on the dynamic interaction between on-board liquid motions and AOCS for spinning and three-axis-stabilised spacecraft.

Energy generation, conversion and transport

A number of format specifications were initiated in 1979. The approach used was to compile, from existing industry-generated power-subsystem specifications, an overall format and terminology that could be genuinely standardised and comprehensive.

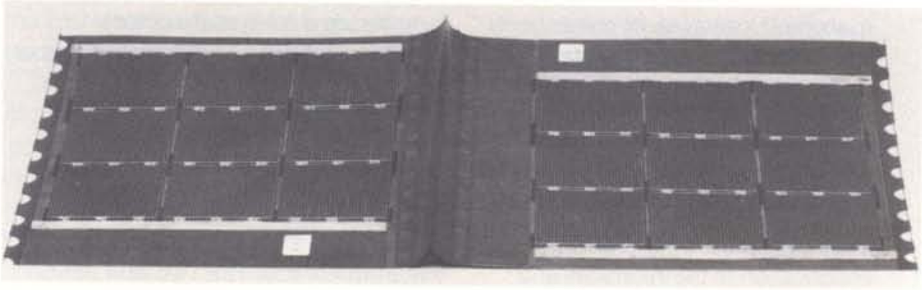
Existing and projected documents are:
- power-subsystem definitions and interfaces; draft specifications resulting from an initial external contract have been used experimentally within the Giotto and Hipparcos programmes
- solar-array electrical design handbook and format specification
- solar-cell format specification, already widely used by projects
- format specification for batteries
- a harness design handbook, an initial version of which was issued in 1975.

Product-assurance standards and guidelines

For some years there has been a major and developing activity in the preparation, updating and distribution of standard specifications relating to the disciplines and procedures of reliability, quality and safety assurance, configuration management, cleanliness control, and related terminology, as well as the selection, control and application of materials, processes and electronic components.

In 1980, plans were finalised for starting a

Figure 3 – Solar cells have been the subject of gradual standardisation since the earliest days of space exploration



general revision and restructuring of the Product Assurance Standards to provide a more systematic basis for the control of the Agency's future space projects and technology development programmes (see ESA Bulletin No. 31, pp. 100-105). The main specifications (level-I and -II) of the revised system are being used for the Agency's new projects, i.e. Giotto, Hipparcos and ERS-1. The revision of the secondary specifications (level-III) supporting the level-II specifications, covering ESA-preferred methods, processes and procedures related to the use of materials, electronic components and other product-assurance disciplines, is continuing and should be completed this year.

The new specifications are organised in a three-level hierarchical structure. Requirements have been modified or extended to reflect experience gained, the demands of new technologies, and the views of industry as far as is practicable. Regroupings of requirements have been made to facilitate their selection and application to different types of project in a controlled manner.

Structures
Standards and guidelines in the structures area are constrained by the one-off approach used essentially for spacecraft structures, and the very wide range of requirements on structures dictated by spacecraft-configuration constraints. With the stabilisation of launcher, and hence structural, input requirements to the Ariane and STS vehicles, it may be possible to evolve at least a guideline document relating the launcher characteristics to design and mathematical-analysis tools and to testing methods. At a lower level of detail, some work is already being done on inserts, for example.

Potential future documents include:
- a draft design guideline for Ariane- and STS-launched structures
- a handbook of applications of CFRP to satellite structures
- a guideline on designing for acoustic exposure.

Thermal
In some respects, the possibility of standardisation in the thermal area is limited for the same reasons as structures standardisation. Primary documents are:
- the thermal-control designer's handbook, and
- the guideline/standard for heat-pipe qualification.

Mechanisms
Extensive work, leading to potential guidelines and handbooks, is being conducted at the European Space Tribology Laboratory (ESTL) in Risley (UK).

The documentation produced includes:
- guidelines for the testing of space mechanisms to establish qualification or acceptance
- a handbook on space tribology, and
- a guideline for the design of pyrotechnic subsystems.

Environmental testing
The preparation of standards for environmental testing is also hindered by the considerations that affect structure design. An all-enveloping approach for an environmental specification would certainly result in figures requiring overdesign for the majority of cases. Studies aimed at resolving this problem are in progress. General requirements for the preparation and execution of environmental tests, and for specific, limited test areas such as physical measurement, exist. New ones will address:
- general requirements for environmental tests (guideline)
- dynamic tests
- thermal tests
- physical-measurement tests, and
- EMC/EMI tests.

Systems
The aim of the system effort in standards and guidelines is to cover those areas that are essentially multidisciplinary, such as assembly, integration and verification (AIV); those areas that contain interfaces which are transdisciplinary, such as EMC; and, where possible those areas that are essentially at system level, such as the general configuration of satellites. The approach taken is that of: a survey of the field concerned and identification of problem areas; assessment of existing practices and the selection of the most effective; special study of areas where no really satisfactory approach yet exists; and finally integration of available information into (normally) guideline-level documents.

Current activities cover:
- the development of an AIV guideline, aimed at providing criteria for the selection of alternative test and integration-model approaches, given a specific project environment
- an associated handbook of AIV techniques
- formats for system-verification, test-matrix and related documents, and
- an updating of existing EMC standards and guidelines.

Materials, processes, parts and components

Materials and processes

A system of documents is being developed to ensure that project groups both in ESA and in industry follow a common approach to the selection, test, control and application of materials and processes in the construction of space hardware. Wherever possible these documents are based on recognised standards (ISO, DIN, ASTM, BS etc.) and are extended to cover special space requirements. These documents are issued in the ESA PSS series and cover such topics as 'materials selection', 'standards for soldering', and 'application of paints'. They are continuously reviewed and updated based on inputs from user industry and project experience. The system is being expanded to cover new requirements for composite materials.

Mechanical parts

A system of standards is under development covering mechanical inserts, lubrication processes, pyrotechnics, components for fluid loops, heat pipes, etc., to assure uniform and reliable application of mechanical parts and associated processes. They concern:

- updating of existing standards and parts lists, e.g. standards for lead lubrication, pyrotechnic initiators, a handbook of European pyrotechnics, small mechanical parts
- development of a standard process for use of sputtered MoS_2 films for dry lubrication
- a standard for attachment methods for thermocouples
- standards for components for fluid loops, e.g. pumps, control valves and control units (a development period of several years is anticipated)
- standardisation of heat pipes and their application.

Electronic components

A system of standards and specifications has been developed for the evaluation, qualification and procurement of standard and nonstandard electronic, electrical and electromechanical components. The activity for standard components is carried out in cooperation with and with the support of national experts nominated by the ESA Member States and their parent organisations. This specification system is known as the SCCG System, since it is derived from the work of the ESA Space Components Co-ordination Group (SCCG), which is an Advisory Group to the Director General. This Group establishes the policy for standard components, reviews basic, generic and detail specifications established within working groups or submitted by the user or manufacturing industry, and assures proper integration with relevant manufacturers and distribution of approved documents to interested parties.

At the moment the system consists of 373 approved and integrated documents, 144 approved documents to be negotiated with manufacturers, and 105 documents in draft form. 197 new specifications have already been identified to be written and co-ordinated with potential manufacturers over the next two years.

This standardisation activity also includes a programme for evaluation and qualification of European components. The availability of qualified European components, listed in the ESA-QPL (Qualified Parts List) and approved and integrated specifications, allows a considerable increase in the usage and promotion of European components for ESA projects. This ESA/SCC specification system is continuously reviewed, updated and expanded to cover field experience and actual project needs, with a view to increasing the availability of space-qualified European components.

The further aim is to introduce the requirements of the SCCG System into the more general CECC System (CENELEC Electronic Components Committee). Substantial progress has been achieved already and the basic procedures have been agreed. SCCG experts are participating in the various working groups of CECC to formulate and introduce additional space requirements into CECC documents, but for the time-schedule to be met, significant manpower from the national agencies of the Agency's Member States is required to support the available ESA effort. It is anticipated that it will be possible to standardise the requirements for 'space usage' with those of other specialist users (telecommunications, military, etc.) via the CECC System and it is safe to predict a considerable price reduction for high-reliability components in Europe as a result.

Re-use of hardware designs, including ground-support equipment

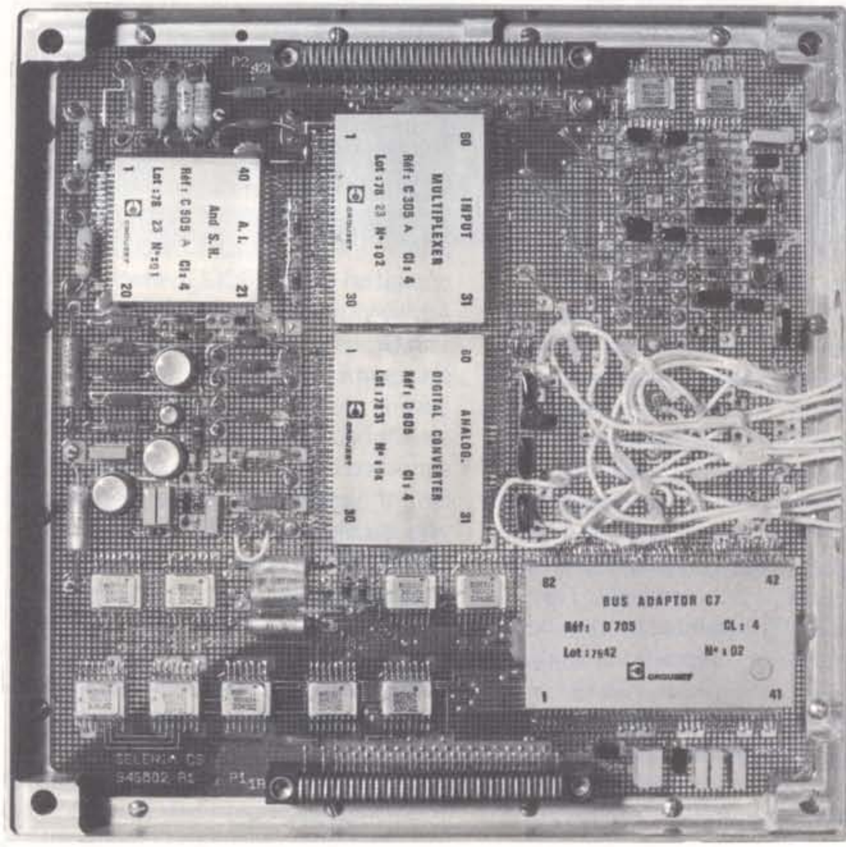
This activity covers the encouragement of the re-use of existing hardware designs or design concepts. It must be recognised that, at the level of space activities in Europe, the concept of real 'off-the-shelf' procurement is most unlikely to be viable. Some moves towards this may, however, be possible, firstly by following up the 'standards and guidelines' activities described above and ensuring that they are applied as widely as possible. Such standards, with special emphasis on interfaces and compatibility for interactive working at all levels of hardware and software, can facilitate re-use of appropriate items and save on redesign costs.

Secondly, by identifying and codifying those requirements affecting hardware/software designs which have a significant effect on interoperability of equipment, the freedom of design (in say a design-to-cost environment) may be significantly widened for future satellites. This is already recognised to some extent at the platform/payload level, and in some of the 'standards and guidelines' mentioned above.

Re-use of on-board hardware

The major part of the cost of providing

Figure 4 – Central core module of an engineering-model data-handling Remote Terminal Unit (RTU). The interfaces of such a unit are defined as part of a standard multilayer specification system (photo courtesy of Selenia)



new equipment for a satellite is normally found to be in the design effort rather than in the cost of materials or of manufacturing. A further heavy cost area is the testing and analysis necessary to prove that a design is qualified for use in a particular role. If an existing, already-qualified design can be re-used in a second or subsequent role, a worthwhile saving in overall costs to the Agency can clearly be made, *provided* that the costs of allowing for such re-use do not outweigh the savings. Typical of the problems to be solved is that of the overdesign (and hence extra cost) needed to meet the envelope of two different mechanical environments.

To reduce the impact of such problems, a number of steps need to be taken. In general terms they include:
- the simple promotion of existing designs
  Examples include the preparation of handbooks and catalogues for, for example, optical attitude sensors, propulsion components or solar-array-drive and antenna pointing mechanisms
- the application of design standards and guidelines to new design work in such a way as to increase the interoperability of equipment
- the development of modular approaches to subsystem design concepts
- maintenance and updating of a reference data bank on all equipment (boxes) used in ESA satellites
- the development of a modular approach for power regulators (200 W–10 kW), of re-usable AC power converters, and of a re-usable battery case
- study of possible common testability features of on-board equipment and other studies leading to the preparation of generally applicable interface requirements affecting a range of possible on-board equipment. Target outputs are environmental, mechanical and related specifications, as well as functional interface specifications for application over a broad field.

Ground Support Equipment (GSE)

The classical test-equipment problem is that the requirements for the test equipment are only fully known when the equipment to be tested has been designed, test equipment is needed to test the first-off user equipment, and a design and manufacturing stage for the test equipment itself has to come between these two events. To overcome this scheduling difficulty to some degree, various forms of standard test equipment or GSE, applicable mainly at subsystem level, have been and are being developed, taking into account the anticipated needs of project ground operations and the technological developments in the (usually) subsystems to be tested. Each development is preceded by the necessary study activities to determine the exact nature of the need and the most economical way of meeting it. This includes:
- the development and manufacture of power-subsystem EGSE (Electrical Ground-Support Equipment) racks
- battery and solar-array simulators
- hydrazine and bipropellant loading equipment
- the definition of leak-detection methods and equipment.

Another major area being worked on by the Agency is the development and provision of the General Purpose Check-Out Equipment (GPCOE), which is applied extensively by European industry, hence avoiding multiple separate developments for different projects. A comprehensive central management system is applied to ensure the efficient application of the standards concerned (more details of this approach are to be found in ESA Journal No. 3, September 1980).

Software standardisation
The goals of software standardisation are to provide guidelines and rules leading to software which is efficient, accurate, reliable (in particular for on-board software), transparent and easily modifiable to meet new requirements, as simple as possible and, where appropriate, transportable.

All software production financed by the Agency follows a management plan in which requirements and designs are clearly specified, reviewed and documented according to a documentation standard.

The Board for Software Standardisation and Control (BSSC) controls and coordinates the Agency software projects and strives to reduce duplication.

Software design techniques and supporting hardware and software available from industry are investigated and the best available methods encouraged with the objective of eliminating inefficient systems.

Separate areas of work in which the software contents are strongly connected are identified, and the responsible management within the Agency encouraged to study and implement common collaborative software projects within the normal course of the Agency's programmes.

Because on-board software not only has special problems regarding reliability, but also has major implications for on-board data handling, ground checkout, and the ground network and control centre, it is important to pay special attention to the formulation of software standards at the correct level.

Conclusion
Standardisation of satellite platforms for multiple applications, and their re-use for specialised missions is beyond the scope of this article. At a more general level, ESA has implemented and will continue to pursue a broad spectrum of measures which all fall under the topic of normalisation and standards. Some of these measures are necessary for operational compatibility of our space systems, others have long been recognised as cost-effective, helping government and industry to develop complex new hard- and software at competitive prices.

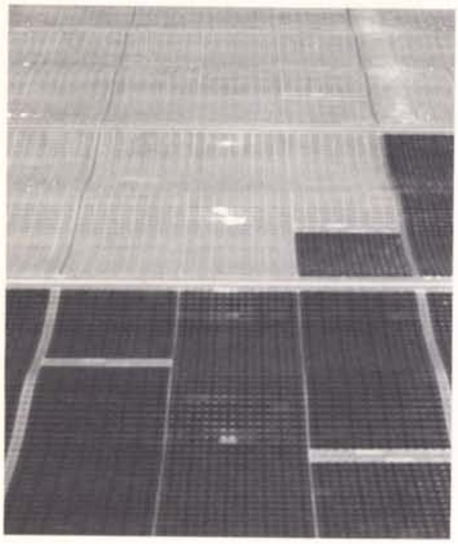
The most serious limitation in pursuing a policy of standardisation lies not in a lack of ideas on what to do next, or where to improve, or on which areas to expand, but in the continuous battle for resources. It is a fact of life that day-to-day project problems will always have priority (in terms of resources) over the analyses necessary to develop effective standards or catalogues promoting proven space hard- or software.

To come back, then, to the comments quoted at the beginning of the article:

- 'Fine for washing machines...'. Some space hardware (and software) can be standardised *provided* a criterion of functional necessity *or* economic return can be satisfied.
- 'Technology moves too fast...'. Yes it does, but then the standards applied must be on at least the next layer above the technological detail in a multilayered system, so that *within* the defined envelope or interface a new technology can be applied. Examples are the data-handling standards for space or the CCITT X25 standards for data communication.
- 'Market too small...'. Yes it is small, but this drives the boundary constraint of economic return to a narrower limit than in the case of, for example, telephones or motor cars. It does not exclude standardisation by definition.
- 'Inhibits innovation...'. Not at all. Innovation must always move in parallel with current work, and then be absorbed into standards (or set off new parallel innovation) as soon as it is shown to be applicable and viable. Yesterday's innovation is tomorrow's standard.
- 'New equipment for new missions...'. Sometimes yes, but there is a lot of scope for re-use of existing designs, and a lot of scope for closer examination of the merits of existing designs, based on a better knowledge of what they actually are and can do. Adequate feed-forward of information from current or past projects to future study activities across the whole European space field is a subject that requires closer attention and probably merits a whole article to itself.

A last word: it is not the hardware that is being standardised – space technology is indeed moving too fast in most areas – it is the interfaces and methods that deserve the emphasis and are the main target of ESA efforts in this field.

Acknowledgement
The following colleagues in the ESA Technical Directorate at ESTEC contributed substantially in the preparation of this article and their individual contributions are gratefully acknowledged: M. Pellet, G. Mica, D. Soo, J. Capart, D. Nutt, U. Ernsberger, R. Somoza, E. Classen, G. Mehwald and A.J. Scheffer.



Accelerated Thermal Cycling of Spacecraft Solar-Cell Modules

J.C. Larue, Solar Generators Section, Mechanical Systems Division, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

ESTEC has accelerated-thermal-cycling facilities designed for testing lightweight solar-cell modules or other spacecraft structural elements with an acceleration factor of 50 compared to low-Earth-orbit conditions. This article describes the operating principles and critical design features of the two facilities (ATC-1 and 2) and recounts some of the test results achieved so far, particularly in relation to solar-cell interconnection problems. The performance and economics of the method are compared with those of conventional vacuum thermal cycling.

Thermo-mechanical stress caused by repeated temperature variations is a problem common to many industries, not only in the aerospace field. Thermal cycling is therefore one of the most widespread types of endurance test when product durability is of primary importance. The items tested in this way range from semiconductor chips to complete aircraft frames.

Spacecraft appendages constitute a special case for thermal-cycling tests because of:
- the high reliability required
- the composite or sandwich nature of the materials with different physical properties, making a theoretical investigation of thermally induced stresses very complex
- the comparatively wide temperature range involved, +100 to −200°C being not uncommon
- the large number of thermal cycles during the spacecraft's lifetime; this can be as high as several tens of thousands, depending on the spacecraft orbit and mission duration.

These problems are as old as space technology itself, but have been steadily amplified because mission durations now often extend to more than five years and also because the trend towards using lighter structures reduces thermal inertia.

In orbit, spacecraft appendages undergo thermal cycling in vacuum as they are alternately exposed to sunlight and shadowed, either by the Earth or by the satellite body. Heat exchanges are therefore mostly radiative, resulting in a peculiar temperature profile across the structure. For this reason and also due to the possible mechanical effect of vacuum (when hollow volumes are present), it has been customary to perform thermal-cycling tests under good vacuum in order to simulate the orbital environment as closely as possible.

Conventional vacuum thermal cycling

The conventional approach to simulating the thermal conditions encountered in space is to use a cryogenic shroud to simulate the deep-space thermal sink and a set of high-power arc lamps to reproduce the radiation spectrum of sunlight. Because of the physical laws of radiation, cooling in particular is very slow, resulting in cycle durations of one hour or more. Vacuum thermal cycling of qualification samples, which have to be subjected to at least the same number of cycles that they will experience in orbit, therefore becomes a long and costly affair. For the Agency's ECS geostationary telecommunications spacecraft's solar panels, for example, 700 cycles are necessary, whilst 3000 are needed for its antennas because of the body shadowing that will occur in orbit.

Various attempts have been made to reduce cycle durations and to adapt as effectively as possible to the constraints of the radiation laws. In the IABG facility in Ottobrunn, for example, three solar panels are mounted on a rotating holder in such a way that two panels are cooling down while the third is heating up. It is also possible to heat and cool the samples from both sides with high-emissivity

Figure 1 – Operating principle of accelerated-thermal-cycling equipment

radiators parallel to the sample surface. This has been done in the NASA MSFC facility in Huntsville, where + 100 to − 100°C cycles as short as 15 minutes can be achieved. This is probably close to the practical and theoretical limits, and it has to be borne in mind that if the vacuum medium is retained, the thermal profile across the structure is no longer accurately simulated.

The test-duration burden has nevertheless been accepted as unavoidable so long as it remained within weeks. For low-orbit spacecraft, which are Earth-shadowed about fifteen times a day, vacuum thermal-cycling tests would last months or even years.

ESA was first faced with this problem in 1976 because of its participation in the Space-Telescope project, for which one of the items provided by Europe is the 4 kW flexible solar array (STSA). The number of thermal cycles to be simulated for the five-year mission was 30 000 and moreover the solar-blanket technology and supplier had to be selected very quickly, which made it even more necessary to shorten the test cycle. More efficient means of thermal exchange had to be considered and this led to the abandonment of the vacuum environment for the five-year mission simulation and the selection of forced convection.

Forced-convection thermal cycling
The basic principle of forced-convection thermal cycling is very simple, and merely involves installing two 'air-conditioning' units around the test chamber (Fig. 1). To accelerate heat exchanges, the thermal capacity of the exchangers has to be much higher than that of the mass to be heated and cooled, i.e. samples plus test-chamber walls. This leads to two essential features of the design: heavy copper thermal exchangers of large area and light stainless-steel chamber walls.

Dry nitrogen (to prevent sample corrosion) is circulated through the test chamber by the fans, heating or cooling the samples according to the positions of the six flaps. The bypasses serve to maintain nitrogen circulation and a stable temperature within the standby thermal exchanger. Temperature control and flap operation are fully programmed for continuous day and night operation. A thermally insulated volume beneath the test chamber allows flexible samples to be equipped with tensioning weights (Fig. 2). Typical thermal cycles achievable with this type of system are presented in Figures 3 and 4.

Two units for different sample sizes (ATC-1 and 2) have now been built along these lines by Weiss Technik, of Reiskirchen, Germany, under ESTEC contract.

Unit for medium-sized samples (ATC-1, Fig. 5)
After completion of an early small-scale prototype in 1971, the first operational accelerated thermal-cycling unit was built in 1977, primarily for the testing of 12 cm × 12 cm flexible Space-Telescope solar-array samples (Fig. 6). It has also been used to test experimental solar-cell modules, in the framework of other qualification programmes, such as that for the French Spot satellite's solar array,

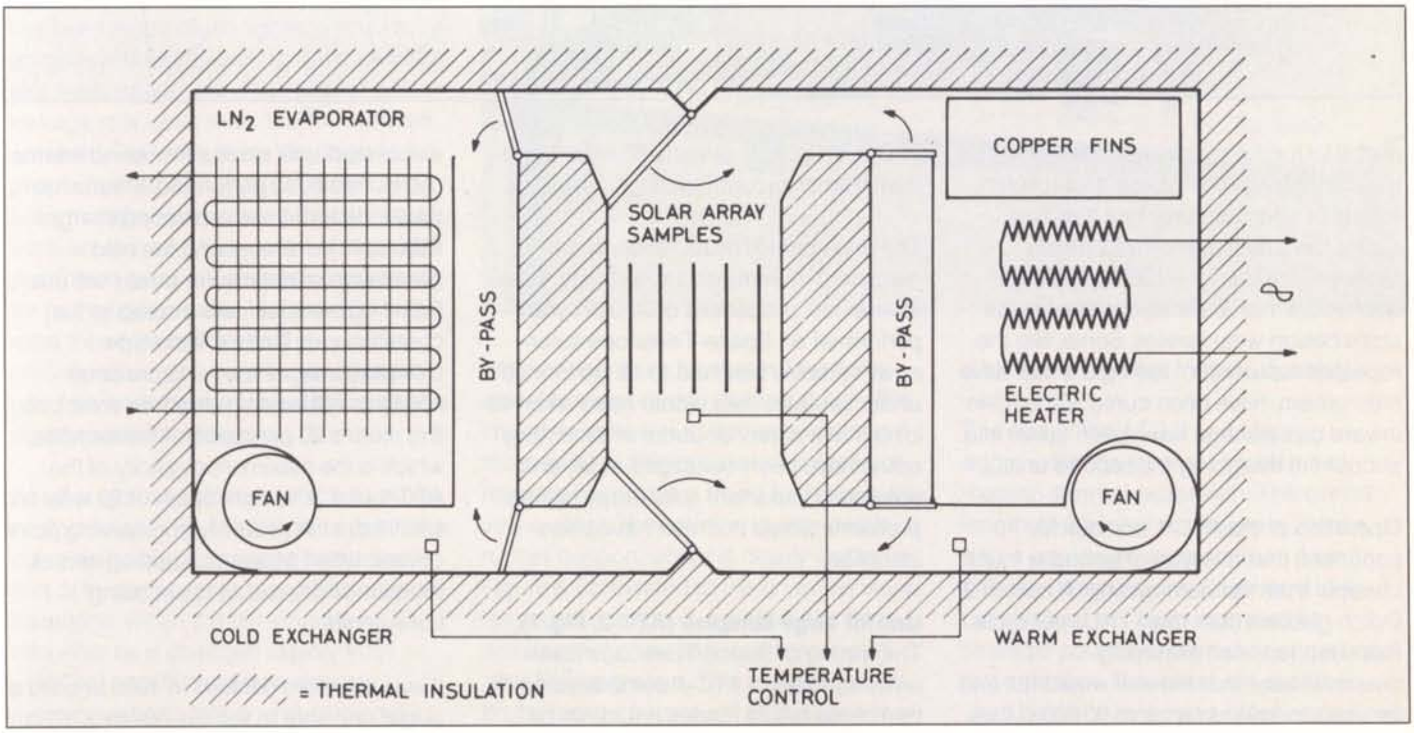


Figure 2 – Samples mounted in test chamber

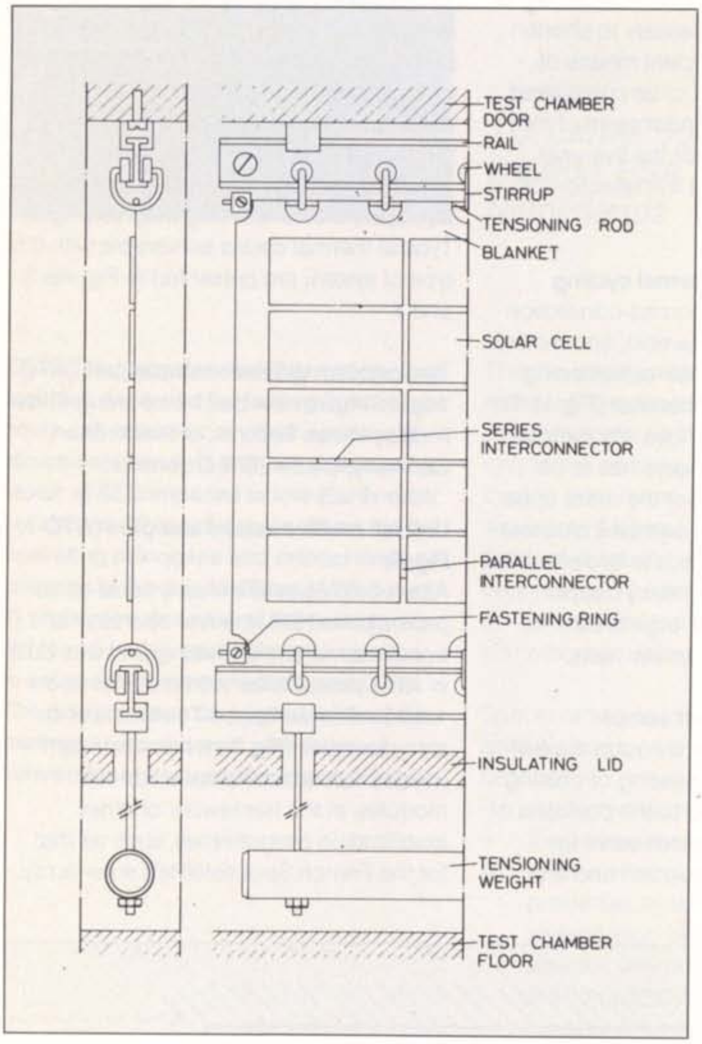


Figure 3 – Typical thermal-cycling profile for Space-Telescope solar-array samples

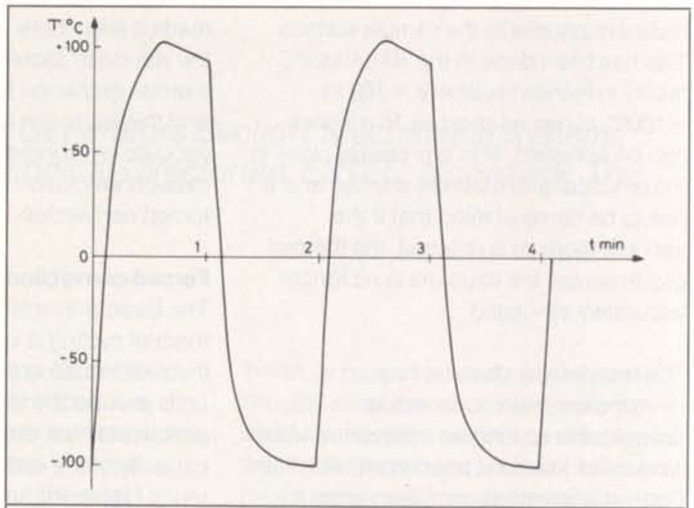
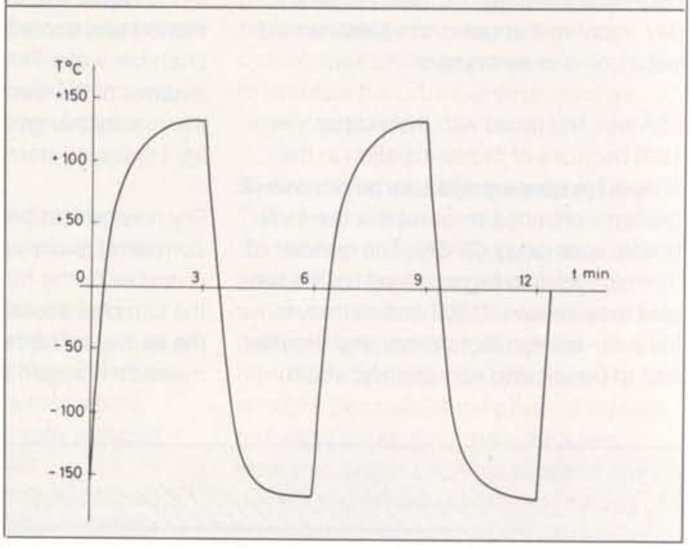


Figure 4 – Typical deep thermal-cycling profile



and also for the pyrotechnic devices to be used on the Agency's Exosat spacecraft. A total of approximately half a million cycles have been performed, mostly between +100 and −100°C. This has been more than sufficient to identify the unit's design weaknesses. Some, like the repeated rupturing of too rigid a flap drive mechanism, have been cured. Others like inward gas leakage have been taken into account in designing the second unit.

Operation of the ATC-1 unit quickly confirmed that this type of testing is much cheaper than vacuum cycling. A cost of 2 Dutch guilders (less than 1 AU) per cycle has been reported assuming, pessimistically, that the unit would fail and be uneconomic to repair at 90 000 cycles. This cost figure is already 20 times lower than that of vacuum cycling.

The main benefit must, however, be measured in terms of elapsed time. If the several test sequences of 30 000 cycles performed on Space-Telescope solar-array samples had had to be performed under vacuum, they would have taken so long that it is very doubtful whether they could have been envisaged at all, and some very important solar-array design problems would not then have been identified.

Unit for large samples (ATC-2, Fig. 7)

The testing of Space-Telescope solar-array samples in ATC-1 demonstrated that some failure modes could not be discovered until several thousand thermal cycles had been performed. Meanwhile the tendency to use increasingly larger solar cells continues and the next generation of large solar arrays will use 5 cm × 5 cm solar cells instead of the contemporary 2 cm × 4 cm type. Consequently, 12 cm × 12 cm array coupons will contain only four solar cells; this means 20 per batch of five samples, which is the maximum capacity of the ATC-1 unit. A sample batch of 20 is far too small from the reliability-engineering point of view, when arrays comprising tens of thousands of solar cells are being considered.

It was therefore decided in 1980 to build a larger unit able to test five 50 cm × 50 cm

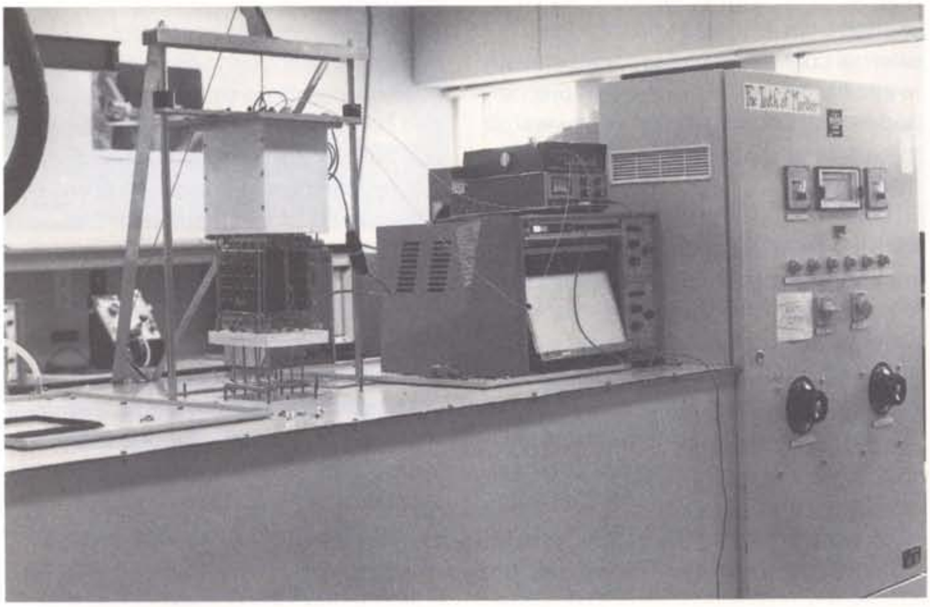


Figure 5 – The ATC-1 unit

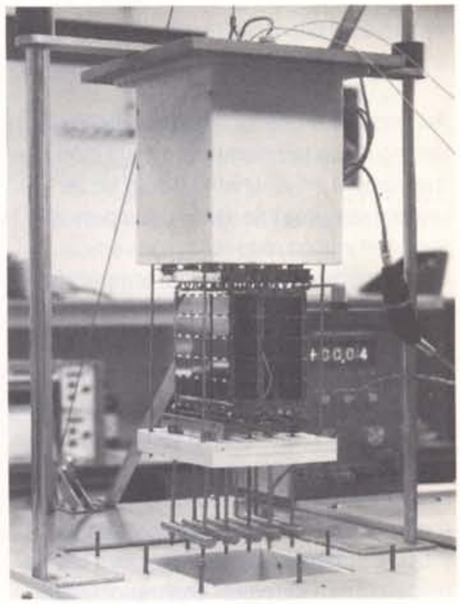


Figure 6 – Solar-cell modules mounted for insertion into the ATC-1 unit

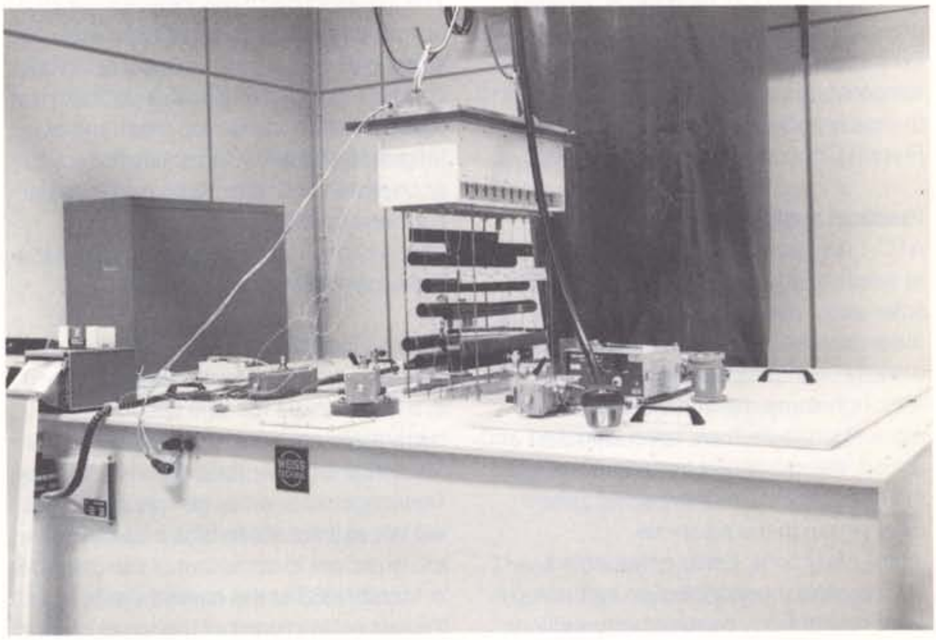


Figure 7 – The ATC-2 unit, for large samples

solar-array samples. The test volume of ATC-2 is 87 dm^3 instead of the 5 dm^3 in ATC-1, which opens the way to testing a greater variety of spacecraft structures of different shapes.

Although the general operating principles of ATC-1 have been retained, some significant design improvements have been introduced. Firstly, the ATC-2 unit has been made much tighter, vacuum components being used for fans and flap-axis feedthroughs, and the goal of a leakage rate lower than 1 m^3/h has been achieved. This may seem very high to people familiar with vacuum technology, but it must be remembered that the inner walls are thin and therefore not very rigid. In addition there are several bolted doors for exchanger repairs. The leakage that must therefore be tolerated is compensated by a continuous nitrogen gas flow, keeping the inner enclosure at a slightly positive pressure.

Another serious problem, which could be neglected on ATC-1 because of its smaller volume and higher leakage tolerance, is that of temperature-induced gas-volume variations. When the test-chamber temperature is changed rapidly from −180 to +130°C (extreme design requirements), the 87 dm^3 gas volume at constant pressure increases four times, and vice versa during cooling down. The chamber bolts would not last very long if this pressure-differential shock were not relieved, the problem being to achieve this very quickly. The solution is provided by a rubber balloon, which is clearly visible in Figure 6, connected to the chamber via a large-section pipe. In addition, the fans are stopped a few seconds before and after flap operation. This provides a less brutal pressure transient at the penalty of a tolerable increase in cycle duration.

The size of the ATC-2 unit also aggravates the inherent problems of metallic thermal expansion. The overall length of the inner enclosure is 218 cm and it would vary by more than 1 cm between temperature extremes, if steel bellows had not been mounted at strategic points between exchangers and test chamber. Flexible shafts are also used between inner and outer enclosures for fan and flap drive mechanisms, which are also equipped with Cardan couplings.

An important characteristic of thermal testing is the temperature distribution over the sample area, which should be as uniform as possible. Both units perform very well in that respect in the vertical direction, but the horizontal temperature distribution, i.e. in the gas-flow direction, is less satisfactory. Gradients as high as 50°C occur during temperature ascents and descents, followed by rapid normalisation at extreme cycle temperatures. This problem was anticipated and it is planned to improve the horizontal temperature pattern by placing lightweight gas deflectors before and between samples. Testing of larger samples would call for a more complex design, with several temperature exchangers with independent temperature controls, as has been used to thermally cycle the fuselage of the Anglo-French Concorde supersonic aircraft.

Practical applications

ATC-1 was specifically designed and used to select and qualify the Space Telescope solar-array-blanket technologies and more than 300 000 thermal cycles have already been performed to that effect. Although some minor problems in the blanket structure have been identified and solved, the prominent test result has been the discovery of an unexpected failure mechanism in the solar-cell interconnections. It was unexpected because the interconnection technology used had already behaved very well on several ESA geostationary-satellite missions where, however, the number of thermal cycles experienced rarely reached a thousand.

This is a typical case of a problem discovered when exploring a new field of application and one not peculiar to European technology; solar-cell interconnection has recently been cited by an American manufacturer as the most critical item for future solar-array designs. ESTEC is devoting a great deal of effort both internally and through external contracts with European industry to identify the failure mechanism precisely and extend interconnection life in view of the very long-duration, low-orbit missions now forseen.

ATC-2, with its larger capacity, will play an important role in that respect, and also in the testing of other future solar-blanket technologies such as large solar cells, and integrated padding and folding devices. The dimensions of ATC-2 also make it possible to test other spacecraft structures, and in fact its first operational task was to test epoxy-carbon-fibre tubes used in the backing structures of antennas (visible in Fig. 7).

The introduction of any new accelerated test prompts discussion of the validity of its equivalence to real-time testing. Work conducted so far under ESA contract on solar-cell-interconnection mechanical fatigue testing seems to justify the accelerated-test approach, and this has not been contradicted by the observations made to date on the Space-Telescope solar-array samples.

It will be instructive in this respect to compare the results with those obtained in a 30 000 cycle thermal vacuum test currently in progress at NASA's Mashall Spaceflight Center (MSFC) on six Space-Telescope solar-array samples. This test will last at least 10 months and samples are expected to come out of the chamber in March 1983 at the earliest. Aside from the technical interest of this experiment, the time involved serves as a further reminder of the impracticability of this method for qualification or design optimisation.

The impact of vacuum mechanical effects should not be overlooked, however, and the Space-Telescope solar-array accelerated-thermal-cycling qualification runs have therefore been complemented with a few slow thermal vacuum cycles before initial, intermediate and final visual inspection. This optimum combination is a necessary adaptation to strict simulation principles in order to achieve practical objectives within acceptable time and cost limits. The combined approach proved fruitful in the case of one of the Space-Telescope test sequences since it helped to highlight an adhesive-delamination problem.

Concern has also been expressed over the possible mechanical effect of 'wind' pressure over the samples during accelerated cycling. The ATC-2 test chamber is equipped with an endoscope shaft, and this has allowed us to observe that the samples do indeed vibrate slightly. Whether this can have any damaging effect is uncertain, and it was proposed to perform a 'blank' test, with the fans running but with the thermal exchangers inactive, to answer this question.

Conclusion

Accelerated thermal cycling is now an established test process that allows quick and comparatively inexpensive simulation of thermally induced stresses in spacecraft structures, and other components also (an acceleration factor of 50 times in-orbit conditions is quite feasible). The aim of accelerated testing is essentially that of solving a practical problem; test results are needed long before spacecraft launch, and preferably before the manufacture of critical items has begun, and this cannot be achieved with real-time vacuum thermal cycling because of time and budgetary constraints.

Acknowledgements

The author would like to acknowledge the assistance and encouragement received from Messrs. H.U. Amberg, U. Kehrein and C. Pfeifer of Weiss Technik, and from many of his ESTEC colleagues in the Solar Generators, Structures and Test Divisions.

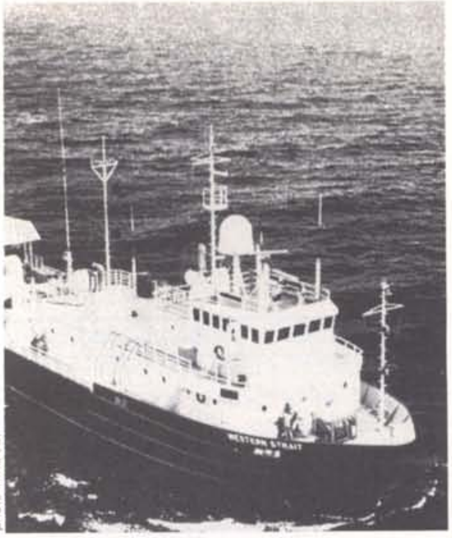


photo inmarsat

The Prosat Programme

R Rogard, Communications Systems Division,
ESA Directorate of Applications Programmes,
ESTEC, Noordwijk, The Netherlands

The Prosat Programme is intended to contribute to the promotion of satellite communications techniques for smaller ship earth stations, as well as for the other fields of mobile communications, such as land-mobile and in particular aeronautical applications. In addition to its promotional goals, the Prosat Programme is also aimed at enabling European industry and users to make a significant contribution to the second-generation Inmarsat system. It will provide the experimental support needed to analyse, assess and validate the basic system characteristics which may be adopted for a second-generation mobile space segment capable of serving 'lightweight' maritime, aeronautical and land-mobile terminals, as well as the Standard-A terminals currently in use.

The Maritime Mobile Satellite Service (MMSS) now being operated by Inmarsat is the first mobile satellite telecommunications service to have reached the operational stage. This service, initially implemented via the Marisat satellites, now benefits from the deployment of a Marecs satellite provided by ESA. The associated Marisat-type terminals installed on large ships (from 1600 grt upwards) are characterised by a high G/T* (−4 dB/K). The high performance figures specified for these terminals result from the basic choices made for the space segment; namely

- global Earth coverage by means of a single beam antenna
- Frequency Division Multiple Access (FDMA)
- use of transparent satellite transponders.

Further expansion of this type of service presupposes a reduction in the size and cost of terminal equipment, whose performance would of course have to be reduced; one may therefore envisage a further development towards satellite systems in which the lower performance of mobile terminals would be offset by an increase in the level of performance afforded by the space segment. This can easily be achieved by increasing the gain of the associated satellite antenna, which would improve both the EIRP** and the figure of merit (G/T) of the satellite (multibeam systems).

* The G/T figure characterises the sensitivity of the terminal receiver; the higher the G/T, the lower the power that needs to be radiated

** Effective Isotropically Radiated Power

The Prosat Programme is divided in two phases. The tests objectives for Phase-1 are:

- to investigate the end-to-end performances of satellite/mobile links under real propagation conditions, for different modulation/encoding, multiplexing and mobile-terminal antenna options
- to select optimal modulation and coding techniques, taking into account the multipath environment associated with different terminal antenna options
- to evaluate and select optimal terminal antenna concepts for each mobile service concerned
- to characterise fully the satellite/mobile link performances for each mobile service concerned and their impact on the design of the second-generation Inmarsat system
- to prepare for the Phase-2 demonstration and evaluation programme.

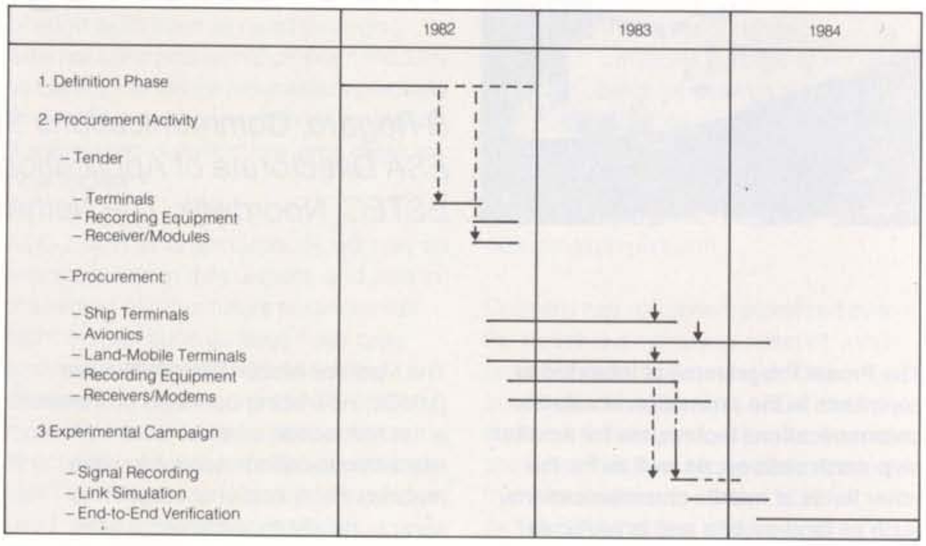
These tests will involve:

- the Agency's Payload-Monitoring Station at Villafranca (Madrid)
- the Marecs satellite located at 26°W
- terminals on-board ships, aircraft and trucks
- link simulation facilities.

The tests will be performed in three steps:

1. Test signals will be transmitted from the Villafranca monitoring station to mobiles via Marecs. They will be recorded at the mobiles and will provide a complete characterisation of the multipath environment associated with each mobile-terminal

Figure 1 — Summary time schedule for the Prosat Programme



antenna option under test.

2. Signals recorded at the mobiles will be used either to adjust, or for playing-back on, the satellite link simulator. The modulation/encoding techniques will be investigated for each mobile terminal and associated multipath environment, using the satellite link simulator, with a view to selecting optimal modulation/encoding characteristics and antenna options.
3. After the selection of optimum modulation and antenna systems on the basis of Step 2, end-to-end verification tests will be performed using the actual satellite link.

This approach has been adopted for several reasons. An important constraint stems from the power limitations of the satellite. Also, test conditions are never identical, and therefore the comparison of results is always difficult. The optimisation process is also complex and therefore time consuming, in view of the large number of parameters to be considered. The approach selected permits the reproduction of identical test conditions in a controlled laboratory environment.

The detailed content of the Phase-2 programme will be decided upon during Phase-1. It is expected to concentrate on demonstrations which may involve fitting additional mobiles with terminals representative of future systems.

The overall time schedule for the Prosat Programme presented in Figure 1 includes:

- the activities related to the development of mobile terminal prototypes, and the manufacturing of demonstration units
- the installation of prototypes and demonstration units
- the procurement of simulation facilities, the baseband equipment for the Villafranca station, and the recording facilities to be installed on-board the mobiles
- the Phase-1 experimental campaign and the Phase-2 technical evaluations and demonstrations.

Definition of the mobile terminals

For Phase-1 of the Programme, the Agency plans to procure:

- 5 types of maritime terminal
- 1 aeronautical terminal
- 2 types of land mobile terminal
- recording equipment
- modems and receivers.

The terminal types to be developed and evaluated have been selected on the basis of the following criteria:

- *Cost:* This is one of the most important criteria since the adoption of a cheap terminal is likely to be a prerequisite to the setting-up of aeronautical and maritime low-G/T services.
- *Ease of installation:* The equipment must be easy to install and hence smaller and lighter than at present.
- *Advanced technology:* Advanced technologies must be used whenever compatible with simplicity in the context of mass production.
- *Compatibility with future satellite techniques:* At this stage it is difficult to predict exactly what the future satellites serving mobile users will look like; it is clear, however, that there is a trend towards multibeam systems as a first step, and regenerative repeaters as a second.
- *Performances:* For the ship terminals a large range of G/T values must be covered to permit accurate system trade-offs when evaluating the overall system (including the satellite). Several systems will need to be tested to 'optimise' performances in the multipath environment.

  For the aeronautical terminal, the G/T value adopted is 2 dB higher than the Aerosat avionics G/T. The current state-of-the-art should permit this performance to be achieved even with simple airborne antenna subsystems.

The five maritime terminal types which have been identified cover the complete G/T range, from about −24 dB/K up to −10 dB/K. The complexity of the antenna system increases across this range. When antenna pointing is required, mechanical systems have been preferred to phased-array solutions for simplicity and therefore cost reasons. They are also preferred to antenna-switching solutions, which in any case require some type of stabilisation if one is aiming to improve the carrier-to-multipath ratio (C/M), and which lead to quite bulky systems. RF tracking is not considered at all, due to the multipath phenomena involved. The simplest terminal antenna selected has a

Figure 2 — Antenna characteristics for various types of maritime terminal

hemispherical radiating pattern and no stabilisation; the terminal with the highest performance corresponds to the Standard-B defined by Inmarsat.

In addition it is intended to procure an RF terminal to investigate the polarisation structure of the received wave in the presence of multipath interference. Figure 2 shows the main characteristics of the antenna concepts selected.

The airborne terminal requires an antenna subsystem providing 2–3 dB minimum gain over the coverage area (solid angle greater than 10° elevation angle referred to the aircraft axis). Studies performed in the framework of the Aerosat programme led to the conclusion that the minimum-gain requirements can easily be achieved with antennas using discrete radiator assemblies. These studies also showed that, because of bandwidth and decoupling problems, it is more advantageous to use separate transmit and receive radiator assemblies.

The main features of the airborne terminal selected are:
- expected G/T: −24 dB/K
- expected C/M: 6–10 dB
- maximum EIRP: 17 dBW.

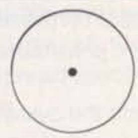
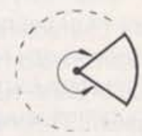
The two land mobile terminals to be procured will also have the same G/T value of −24 dB/K. The two systems differ only with respect to antenna installation constraints. One design, with minor installation constraints, will be suitable for trucks; the other, for which flush-mounting of the antenna is a particular requirement, will be suitable for cars.

Propagation conditions

The Programme covers three types of satellite-to-mobile communications, which involve very different propagation conditions. It is therefore to be expected that the overall system optimisation process will lead to different solutions in system organisation, modulation characteristics, and therefore receiver concepts.

The main propagation effects influencing satellite-to-mobile communication links are:
- the blockage effects
- the Doppler and frequency-instability effect
- the multipath effect.

The blockage effects, which will impair all three types of link, differ in nature for each application. For the maritime mobiles, blockage effects are caused by the ship's superstructure, and can be avoided or at least minimised by proper ship-terminal antenna installation. The same is true for

TERMINAL TYPE	ANTENNA				
	POINTING	STABILISATION	GAIN	PATTERN VERTICAL CUT	PATTERN HORIZONTAL CUT
M1	AZIMUTH – NONE ELEVATION – NONE	NONE	G ≥ 1 dB		
M2	AZIMUTH – NONE ELEVATION – NONE	GRAVITY (PASSIVE)	G ≥ 2 dB		
M3	AZIMUTH – REMOTE ELEVATION – NONE	GRAVITY (PASSIVE)	G ≥ 5 dB		
M4	AZIMUTH – AUTOMATED ELEVATION – LOCAL	GRAVITY (PASSIVE)	G ≥ 7 dB		
M5	AZIMUTH – AUTOMATED ELEVATION – REMOTE	GRAVITY (PASSIVE)	G ≥ 15 dB		

the aeronautical application. Blockage effects in the land mobile system are, however, due to the overall environment, such as the presence of mountains, buildings, tunnels, etc., and cannot therefore be avoided. When operating in the 1.5/1.6 GHz band, blockage effects can lead to complete black-outs lasting several seconds. The communications system must be organised to cope with these types of effect.

Two types of Doppler effect, which also affect the three types of application, will be considered:

(i) The Doppler due to the satellite's motion: part of this effect, the frequency shift in the feeder link (fixed earth station-to-satellite link), may be corrected by frequency control, which also corrects for frequency instabilities in the satellite itself. However, the contribution due to the satellite-to-mobile link cannot be corrected for, as it depends on the relative configuration of satellite and mobiles.

(ii) The Doppler due to the motion of the mobile itself: this will, of course, be an order of magnitude higher in the aeronautical application.

To obtain the overall link-frequency uncertainty budget, one must add in the terminals' frequency instabilities. In view of the low-data-rate requirement for the envisaged services, fast signal acquisition is expected to be very difficult.

A specific characteristic of the satellite-to-mobile transmission channel is the existence of Earth-surface multipath propagation. This involves the interaction of the direct signal between mobiles and satellite with the signal reflected from the Earth's surface.

Several parameters characterise the multipath phenomena and it is one objective of the programme to make a thorough analysis of these parameters, for each type of terminal. The most important effect is the signal fading.

Theoretical analyses, already confirmed by various experiments, show that the signal amplitude follows a Rice distribution. These distribution laws are defined by one parameter, the carrier-to-multipath ratio (C/M). These laws are depicted in Figure 3, the curves of which define fading-depth probability as a function of C/M. For a low-G/T terminal, C/M values as low as 0 dB are expected, and fading depths exceeding 20 dB may be experienced for 1% of the time. These considerations are, of course, most important for the design of a good receiver.

Another parameter of paramount importance to the receiver designer is the fading bandwidth, which itself depends on several parameters, including mobile speed, sea state, etc. The Prosat test-signal recordings will allow statistics to be established for these parameters.

A more detailed analysis of signals will reveal other phenomena like frequency

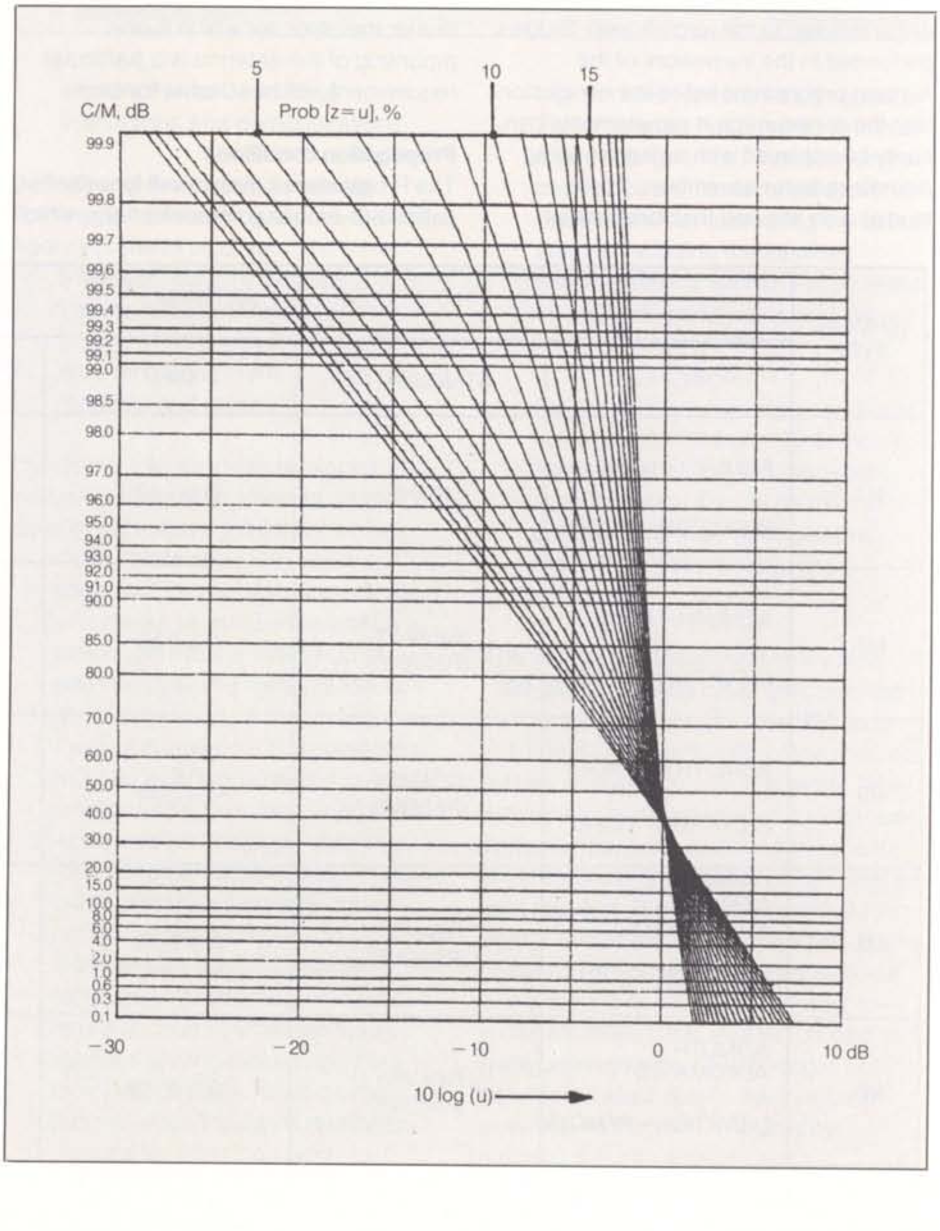


Figure 3 — Inverse distribution function of normalised power (Rayleigh plot) for various carrier-to-multipath (C/M) ratios

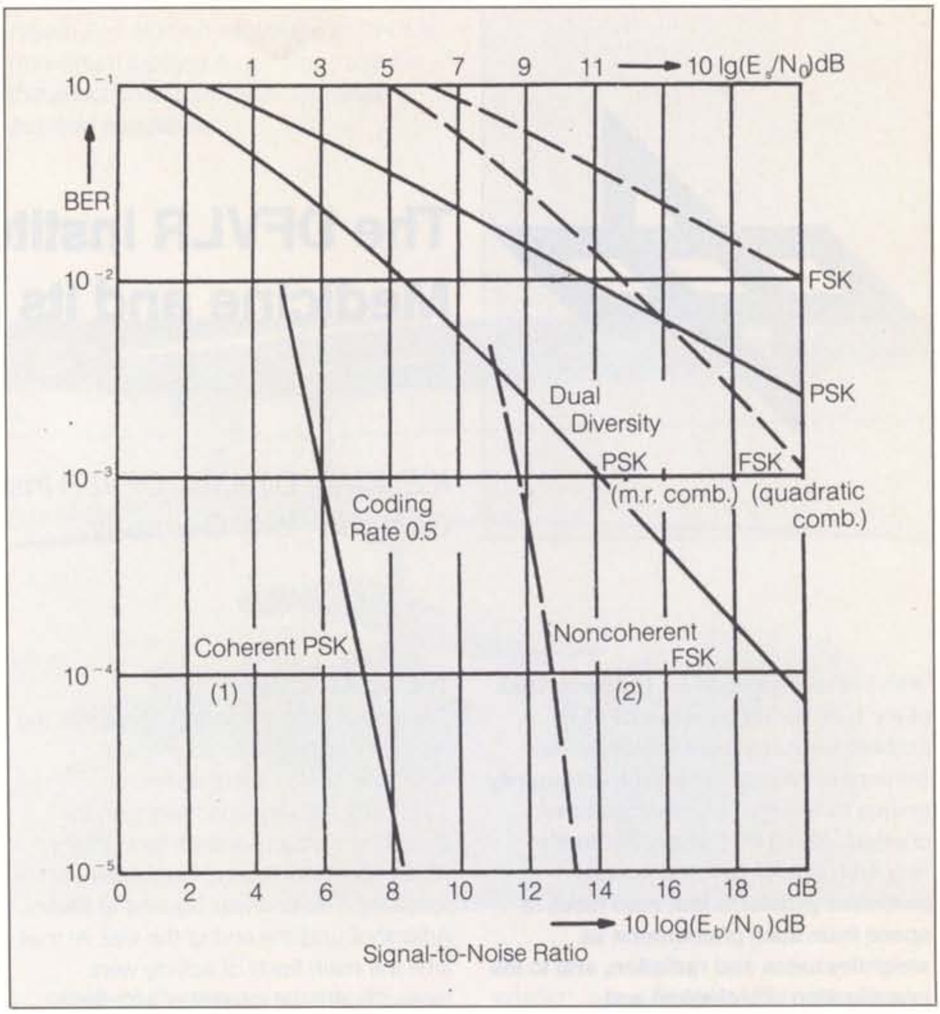


Figure 4 — Bit-error-rate as a function of signal-to-noise ratio for different coding and diversity schemes

and time-spreading due, respectively, to differential Doppler effects and path-length differentials in the various signal components.

The frequency- or phase-tracking performance of the receiver will be impaired by these effects. On the other hand one may take advantage of these effects to provide some multipath discrimination, for instance by using spread-spectrum techniques.

Modulation schemes and system organisation

The theoretical effects of the multipath phenomena on a data-transmission link (in the extreme case of Rayleigh fading) are presented in Figure 4, for two modulation types, FSK (Frequency-Shift Keying) and BPSK (Binary Phase-Shift Keying). The requisite propagation margin for such a scheme (in excess of 20 dB for a bit-error-rate of 10^{-5}) obviously cannot be provided by a corresponding margin in satellite EIRP. However, other solutions can be envisaged: although diversity techniques provide some improvement, in practice the improvements attainable are limited, and in any event difficult and more expensive to implement. Coding techniques offer a better alternative, as the theoretical curve represented in Figure 4 for a coherent PSK link with soft decision, and full channel-state information, testifies. However, one should not jump to the conclusion that this is the complete answer for mobile-satellite-link design. In fact, these curves assume an ideal coherent receiver, i.e. equipment for which all synchronisation/acquisition problems have been solved. The signal characteristics presented here show that receiver design is in fact a major item of concern. It is an objective of the Prosat Programme to solve this type of problem.

Three areas of solution are to be investigated:

- overall system organisation
- modulation-scheme definition
- optimisation of receivers.

Overall system organisation is a key aspect of the problem. The magnitude of the task of the receiver designer will depend on the type of system organisation adopted.

In practice, overall system organisation will be a consequence of receiver performance and cost; whenever fast signal acquisition is possible, TDMA systems can be adopted. On the other hand, when fast acquisition is not possible, or is too expensive, both TDMA and random-access techniques are precluded.

The choice of possible modulation schemes will also be a consequence of receiver capabilities. Whenever carrier acquisition proves difficult, it may be necessary to depart from the standard PSK scheme to maintain a sufficient carrier power margin.

At this stage, it is not planned to optimise the modulation scheme for spectrum conservation and therefore MSK modulation techniques are not yet envisaged. On the other hand, wideband techniques are required for some applications (ranging function for the aeronautical services, or CDMA technique for multiple-access system organisation) or might help in discriminating between the main and the multipath signals. It has therefore been decided to study the implications of using spread-spectrum modulation techniques.

As a consequence of the above considerations, a wide range of receiver techniques need to be studied. These receivers, the function of which is mainly to demodulate the 70 MHz signals down to baseband, are intended to be tested in the laboratory with the link simulator, and used eventually in end-to-end verification tests. Six different receiver configurations have been identified, each configuration covering a wide range of system parameters.

The DFVLR Institute for Aerospace Medicine and its New Facilities

K.E. Klein, Director, DFVLR Institute for Aerospace Medicine, Cologne-Porz, Germany

With the inauguration on 10 March 1982 of the new buildings of the DFVLR Institute for Aerospace Medicine, an aerospace medical research community unique in western Europe has been created. About 40% of the Institute's research is now devoted to the particular problems that man faces in space from such phenomena as weightlessness and radiation, and to the investigation of biological and physiological cell processes under microgravity conditions.

The Institute's history

Cologne-Porz is the fourth home that the Institute has had in its 48 years of existence, since its foundation on 1 January 1934 by what was then the Deutsche Versuchsanstalt für Luftfahrt (DVL) (German Testing Establishment for Aviation). The unit was housed at Berlin-Adlershof until the end of the war. At that time the main fields of activity were research into the causes of accidents, and into noise, acceleration and the effects of vibration, and the formulation of a medical basis for the design of life-saving equipment.

In 1952, the establishment of a Medical Test Centre for Flight Crews in a Bonn barracks marked the beginning of a new phase after a lapse of seven years. The first equipment of any size to be installed was a vacuum chamber in which fundamental research was carried out into high-altitude and low-pressure physiology. This was the starting point for the development of theories for similar problems facing divers and diving-bell workers, which led in 1966 to the World's first experiment in saturation diving to a depth of 220 m, and to the opening in 1966 of an underwater laboratory in Helgoland.

In the meantime, the increasing amount of research work forced the Institute to move house again. Since insufficient funds were available for a new building, it was decided to buy a large house in Bad-Godesberg, which the Institute took over in 1956 after the necessary conversion work had been completed. It was here that a centrifuge was installed for continuation of the biodynamic programme. The premises were extended and initial biological studies in the space domain were begun, turning finally to medical topics resulting from European participation in manned space programmes.

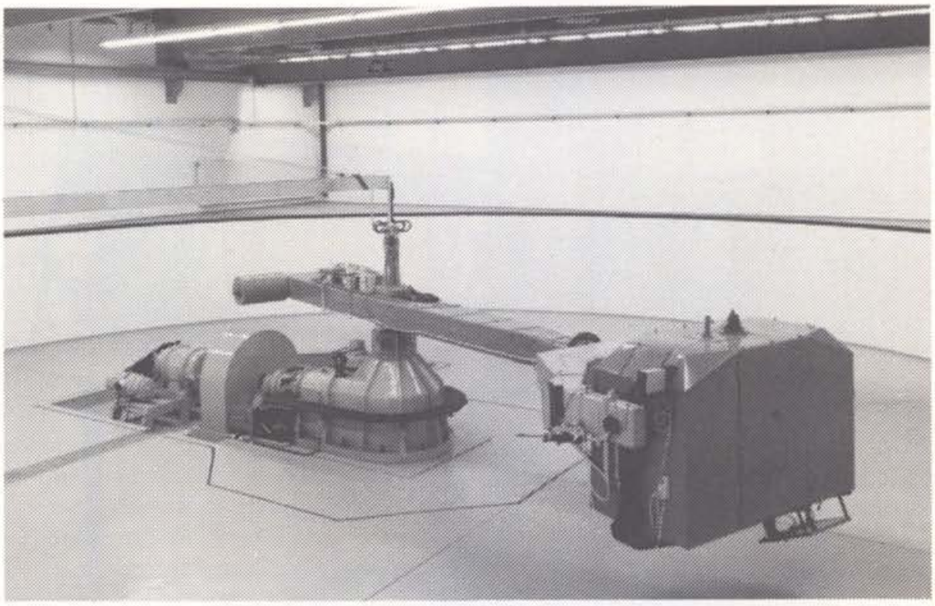
By the beginning of the 1970s, transfer of the Institute to Porz was being envisaged within the framework of a regional development programme, the final decision to do so being taken on 27 May 1974 by the Supervisory Board (composed of representatives of government, science and industry). The foundation stone of the new buildings was laid on 9 January 1979 by Walter Scheel, then President of the Federal Republic.

The Porz buildings (Fig. 1) now accommodate not only the Medical and Biological Test and Laboratory Facilities previously located at Bad-Godesberg, but also the Biophysics Department, which was formally located in Frankfurt. Only the aerospace-psychology working group will remain in Hamburg as a department of the Institute, because of the need for close cooperation between it and the selection committees and training schools for Lufthansa air crews.

The Institute for Aerospace Medicine currently has more than 90 staff. The new buildings, built at a cost of 23 million DM, cover an area of 5000 m², an increase of 2400 m² compared with the previous site. Some two-thirds of this increase is taken up by the new test hall, which will eventually house a new diving simulator

Figure 1 — The DFVLR Institute for Aerospace Medicine, Cologne-Porz, Germany

Figure 2 — Human centrifuge at DFVLR (maximum loading 40 g, 15 g/s) used in the selection of European Spacelab payload specialists



in addition to the large units already there: Spacelab simulator, human centrifuge (Fig. 2), vibration table, high- and low-pressure chambers, vacuum and ultra-violet irradiation facilities.

The work of the Institute
The Institute's work is centred around the human being, and all the stresses he undergoes whilst working with complex technological systems and in a hazardous environment.

The work at Porz can be subdivided into two main parts: that relating to aerospace topics, and that dealing particularly with oceanography. The problems raised and the results achieved often transcend the boundaries of these two, at first sight quite divorced, sectors of research.

Diving medicine accounts for about 20% of the research undertaken at the Institute. A deep-diving simulator, Titan (Fig. 3), will be completed in the middle of 1983, which will provide the programme with a 100 bar (1000 m depth) facility for research with human subjects, and 150 bar for research with animals. This should meet all foreseeable experimental requirements for investigating the possibility of divers working at such depths.

Turning to the Institute's aerospace activities, which represent some 25% of the day-to-day research and development effort, one of the most important areas of work is that on pilot workloads and performances.

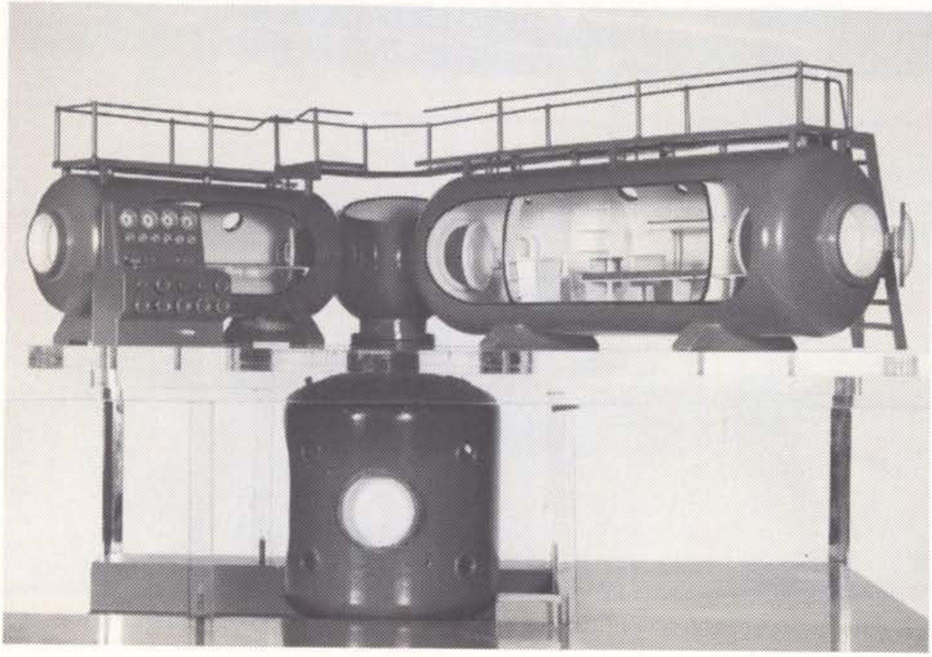
When jet aircraft were introduced to civil aviation, a number of problems became increasingly pressing, especially those related to mental fatigue caused by long flights and the disturbance of the daily biological cycle. In this context, the operational importance of this kind of constraint, mainly on the long North Atlantic routes, but also for air traffic within Europe, is being analysed. Even in factory shift work there are substantial individual differences in the human's ability to withstand disturbances in biological rhythm. DFVLR's work in this field is now focussed on the experimental development of criteria for selecting people with a relatively high resistance to these stresses. There is now a test facility available in which the time lags in the work/rest pattern as they arise on flights across time zones, in shift work and, in a slightly different form, on space flights, can be simulated.

Future work at DFVLR in this area will concentrate particularly on stresses of another kind, imposed on pilots by new cockpit technology involving new kinds of display and control functions, by greater automation, and by crew reductions.

In the space domain, the Institute has been charged by the European Space

Figure 3 – Model of DFVLR's Titan deep-diving simulator

Figure 4 – ESA payload specialist Ulf Merbold (lying down) and European mission specialist Claude Nicollier during biomedical training at DFVLR



Agency with the research studies and tests for the selection, medical and psychological monitoring and part of the biomedical training of the three European Spacelab astronaut candidates (Fig. 4), one of whom has recently been chosen as the European payload specialist for the first Spacelab mission in September 1983 (see page 83). DFVLR will play a similar role for the German national Spacelab D 1 mission in 1985, in which three Europeans will take part. In preparation for that mission, a new Spacelab simulator located at the Institute will be used for the first time for crew training.

With the Frankfurt working group on Space Biophysics now part of the Institute, space-related research activities will account for about 40% of staff effort and 45% of laboratory space and test equipment.

Endeavours in this area are concentrated on the scientific problems of:
- redistribution of body fluid and responses of the human cardiovascular and endocrinological systems to the changing g-forces encountered during a space mission
- cell-functions and gravity-sensing organ development in small animals in the microgravity environment
- effects of high-energy cosmic radiation, vacuum, and ultraviolet irradiation on biological and biochemical samples.

Between 1983 and 1985, it is planned to fly a total of eight experiments prepared by the DFVLR Institute for Aerospace Medicine as national or European Spacelab experiments and on US Space Shuttle flights.

In Brief

Ariane L5 Launch Investigation

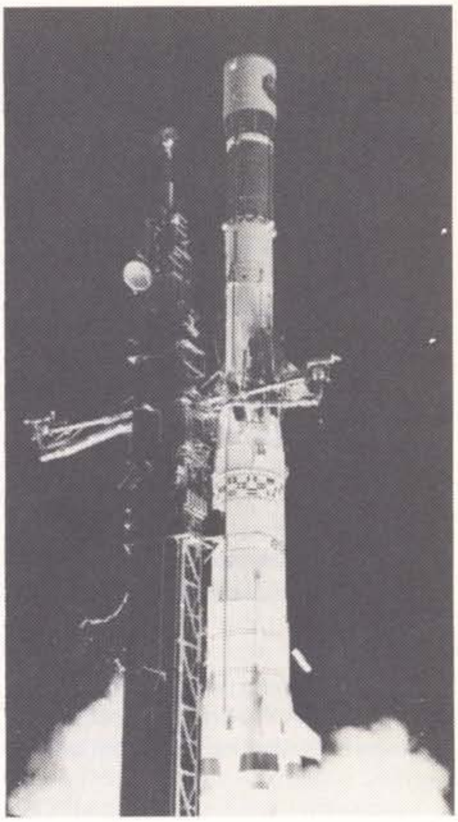
Initial investigations into the failure of the third stage of Ariane during the L5 launch on 10 September, suggest that it was due to a problem with that stage's turbopump.

The launcher's first and second stages performed nominally, and the third-stage engine ignited correctly 285 s into the flight. It functioned correctly for 275 s, at which point the turbopump speed dropped by 1000 rev/min; 1 s later its speed fell from 60 000 to 30 000 rev/min, and the pump finally stopped after 325 s of running. The drop in thrust and the consequent engine cut-out caused the loss of the launcher.

The most probable reason for the cut-out is thought to be damage to the reduction gear trains in the turbopump, owing to either:

- faulty lubrication during calibration and acceptance and qualification testing on the ground, or
- a defect in the gear trains themselves

(this hypothesis remains to be validated or rejected by the Board of Enquiry mentioned below).



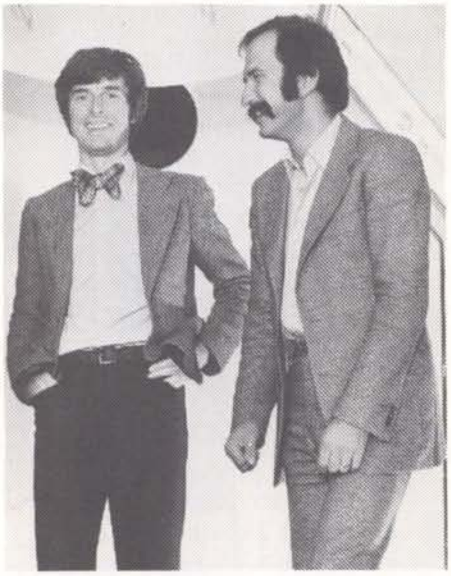
Lift-off of Ariane L5

To ensure that no such failure can recur during the next launch (L6), ESA and CNES have set up:

- a Board of Enquiry composed of European experts, whose task is to determine the cause of the malfunction. This Board is due to submit its results in mid-October
- an Ariane Programme Review Group, whose task is to check that the L6 launcher conforms to qualification and manufacturing specifications prior to authorising its shipment to the launch base in French Guiana.

Ariane's guidance and flight-control systems, and stage and fairing separation systems performed flawlessly during the L5 flight.

Spacelab-1 Flight and Back-up Payload Specialists named



Ulf Merbold (left) and Wubbo Ockels (right)

ESA and NASA have named their prime and back-up Payload Specialists for the first Spacelab mission, scheduled for 30 September 1983 with the ninth Space Shuttle launch (STS-9).

ESA has nominated Dr. Ulf Merbold (German physicist) and NASA Dr. Byron K. Lichtenberg (biomedical engineer) as on-board Payload Specialists. The second European, Dr. Wubbo Ockels (Dutch physicist), and the second American, Dr. Michael L. Lampton (physicist) will act as flight reserves and will be heavily involved in the payload operations from the ground throughout the mission.

The complete Spacelab-1/STS-9 crew consists of Ulf Merbold and Byron K. Lichtenberg, Payload Specialists; Owen Garriott and Bob Parker, Mission Specialists; and John Young and Brewster Shaw, Space Shuttle Commander and Pilot, respectively.

As Payload Specialists, Ulf Merbold and Byron K. Lichtenberg will perform experiments aboard Spacelab using 38 different scientific packages (experiments and experiment facilities) both inside the habitable Spacelab Module and on the Pallet. In this role, they will represent more than 70 different scientific investigators from Europe, Japan and the United States.

Relations between ESA and Canada

In the course of the Review by Canadian Government representatives of current cooperation between Canada and the Agency, which took place at ESA's headquarters in Paris on 24 and 25 June 1982,

- the Arrangement concerning Canada's participation in the development phase of the L-Sat programme was signed, and, in accordance with its Article 6, entered into force
- an Exchange of Letters took place relating to the increase in Canada's contribution to the fixed costs of the Agency.

The accompanying photograph shows the signature of the Exchange of Letters in progress on 25 June, with, from left to right:

- Mr. Alexander Curran, Assistant Deputy Minister (Space Programme), Canadian Department of Communication
- Dr. Michel Bourely, Legal Advisor, ESA
- Mr. Erik Quistgaard, Director General, ESA.

Other representatives from Canada present at the Review were:

- Dr. David Low, Chairman, Interdepartmental Committee on Space, Canadian Ministry of State for Science and Technology
- Dr. Kenneth Pulfer, Vice President, Canadian National Research Council
- Dr. Lee Godby, Director General, Canadian Centre for Remote Sensing
- Mr. Stephen Heeney, Director, Science Environment and Transportation Policy Division, Canadian Department of External Affairs.

Top-Level ESA/NASA Talks in Paris

The second meeting between Mr. James Beggs, NASA's Administrator, and Mr. Erik Quistgaard, ESA's Director General (left and right in the accompanying photo) took place in Paris last June.

The discussion covered a wide variety of topics, including not only the present cooperative programmes between the two Agencies (Spacelab, ISPM, and the Space Telescope), but also areas of possible future cooperation. In the context of the Spacelab agreements, which provide for mutual consultation on future developments of the US Space Transportation System, of which Spacelab is one element, the NASA Administrator outlined his Agency's planning studies for possible manned space station development and utilisation. Europe is presently devoting considerable thought to space-transportation-system programmes beyond Ariane and Spacelab, in the framework of its long-term space-transportation programme, now being discussed by ESA Member States.

An exchange of views also took place on remote-sensing interests, during which ESA presented its new programme, ERS-1. NASA expressed considerable interest in the programme and it was agreed to hold further talks to explore whether some form of cooperation could be envisaged for this particular programme.

Both ESA's Director General and the NASA Administrator stressed the need for close cooperation in the scientific field and noted the possibility of offering reciprocal opportunities of access to each other's scientific programmes. Such initiatives demonstrate the high regard in which Europe and the United States hold each other's scientific achievements in space.

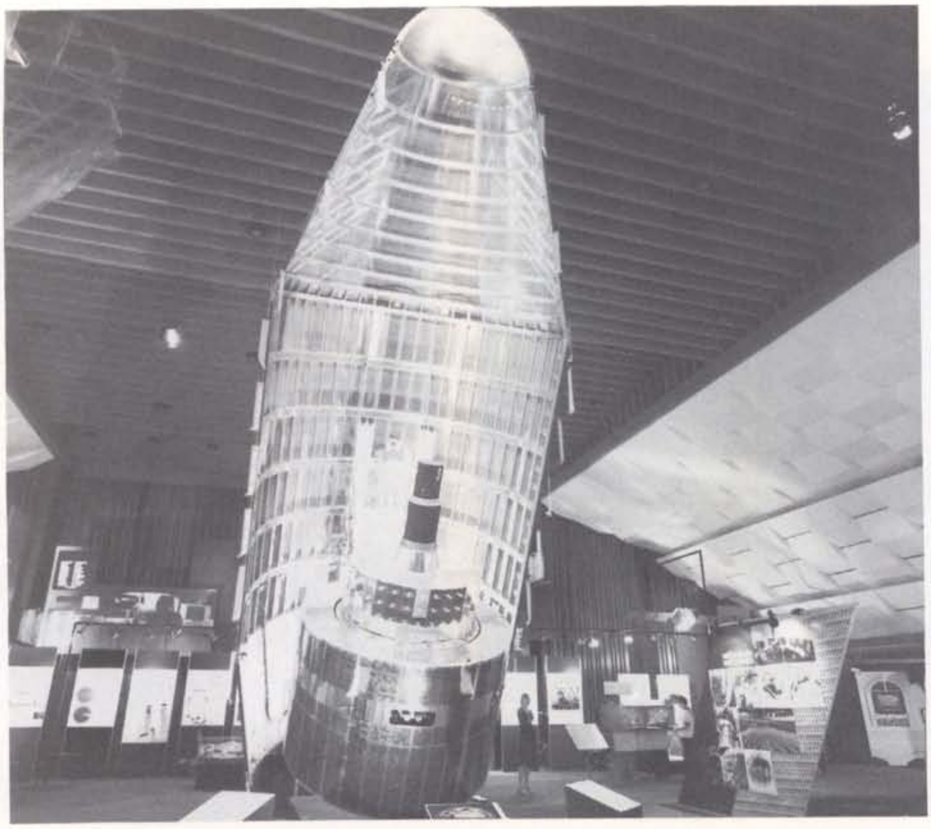
ESA at the 'Comptoir Suisse' – Space Exhibition

Switzerland is one of the founder members of the European Space Agency and has participated in its programmes and those of its predecessor organisation (ESRO) since the start of European activities in the space field in the early 1960's. Reflecting these efforts by Switzerland and by Swiss industry, this year's 'Comptoir Suisse', held in Lausanne from 11 to 26 September, gave pride of place to a Space Exhibition. This Exhibition included stands from Swiss industry and universities, the Swiss PTT, the European Space Agency, Arianespace, CNES and Eurosat.

Visitors to the ESA stand were able to see:
- a full-sized model of the Agency's meteorological satellite Meteosat, displayed inside the Ariane fairing manufactured by the Swiss firm Contraves
- a full-scale model of the European maritime communications satellite, Marecs
- a presentation on the Stella experiment, a collaborative project involving ESA, the European Economic Community and a group of European high-energy physics laboratories headed by CERN. This

experiment is designed to explore the technical feasibility and usefulness of high-speed transmission of data to a number of European laboratories from CERN via the Agency's Orbital Test Satellite, OTS.

The ESA stand at this year's 'Comptoir Suisse'



The Materials-Science Element of the First Spacelab Payload (FSLP)

The Materials-Science Payload for the First Spacelab mission represents a considerable intellectual and financial investment by ESA Member States. Following selection of the experiments in 1976, and the ensuing decision regarding the hardware elements for the Materials-Science Payload, the major part of the financial commitment was taken over by Germany, represented by the Bundesministerium für Forschung und Technologie (BMFT). The Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt (DFVLR-BPT) assumed the project-management role for the Materials-Science Double Rack (MSDR).

The development of the Isothermal Heating Facility (IHF), the Mirror Heating Facility (MHF) and all subsystems of the MSDR (e.g. central control, vacuum and gas system, cooling system, power supply) forms part of Germany's contribution and the integration of the MSDR, the flight-preparation ground operations, and major parts of the crew training are among DFVLR's tasks.

France's Centre national d'Etudes spatiales (CNES) is responsible for and is financing the Gradient Heating Facility (GHF).

The Italian contribution (CNR – Piano Spaziale Nazionale) consists of the development of the Fluid Physics Module (FPM).

All other experiment equipment and the individual experiments of the Materials-Science Payload are being developed and delivered by the relevant Member States.

ESA SPICE (Spacelab Payload Integration and Coordination in Europe) has been responsible for management of remaining flight-preparation tasks, on behalf of BMFT, since the autumn of 1981.

(The above information supplements that to be found in the article on the Materials-Science Payload published in the last issue of ESA Bulletin).

The European Pavilion at UNISPACE 82

The Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) was held in the Hofburg in Vienna from 9 to 21 August 1982. Concurrently, an exhibition was staged in the Messepalast at which United Nations Member States and International Organisations were invited to demonstrate their space programmes.

The European Pavilion, divided between the Messepalast and the Maria Theresien Park and covering a total area of 2400 m^2, was made up of three elements:

- a common area for the display of full-scale models
- the stands of the participants: ESA, The European Community, Eutelsat and the national stands of ESA's Member and Associate Member States
- the tented area on the Maria Theresien Park for the larger exhibits.

The highlights of the European Pavilion were full-scale models of:

- Spacelab, with Short Module, Pallet and Instrument-Pointing System (IPS)
- L-Sat, ESA's latest communications satellite
- Meteosat, ESA's meteorological satellite
- OTS, ESA's Orbital Test Satellite for experimental and pre-operational communications
- ECS, ESA's communications satellite
- Marecs, ESA's maritime communications satellite, which forms part of the Inmarsat global network
- Exosat, ESA's next scientific satellite, due to be launched by Ariane at the end of 1982
- Sirio-1, the Italian experimental communications satellite launched in 1977
- TV-Sat, the Franco-German direct-broadcast TV satellite.

A 1:10 model of the current version of the Ariane launcher and 1:15 scale models of future versions were also displayed, jointly by ESA and Arianespace.

A number of demonstrations of Europe's latest space technology and facilities were staged in the European Pavilion, including satellite transmission/reception demonstrations for the Conference at the Hofburg, a detailed description of which can be found elsewhere in this issue (see page 11).

1

1. Inauguration of the Space Exhibition at the Messepalast by UN Secretary General, Mr. Javier Perez de Cuellar

2. Opening ceremony of the UNISPACE-82 Conference in the Hofburg with Prof. Yash Pal, UNISPACE-82 Secretary General, on the left

3. Mr. E. Quistgaard, ESA's Director General, presenting the Agency's programme to the main assembly in the Hofburg

2

3

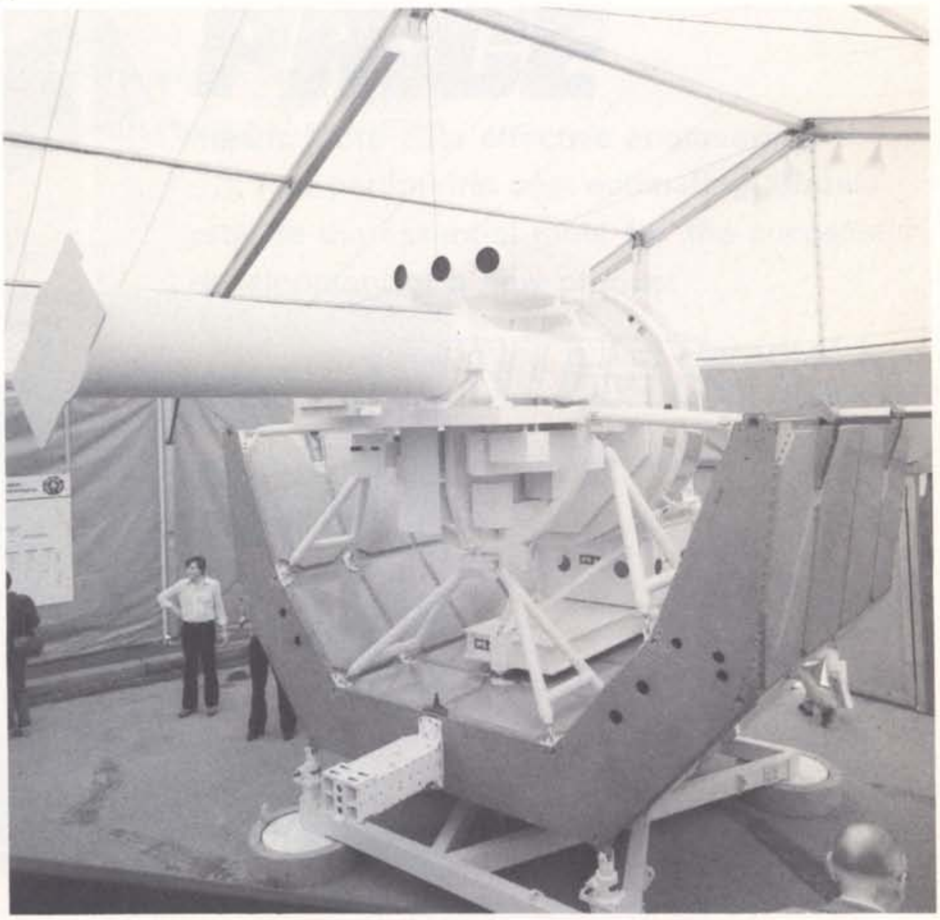
4

4. A view of ESA's stand in the European Pavilion at the Messepalast

5. Spacelab's Instrument Pointing System (IPS) on display in the Maria Theresien Park

6. Demonstrations of ESA's satellite-based data-transmission/reception (left) and information-retrieval (right) capabilities in the Hofburg

5



6

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table on page 95 and using the Order-Form on page 96.

ESA Journal

The following papers have been published in ESA Journal Vol. 6, No. 3 (September 1982):

QUALITY ASSESSMENT OF REMOTE-SENSING DATA: THE SAR CASE
BRUZZI S, GUIGNARD J-P & PIKE T

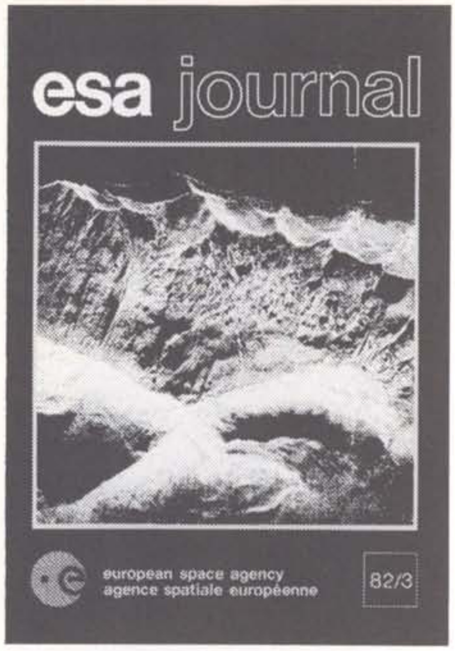
FEASIBILITY STUDY OF TOTAL-POWER RADIOMETERS: CALIBRATION ACCURACY AND SENSITIVITY OF DIFFERENT RADIOMETER TYPES
SKOU N & GUIJARRO J

ORBIT MANOEUVRES WITH FINITE THRUST: A STUDY AND PRESENTATION OF RESULTS
IRELAND B & WALKER M J H

ESACAP: A MINICOMPUTER-ORIENTED NETWORK-ANALYSIS PROGRAM
STANGERUP P

POWER-SYSTEM SIMULATION FOR LOW-ORBIT SPACECRAFT: THE EBLOS COMPUTER PROGRAMME
CAPEL A ET AL

DUAL-MODE REALISATIONS FOR ASYMMETRIC FILTER CHARACTERISTICS
CAMERON R J



Special Publications

ESA SP-175 // 240 PP
SATELLITE REMOTE SENSING FOR DEVELOPING COUNTRIES
LONGDON N & LEVY G (EDS)

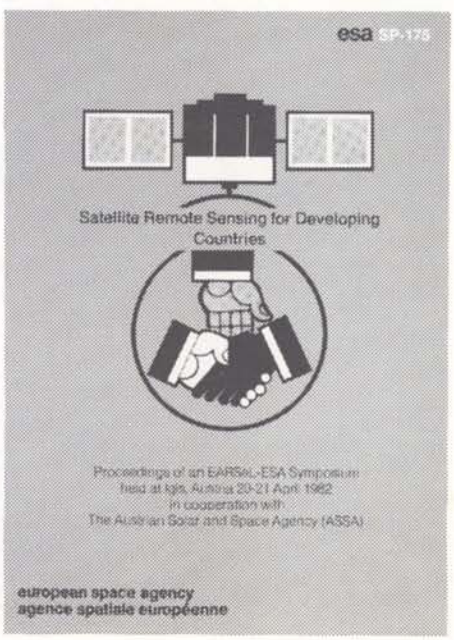
ESA SP-177 // VIII + 242 PP
THE SCIENTIFIC ASPECTS OF THE HIPPARCOS ASTROMETRY MISSION
PERRYMAN M A C & GUYENNE T D (EDS)

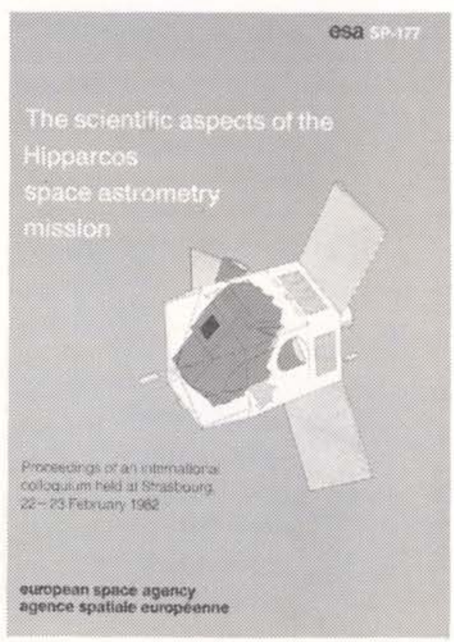
ESA SP-1042 // 82 PP
REPORT ON THE ACTIVITIES OF ESA SPACE SCIENCE DEPARTMENT IN 1980-81
PAGE D E ET AL

Brochures

ESA BR-07 // 104 PP
SPACE SCIENCE AND TECHNOLOGY IN EUROPE TODAY – SCIENCE ET TECHNOLOGIE SPATIALES EN EUROPE AUJOURD'HUI – CIENCIA Y TECHNOLOGIA ESPACIALES EN LA EUROPA DE HOY –
GUYENNE T D & BATTRICK B (EDS)
AVAILABLE IN ENGLISH, FRENCH OR SPANISH

ESA BR-08 // 39 PP
ECS DATA BOOK
SALISBURY R & BRAKES H F





ESA BR-09 // 55 PP
MICROGRAVITY AS AN ADDITIONAL TOOL FOR RESEARCH IN HUMAN PHYSIOLOGY
BONDE-PETERSEN F, HINGHOFER-SZALKAY H & HORDINSKY J

ESA BR-11 (6-PAGE FOLDER, NO CHARGE)
DATA TRANSMISSION BY SATELLITE,
ESA COMMUNICATIONS SYSTEMS DIVISION

Procedures, Standards & Specifications

ESA PSS-01-603 ISSUE 1 REV 0 // 15 PP
ESA PREFERRED PARTS LIST,
PRODUCT ASSURANCE DIVISION, ESTEC

Technical Translations

ESA TT-717 // 68 PP
PROPOSAL FOR AN EARTH STATION ANTENNA FOR GEOSTATIONARY SATELLITES WITH A SIMPLE CONCEPT OF BEAM STEERING
SLIWINSKI P & STEINER H-J, DFVLR, GERMANY

ESA TT-721 // 47 PP
HELIUM II COOLING SYSTEMS WITH LONG SERVICE LIVES FOR SPACE USE. PHASE SEPARATION, HYBRID COOLING SYSTEMS
KLIPPING G, KLIPPING I & SCHMIDTCHEN U, FREIE UNIV. BERLIN, GERMANY

ESA TT-723 // 64 PP
NOISE REDUCTION IN CENTRIFUGAL FANS BY THE USE OF $\lambda/4$ RESONATORS
NEISE W & KOOPMANN G, DFVLR, GERMANY

ESA TT-724 // 50 PP
MATHEMATICAL MODEL FOR A MAINTENANCE PROGRAM FOR MODERN JET AIRCRAFT
PRINZ R ET AL, DFVLR, GERMANY

ESA TT-727 // 283 PP
THE CRACK GROWTH RESISTANCE CURVE AS A SINGLE-PARAMETER REPRESENTATION OF STABLE CRACK PROPAGATION IN THIN-WALLED STRUCTURES
SETZ W, DFVLR, GERMANY

ESA TT-728 // 59 PP
TIME LINEARIZED CALCULATION OF TWO-DIMENSIONAL UNSTEADY TRANSONIC POTENTIAL FLOW AT SMALL DISTURBANCES
VOSS R, DFVLR, GERMANY

ESA TT-729 // 29 PP
ON THE ACCURACY OF RADIO LOCATION IN MEDIA WITH INDIRECT WAVE PROPAGATION
SAPPL E, DFVLR, GERMANY

ESA TT-730 // 177 PP
SCENARIOS OF ECONOMIC DEVELOPMENT WITHIN THE EUROPEAN COMMUNITY UP TO THE YEAR 2000
KEIMEL H & SCHMITT A, DFVLR, GERMANY

ESA TT-731 // 21 PP
RESULTS OF A SLANT-RANGE VISIBILITY FIELD EXPERIMENT USING THE MODIFIED DFLVR MINI LIDAR
WERNER C, DFVLR, GERMANY

ESA TT-734 // 63 PP
VISUAL EVALUATION OF SLAR IMAGERY
NITHACK J, DFVLR, GERMANY

ESA TT-735 // 138 PP
THE ATLAS-C MISSION
PULS J (COORDINATOR) ET AL, DFVLR, GERMANY

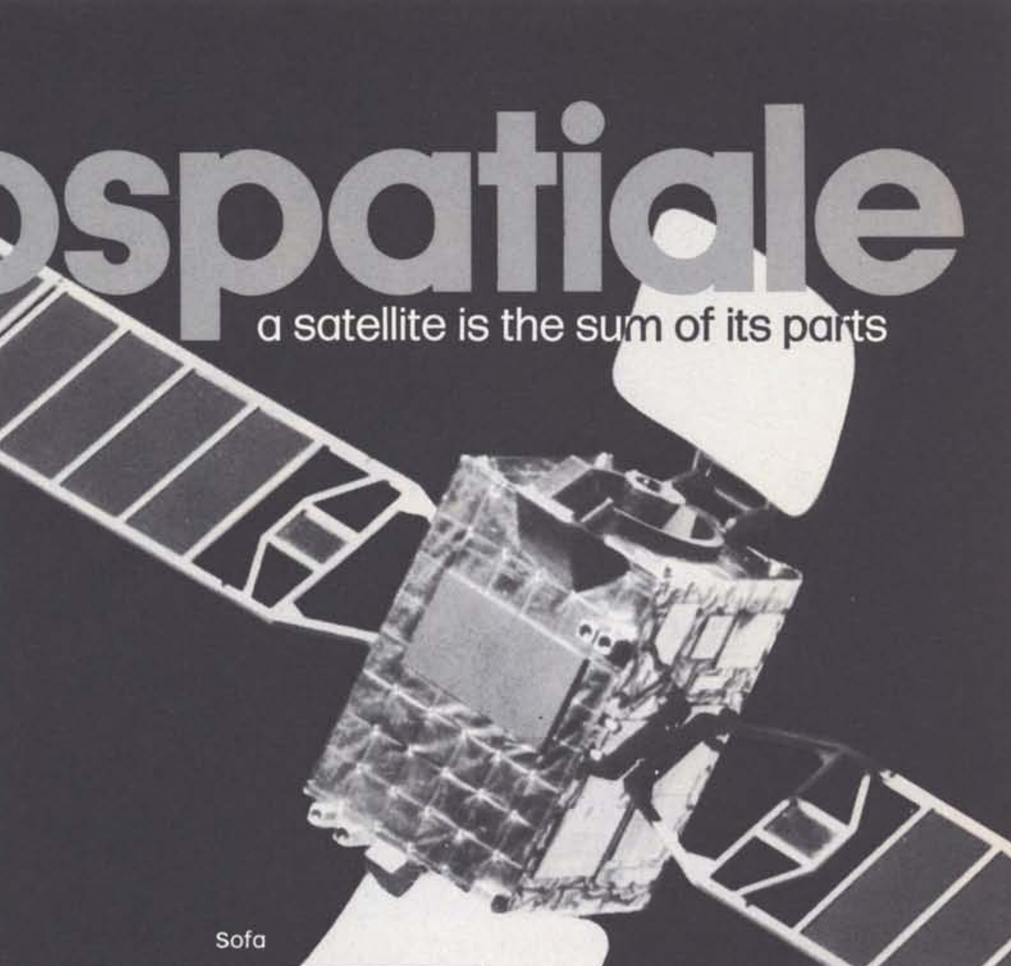
ESA TT-739 // 115 PP
ANALYSIS OF TWO AIR TRAFFIC SAMPLES IN THE FRANKFURT/MAIN AIRPORT TERMINAL AREA, AUGUST 4, 1978
VOELCKERS U, SCHUBERT M & SEYFRIED A, DFVLR, GERMANY

ESA TT-741 // 73 PP
LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1981-6
ONERA, FRANCE

ESA TT-755 // 65 PP
LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1982-1
ONERA, FRANCE

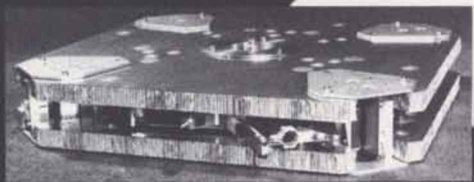
aerospatiale

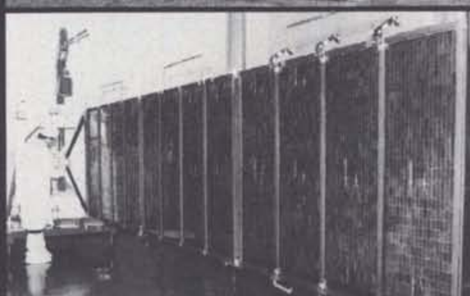
a satellite is the sum of its parts



reaction wheel ± 3000 rpm

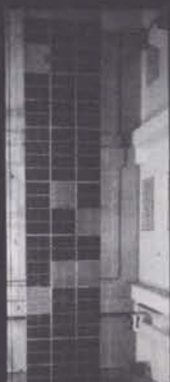
Sofa





0 to 6 kW

Ilsa



4 to 7 kW and up

Intelsat V

Aerospatiale has more than 20 scientific, communications, and meteorological satellites in orbit. We're prime contracting Arabsat and Meteosat, contributing to Intelsat V...

Qualified hardware and sub-systems resulting from 20 years experience include:

- Momentum and reaction wheels on magnetic bearings.
- Sofa , high precision (0.01°) antenna pointing device.
- Both light weight, graphite epoxy framed solar arrays, and flexible fold-up Kapton skin generators.
- Advanced spacecraft and antenna disk structures.

aerospatiale is Europe's first name in Space - watch for it!

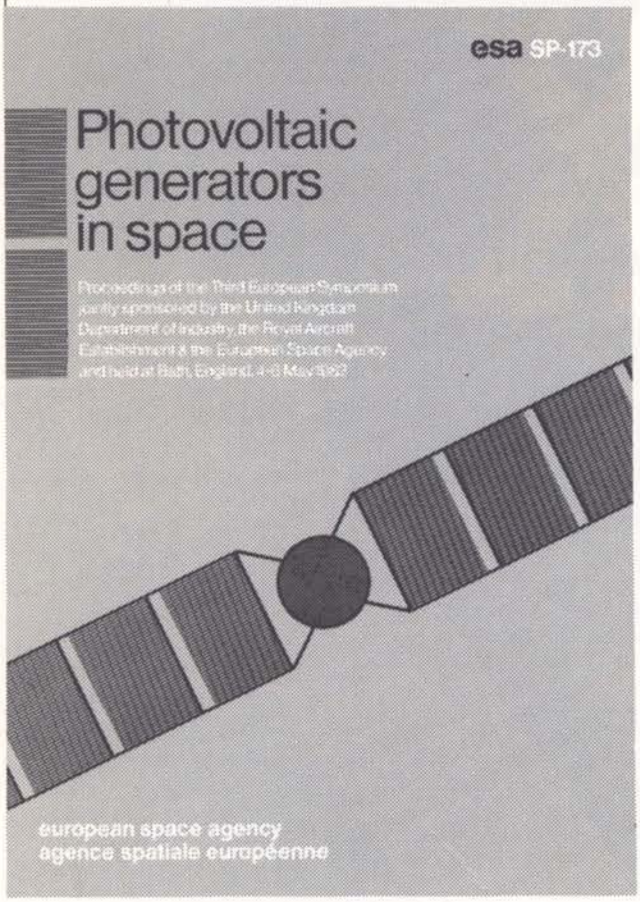
aerospatiale

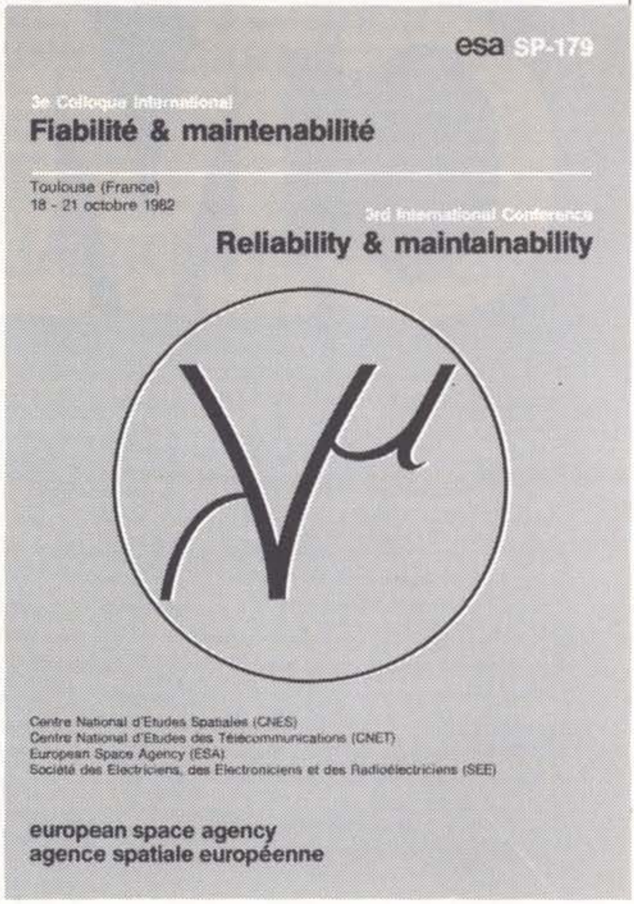
Division systèmes balistiques et spatiaux : B.P. 96 – 78130 Les Mureaux – France

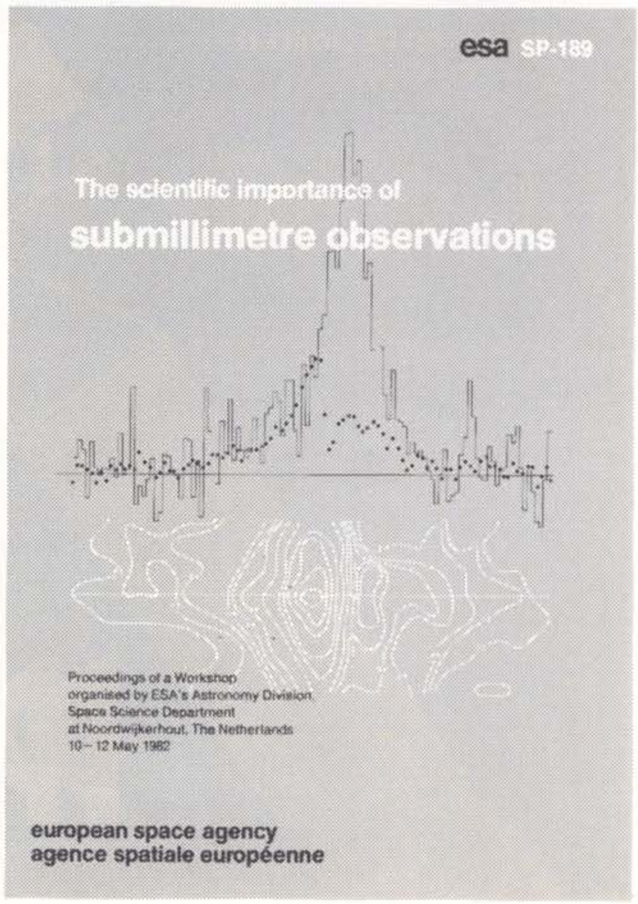
S/1347/Systèmes


PILKINGTON
CMX
Pilkington CMX is a new Cerium doped glass material for solar cell covers and thermal control mirror surfaces.
Pilkington CMX is a further development of the widely used Pilkington CMS glass that has been selected for use in over fifty major space programmes.
Pilkington CMX radiation resistant glass is manufactured by a continuous drawn ribbon process, and is now available in a range of thicknesses from 300μm down to 50μm, offering a cost effective solution for large area lightweight arrays.
Major programmes using CMS covers include L-SAT, TDRSS, DSCS 111, TELECOM, ARABSAT, DSP (MOD 35), INTELSAT V, METEOSAT, ECS/MARECS, SPACE TELESCOPE.
Pilkington PE Limited,
Glascoed Road,
St. Asaph,
Clwyd. LL17 0LL. UK.
Tel: St. Asaph (0745) 583301
Telex: 61291
Cables: Optical St. Asaph
PPE
A Company With Vision.

Latest publications







Availability of ESA and NASA Publications

Publications	Series	Available as	From
Periodicals			
ESA Bulletin		Available without charge as a regular issue	
ESA Journal		or back numbers (as long as stocks last)	
Special Publications	SP	Hard (printed) copy as long as stocks last; thereafter in microfiche or photocopy	ESA Scientific and Technical Publications Branch, ESTEC, 2200 AG Noordwijk, Netherlands
Brochures	BR		
Tribology series	TRIB		
Scientific Reports, Notes and Memoranda	SR, SN, SM		
Technical Reports, Notes and Memoranda	TR, TN, TM		
Scientific and Technical Reports	STR		
Scientific and Technical Memoranda	STM		
Procedures, Standards and Specifications	PSS		
Contractor Reports	CR		
	CR(P)	Microfiche or photocopy only	
	CR(X)	Restricted distribution; not for sale	
Electronics Component Databank Catalogue	ECDB	Hard (printed) copy as long as stocks last	
Technical Translations	TT	Microfiche or photocopy only	
Public relations material		General literature, posters, photographs, films, etc.	ESA Public Relations Service 8-10 rue Mario-Nikis, 75738 Paris 15, France

Charges for printed documents

	Currency:	AS	BF	CD$	DKR	FF	DM	I£	LIT	DFL	NKR	PTS	SF	SKR	£	US$
Price code	Number of pages															
E1/C1	1-100	200	415	16	80	60	25	7	12.600	28	70	1.007	22	55	6	15
E2/C2	101-200	290	620	24	120	90	38	10	19.000	42	104	1.510	33	80	9	22
E3/C3	201-500	440	950	37	185	140	58	16	30.000	65	162	2.317	51	124	14	34
E4/C4	over 500	560	1.200	47	230	175	73	20	37.000	82	208	2.920	64	160	17	44

1 Photocopies will be supplied if the original document is out of print, unless microfiche is specified.
2 Prices subject to change without prior notice.
3 Postal charges (non Member States only): Austria AS 90; Canada CD$ 8; Norway NKR 35; other countries US$ 7.

ORDER FORM FOR ESA/NASA PUBLICATIONS

TO: DISTRIBUTION OFFICE
ESA SCIENTIFIC & TECHNICAL PUBLICATIONS BRANCH
ESTEC, POSTBUS 299, 2200 AG NOORDWIJK
THE NETHERLANDS

From: ....

....

....

Customer's Ref.: .... Signature: ....

No. of copies			ESA or NASA Reference	Title	Price code	Date of order
Printed	Micro-fiche	Photo copy				

IF OUT OF PRINT SUPPLY / DO NOT SUPPLY IN MICROFICHE

MAILING AND INVOICING ADDRESS (Print or type carefully)

Name or function ....

Organisation..

Street address..

Town, Province, Postal code ....

Country ....

ADDITIONAL INFORMATION

1. Publications are available in printed form (as long as stocks last), in microfiche and as photocopies.
2. Publications in the following series are not available in printed form:
   - the ESA TT series;
   - all NASA series.
3. Publications in the CR(X) series are not available from ESA as they have a very restricted distribution in printed form to the States participating in the relevant programme.
4. If a publication ordered in printed form is out of print, a microfiche copy will be supplied unless indicated otherwise on the Order Form.
5. Printed copies are despatched from ESTEC, and microfiche and photocopies from ESA Head Office. They will arrive in different packages at different times.

european space agency
agence spatiale européenne

member states

belgium
denmark
france
germany
ireland
italy
netherlands
spain
sweden
switzerland
united kingdom

etats membres

allemagne
belgique
danemark
espagne
france
irlande
italie
pays bas
royaume-uni
suède
suisse