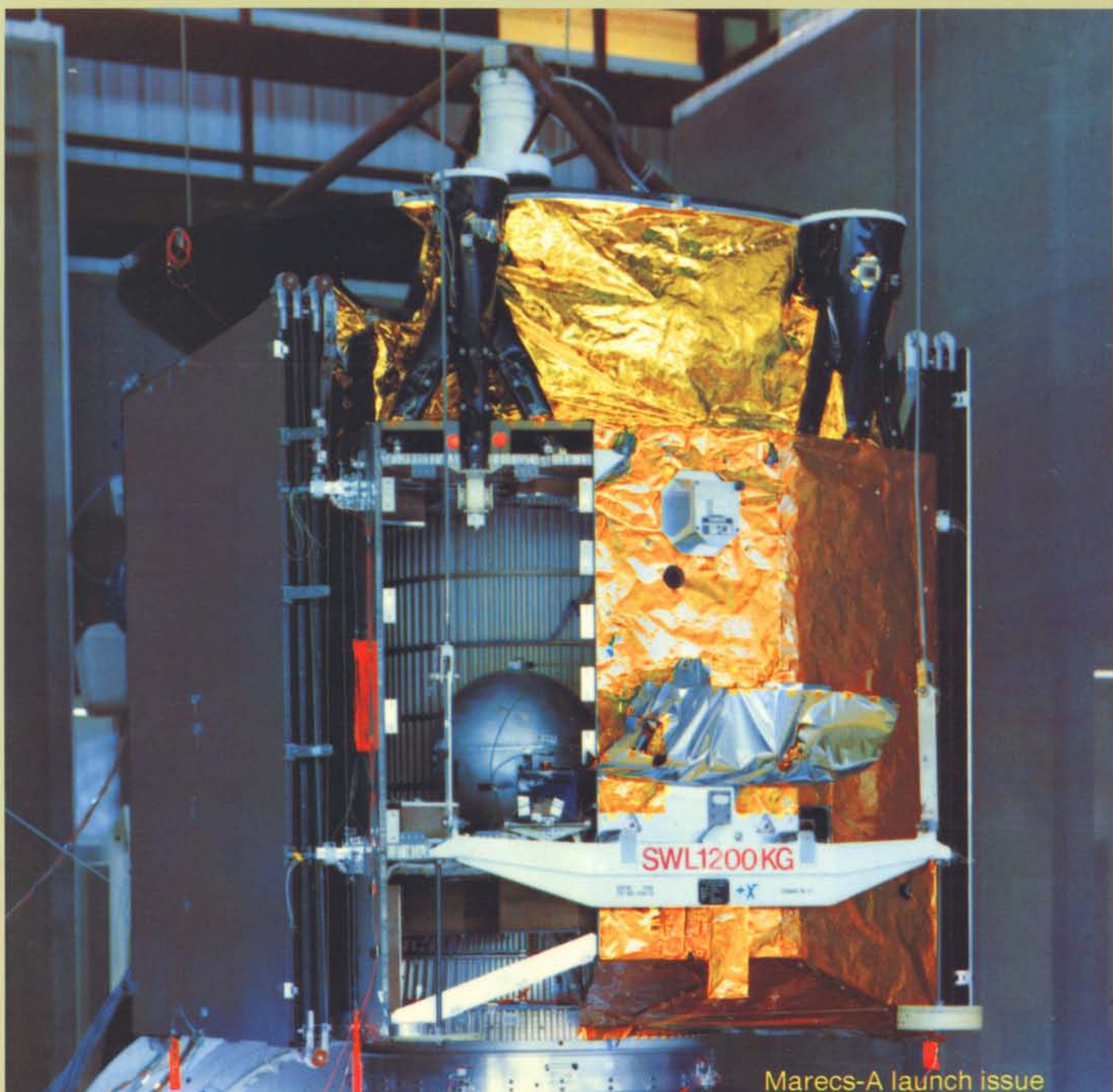
esa bulletin

number 28

november 1981



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 is an Associate Member of the Agency. Canada and Norway have 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 est un membre associé de l'Agence. Le Canada et la Norvège bénéficient 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. 28 november 1981

contents/sommaire

Front cover: Marecs structural model during vibration testing at CNES, Toulouse (F)

Back cover: Marecs flight-model payload, photographed at MSDS (UK)

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 Assistant
Gabrielle Lévy

Layout
Carel Haakman

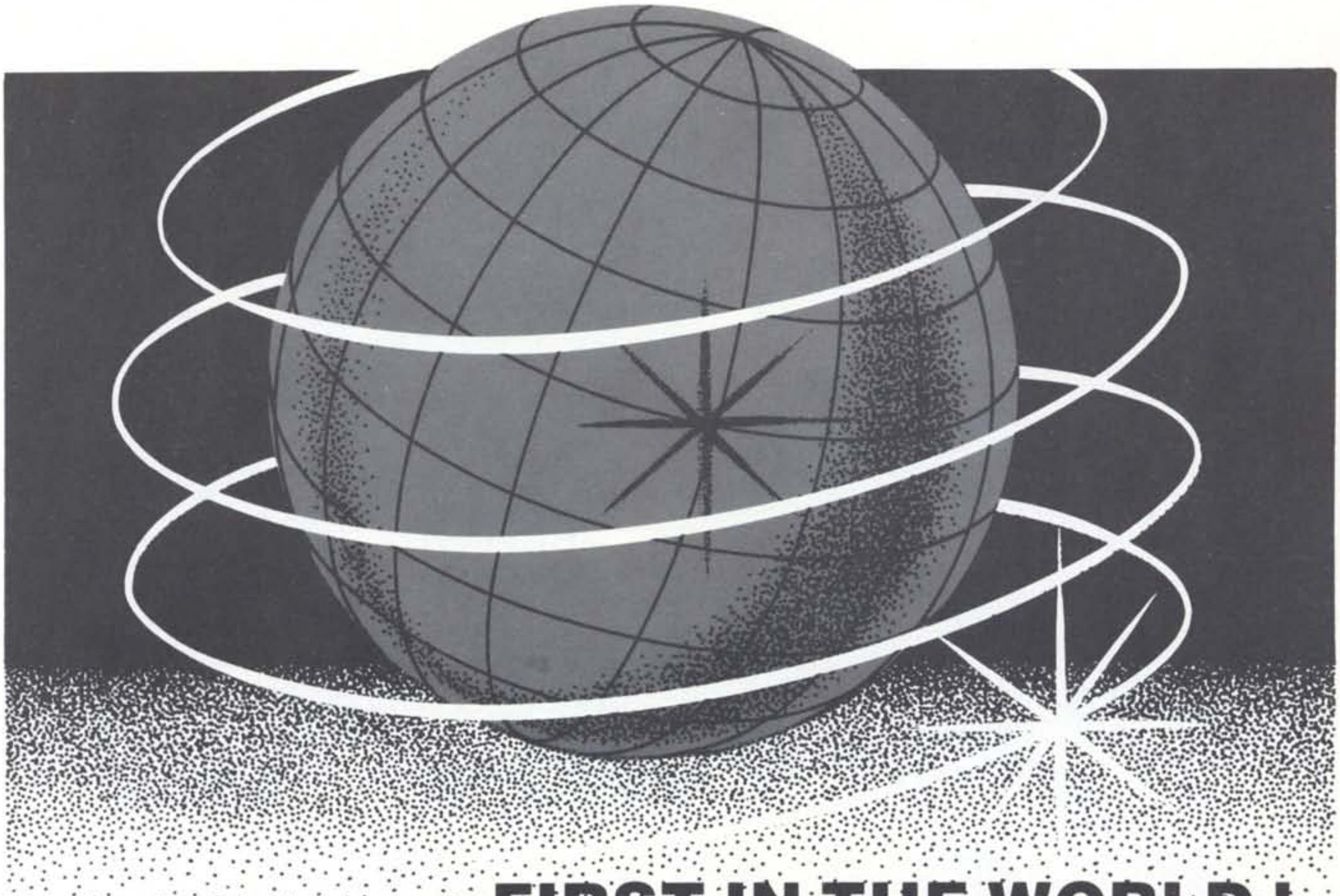
Advertising Agent
La Presse Technique SA
3 rue du Vieux-Billard
CH-1211 Geneva 4

Printed in The Netherlands by ESTEC Reproduction Services 811536
ISSN 0376-4265

european space agency
agence spatiale européenne

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


ariane
and
aerospatiale
we put all the pieces together
ARIANE is built in Europe by some fifty firms in 10 countries*. One industrial company puts it all together. One firm checks out all the interfaces between the numerous subsystems and components.
It's AEROSPATIALE, France.
Studies, Technical management, Production, Integration, Testing.
* ESA sponsored program, Prime contractor, CNES.
Société Nationale Industrielle
aerospatiale
DIVISION SYSTEMES BALISTIQUES ET SPATIAUX
B.P. 96 - 78130 Les Mureaux - France



FIRST IN THE WORLD!

The SPOT/LANDSAT D Receiver

Captures the vital images from Space!

Bell Telephone's SPOT/LANDSAT D Receiving System easily and unremittingly gathers all the image data for you.
The system includes down convertor multicoupler, BPSK/UQPSK demodulator, bit synchroniser, test modulator and test up convertor.

SPOT/LANDSAT D Receiver
The world is yours.

For detailed information, write or call today

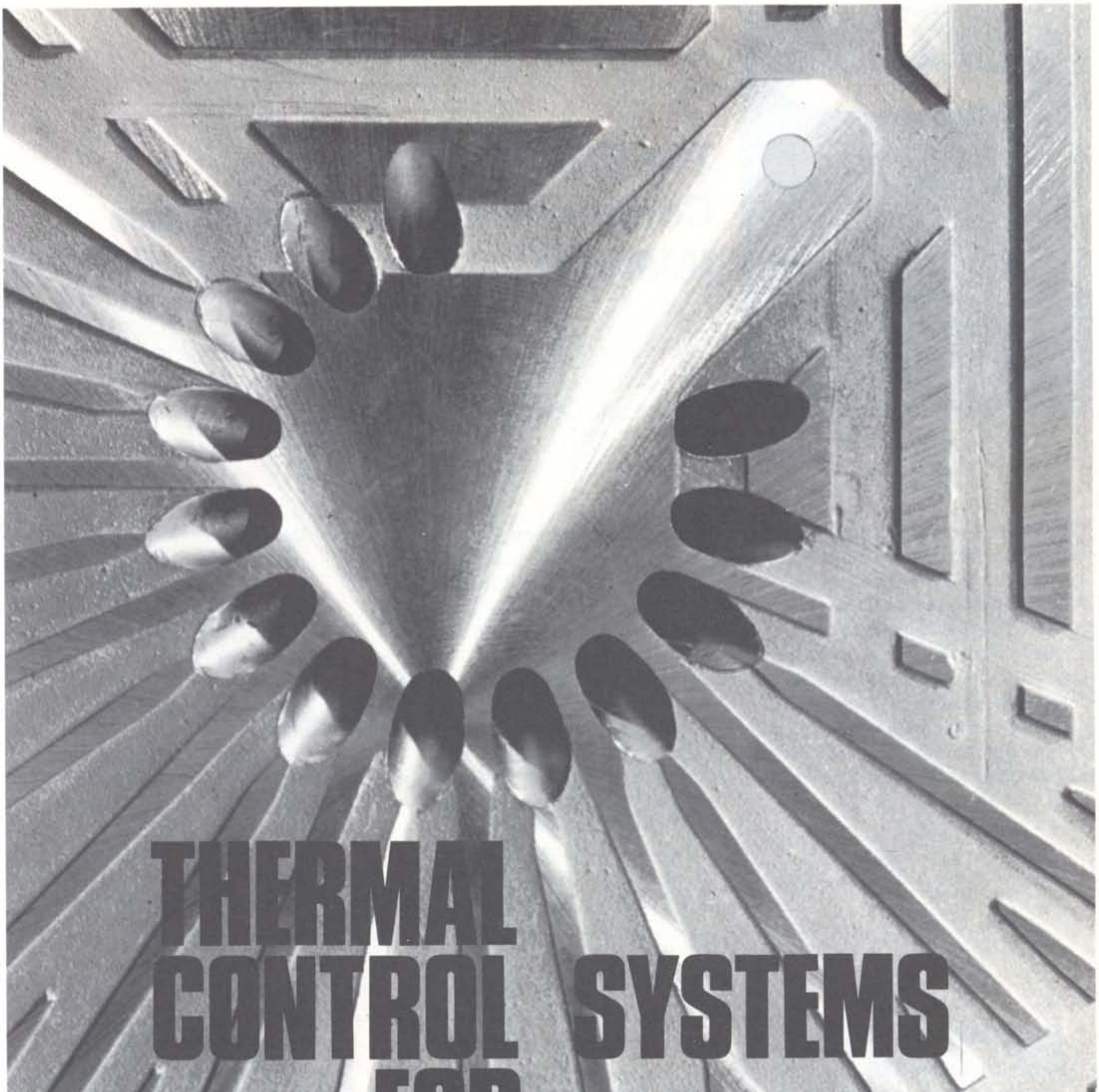
CM207

Bell Telephone Manufacturing Company S.A.

ACo

DEFENSE & AEROSPACE GROUP

F. Wellesplein 1 – B-2000 ANTWERPEN (Belgium) – Tel.: 3231 37.17.17 - Ext.: 1367



designed and made by

MICROTECNICA

TORINO/ITALY

The ESA Maritime Communications Programme (Marecs)

J.-J. Dumesnil, Maritime Satellites Project Division, Directorate of Application Programmes, ESTEC, Noordwijk, Netherlands

The first of the two Marecs maritime communications satellites will be launched on 18 December from the Agency's Guiana Space Centre in Kourou. The Marecs programme, originally started as an experimental one, will be the Agency's first in the commercial satellite business, since the satellites' communications capacity will be leased to the International Maritime Satellite Organisation (Inmarsat) for at least five years.

Historical developments

ESA's involvement with maritime-satellite development dates from 1973, when several ESA Member States (Belgium, France, Italy, United Kingdom, Spain and Germany, later joined by the Netherlands, Norway and Sweden) undertook to fund the development of such a satellite in recognition of the opinion expressed by the Intergovernmental Maritime Consultative Organisation (IMCO) that 'the use of space techniques could significantly improve maritime communications and thus the safety and navigation of ships and other units operating at sea, as well as the efficiency and economy of shipping, which carries 80% of the World's international trade'.

The satellite which it was agreed to develop at that time was designated Marots. It was intended to reuse the basic satellite bus configuration of the OTS satellite then under development, in combination with an L-band payload developed specifically to satisfy the maritime requirements as then stated (OTS and Marots were to share a common spare spacecraft platform also). These were:

(a) General communications
- Evaluation of various types of ship terminals.
- Evaluation of ship-to-shore links for telephony, telegraphy, data transfer and facsimile using L-band frequencies between satellite and ships, various modulation and signal-processing techniques, and a range of signal-to-noise ratios.
- Demonstration of compatibility with public telephony and telegraphy networks.
- Demonstration of access to satellite communications by multiple ship and shore stations.

(b) Distress, search and rescue, and safety
- Evaluation of immediate priority-access techniques for distress equipment, including Emergency Position Indicating Beacons.
- Demonstration of 'all ships' information broadcasts and weather routing via satellite to individual mobiles.

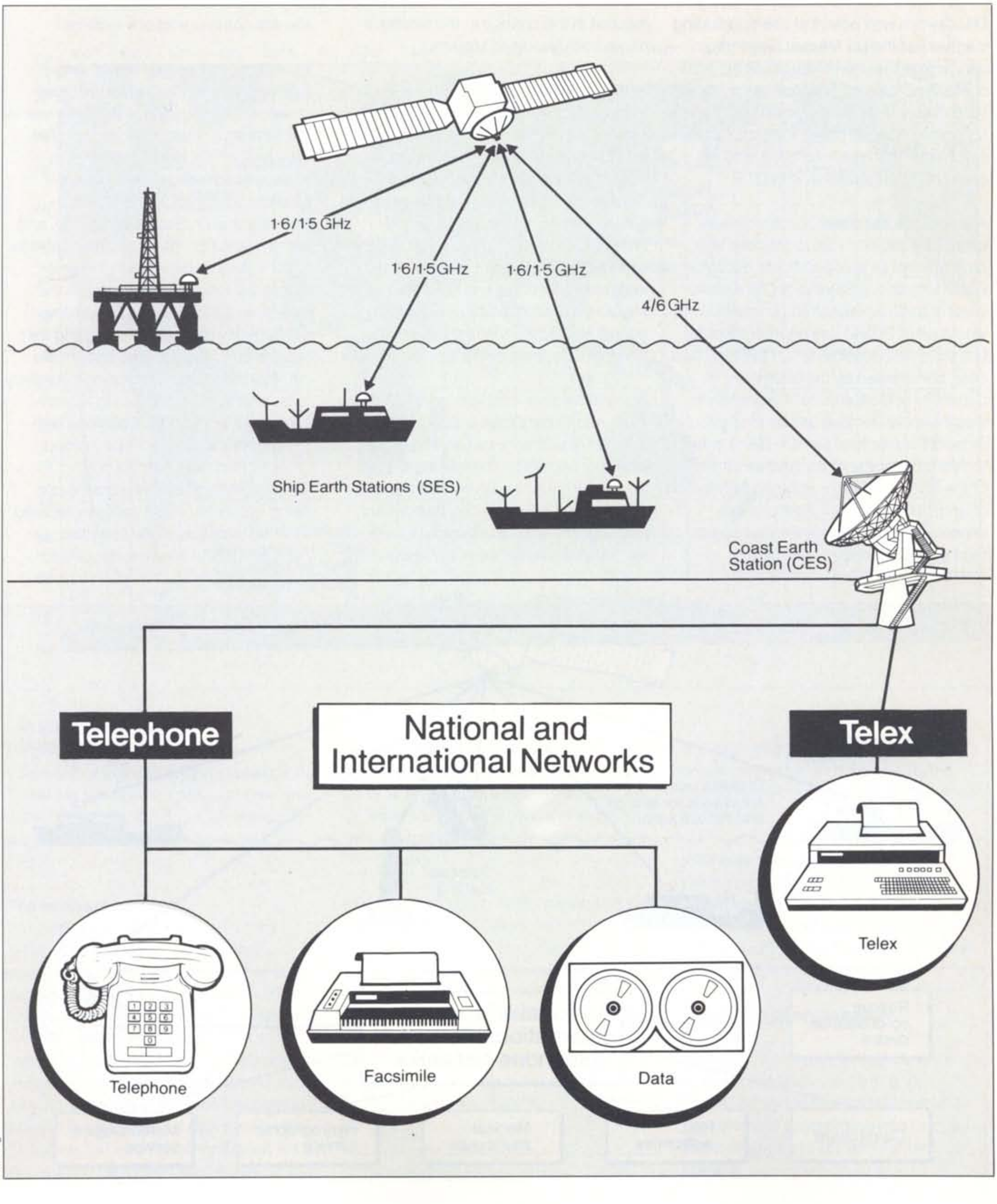
(c) Radio determination
- Evaluation of ranging techniques for line-of-position determinations.

In addition to the satellite development per se, the Marots agreement called for the procurement of a set of ground facilities, consisting of:

(a) Satellite Control Facilities (SCF)
One set of Satellite Control Facilities to be located in Villafranca (Spain) and a Satellite Control Centre connected to a Satellite Control Earth Terminal which would perform telemetry, tracking and all command services and link calibration functions.

(b) Electronic Test Sets (ETS)
Several Electronic Test Sets which would support system-performance evaluation and calibration and would be capable of transmitting and receiving all L-band signals to and from the satellites.

Figure 1 – Outline of maritime satellite communications



drawing inmarsat

Figure 2 – Inmarsat's role in a global maritime distress and safety system

Discussions with potential users, including members of the US Marisat Consortium, concerning the use of Marots as an operational satellite first took place during 1976. These discussions were held against the background of a programme which encompassed Marots-A and its common spare platform with OTS.

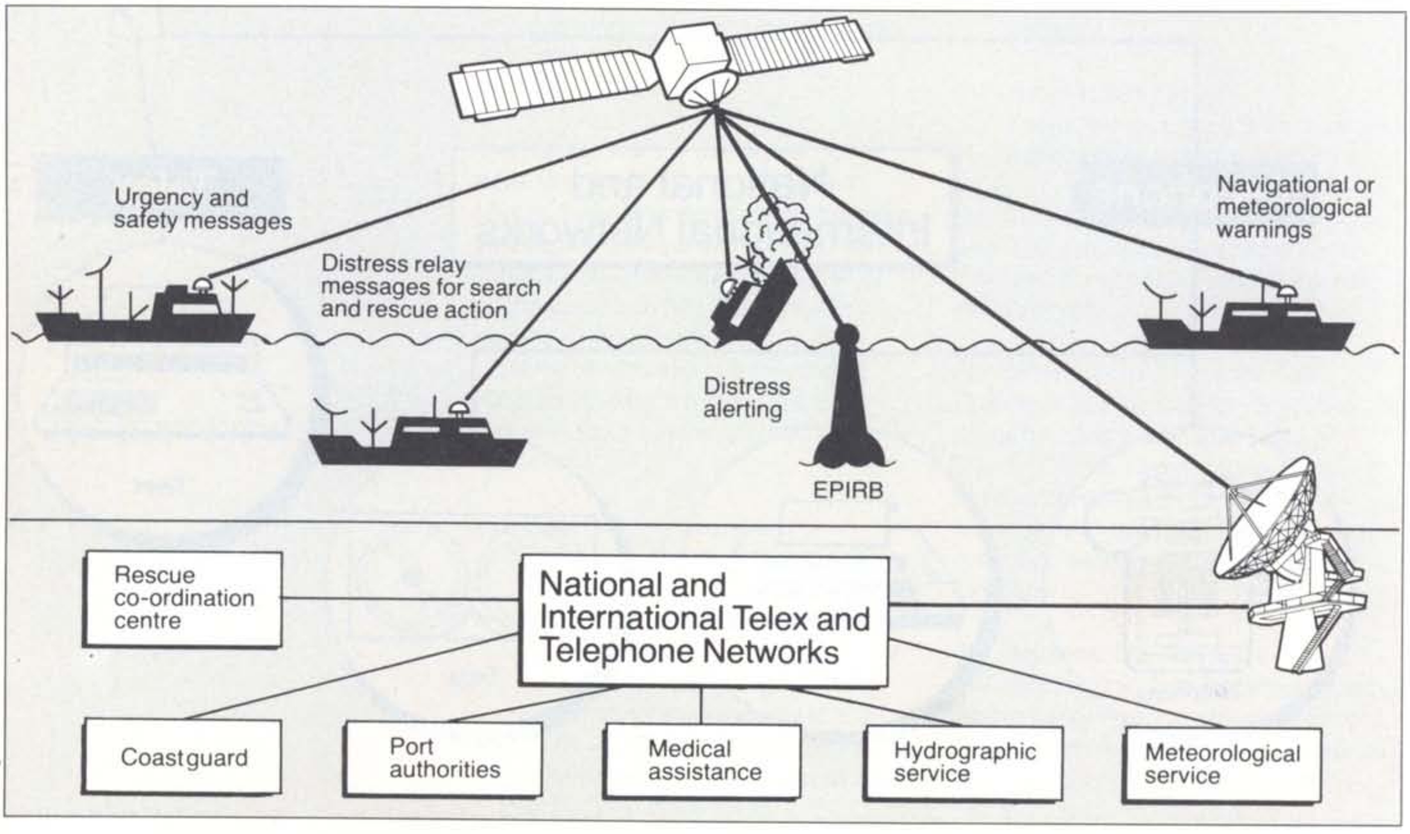
At about the same time, decisions were taken that allowed ESA to proceed with development of an operational European Communications Satellite (ECS) system, which was to be launched by Ariane. This would allow ECS to use a larger satellite bus than was possible for OTS, which had been constrained by the maximum capability of the Delta-3914 launcher. It was therefore decided at that time to redirect the maritime satellite development to take advantage of the greater capacity of the ECS bus. This, combined with the change in emphasis from a primarily experimental satellite to one that could form part of an operational system, resulted in the change in the satellite's name from Marots to Marecs.

At the beginning of 1977, with the decision to manufacture a second dedicated satellite (Marecs-B) arising as a result of an ESA Council meeting at Ministerial level, it was proposed that two additional satellites of the series should be procured (C&D), thereby generating a global coverage capability with a built-in spare satellite. Furthermore, it was proposed that these additional two satellites (C&D) should be funded jointly by European operators and the Marisat Consortium (the initial partners of the 'Joint Venture').

Discussion on this topic continued during 1977, and in the October ESA took another major technical and financial decision, namely to change the satellite-to-shore frequencies from 11/14 GHz to 4/6 GHz and the operating bandwidth from 2.5 MHz to 5 MHz in order to achieve full compatibility between the Marisat and Marecs communications systems.

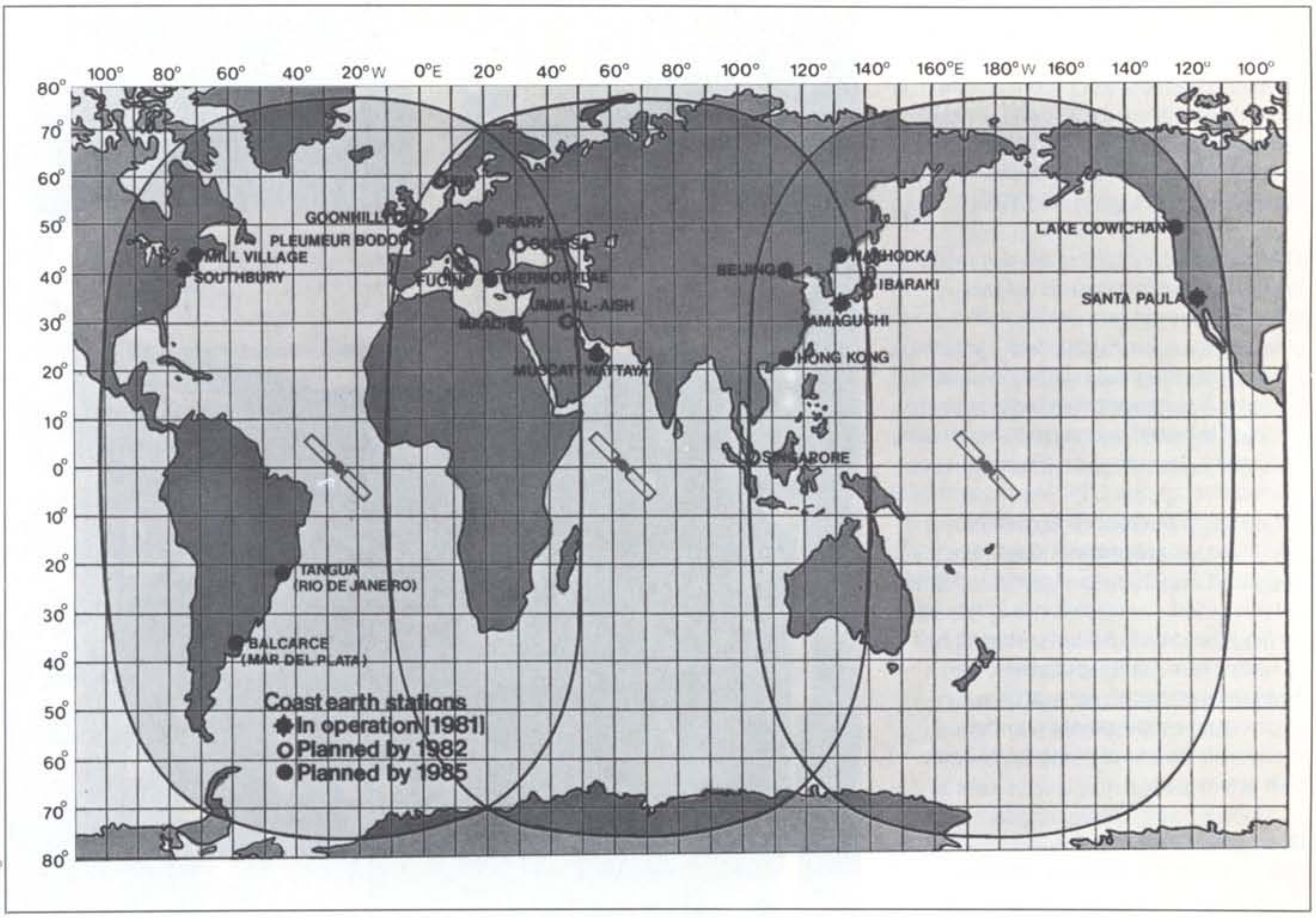
From this point several options were offered for the consideration of those countries participating to the pre-Inmarsat Joint Venture. These options included from two to four Marecs satellites in various combinations with Intelsat-V satellites equipped with a Maritime Communication Subsystem (MCS), and with the already orbiting Marisat satellites. No firm decision was taken, however, during the following two years. In the meantime (1979) ESA had taken the contingency measure of procuring the Marecs-specific hardware (essentially communication payload units) necessary to be able to integrate a third Marecs spacecraft from an ECS platform with minimum delay, should it be needed.

The Inmarsat organisation came into being in July 1979 and actively prepared itself to set up a world-wide system. In February 1980 it issued a Request for



drawing inmarsat

Figure 3 – Inmarsat system's global coverage



drawing inmarsat

Proposals for the lease of maritime communications capacity via satellites. Following submission of its proposal and subsequent negotiations, ESA signed a contract with Inmarsat in November 1980.

The Inmarsat contract

The terms of this contract call for the lease of the Marecs-A and B satellite capacity for an integrated period of ten satellite-years in orbit, with options for extension beyond that period. Marecs-A will be placed over the Atlantic Ocean region and will be controlled (TTC and performance monitoring) via the Agency's existing station at Villafranca near Madrid. Marecs-B will be placed over the Pacific Ocean region and will be controlled via a new station being built specifically for that purpose in Ibaraki (Japan). ESA's European Space Operations Centre (ESOC) in Darmstadt, near Frankfurt, will be responsible for the overall station network and satellite operations coordination.

Assuming a 19 dBW EIRP* per channel as derived from the CCIR recommendations, the Marecs shore-to-ship link capacity will be 35 channels. The ship-to-shore link capacity will be 50 channels. These capacities will satisfy the expected traffic requirements over any ocean region until 1987. A unique feature of the Marecs ship-to-shore transponder is the incorporation of a high-gain repeater intended to provide a Search and Rescue (SAR) capability involving the use of free-floating buoys.

With their scheduled launch dates in December 1981 and April 1982, respectively, Marecs-A and Marecs-B should enter into commercial service in February and June 1982, i.e. before the 1 July 1982 limit set by Inmarsat.

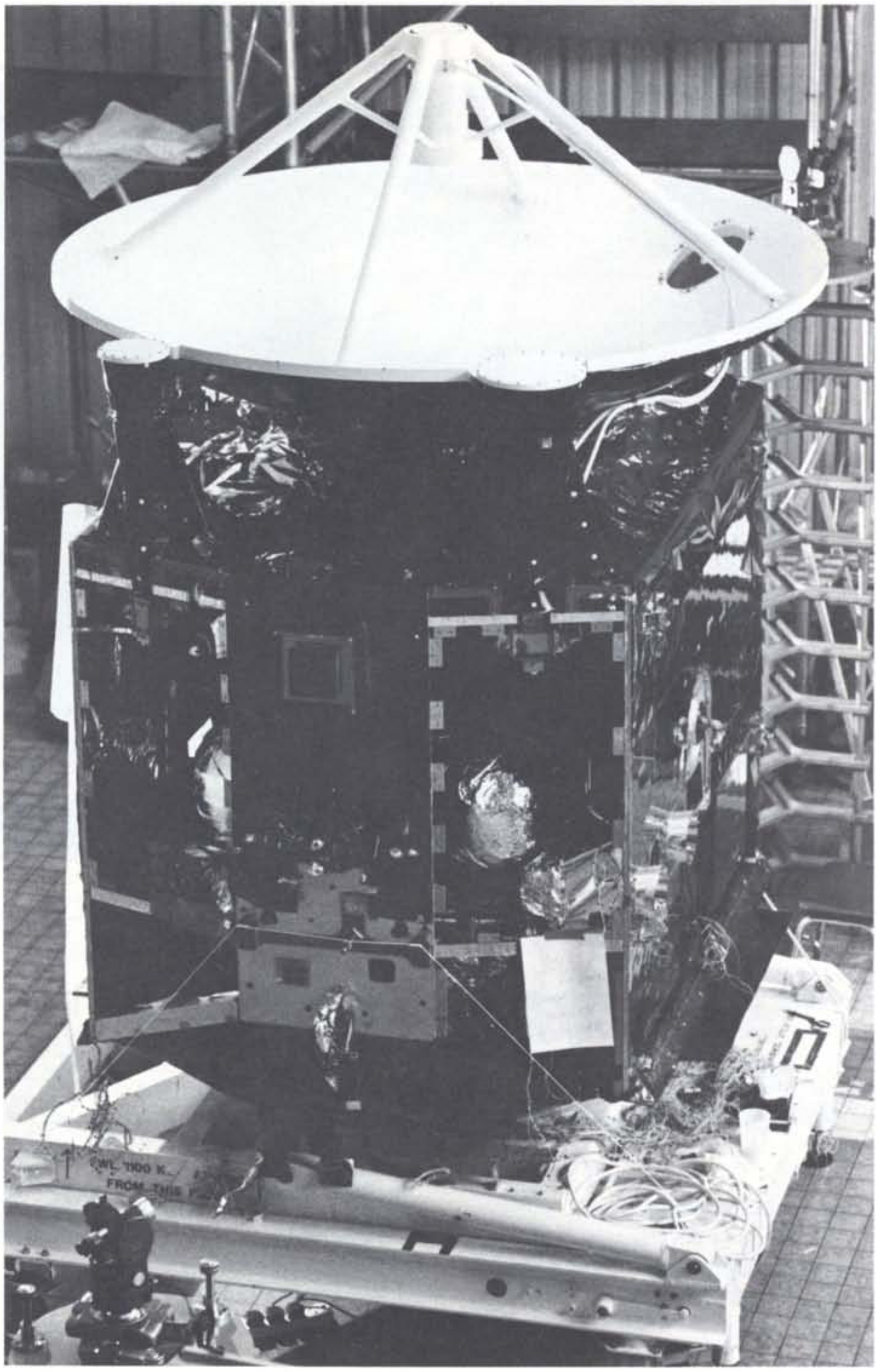
The industrial organisation

Satellite

Originally split in the Marots days into two distinct contracts (platform and communications payload), the satellite procurement programme was merged into a single contract with the birth of Marecs.

* Effective Isotropically Radiated Power

Figure 4 – The Marecs flight-model spacecraft being prepared for test at CNES, Toulouse



British Aerospace acts as the prime contractor, with MSDS, Matra, ERNO, Saab and Aeritalia as co-contractors. The subcontractors are INTA, SAFT, Fokker, Contraves, AEG-Telefunken, BTM, TNO, Galileo, Teldix, CRA, LME, SNIAS, Thomson-CSF, Hughes and TRW.

The contract calls for the development, integration, test and launch of two satellites, plus the procurement of elements for a third spacecraft, including a complete, integrated communications payload. The development approach adopted is based on the proto-flight philosophy. By relying on the experience gained through the OTS, Marots and ECS projects, this philosophy allows the manufacture, assembly and test of a dedicated qualification-model spacecraft to be avoided. Qualification is achieved on flight hardware, half at unit level, half at system level. Of the possible development models, only an engineering-model payload and a spacecraft structural model have been built and tested.

Ground facilities

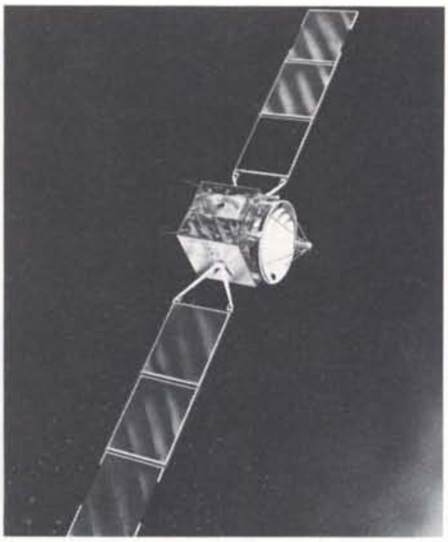
The Villafranca station was initially designed and installed by Siemens. When TTC frequencies were changed from 11/14 GHz to 4/6 GHz, NERA was contracted to modify the station accordingly.

As already mentioned, another station is being built at Ibaraki in Japan by KDD and is due for delivery two months before the Marecs-B launch.

A Payload Test Laboratory (PTL) is being installed at each station by ESA to determine satellite communications performances both at acceptance and during routine operations.

Conclusion

Originally started on experimental grounds by a limited number of Member States, the ESA Maritime Communications Programme has gradually evolved to become a major European breakthrough in the international market of communications satellites. Steps are already being taken to maintain this position in the future by actively preparing the definition of the next generation of mobile communication satellites, and by supporting European industry in developing the advanced technology that it will require.



The Marecs Communications System

R. Rogard, Communications Systems Division, Directorate of Application Programmes, ESTEC, Noordwijk, Netherlands

Fixed-service communications satellites have experienced tremendous development in the last two decades, the Intelsats being a typical example. Although satellite techniques are now more appropriate for mobile services also, the development of commercial services has been slow, perhaps due partially to the very different nature of the two services (fixed and mobile).

Introduction

For the fixed services the satellite was introduced initially as an alternative technique for routing communications, without causing the end user to change his equipment. For the mobile services, going to satellite techniques requires an immediate decision by the conventionally equipped end user (HF and/or VHF) to invest in new, more expensive equipment.

With the formation of Inmarsat, however, any earlier reservations on the part of some potential maritime users concerning satellite service continuity are no longer grounded and the attractions of a better service, with better voice quality and immediate access, are expected to lead to a similar expansion in maritime mobile services to that which has already occurred for fixed services. In fact, by the end of this year, about one thousand ship terminals will have been installed on a wide variety of ships, including tankers, passenger liners, container ships, seismic vessels and offshore drilling rigs.

The services to be provided initially by the maritime mobile satellite system that Inmarsat will begin operating in February 1982 are:

- a telephone service with access to the international public telephone network, and which will be capable of supporting facsimile and data transmission
- a telex service with access to the international public telex network
- a high-speed ship-to-shore data service (56 kbit/s)
- handling of priority messages for the maritime distress and safety services

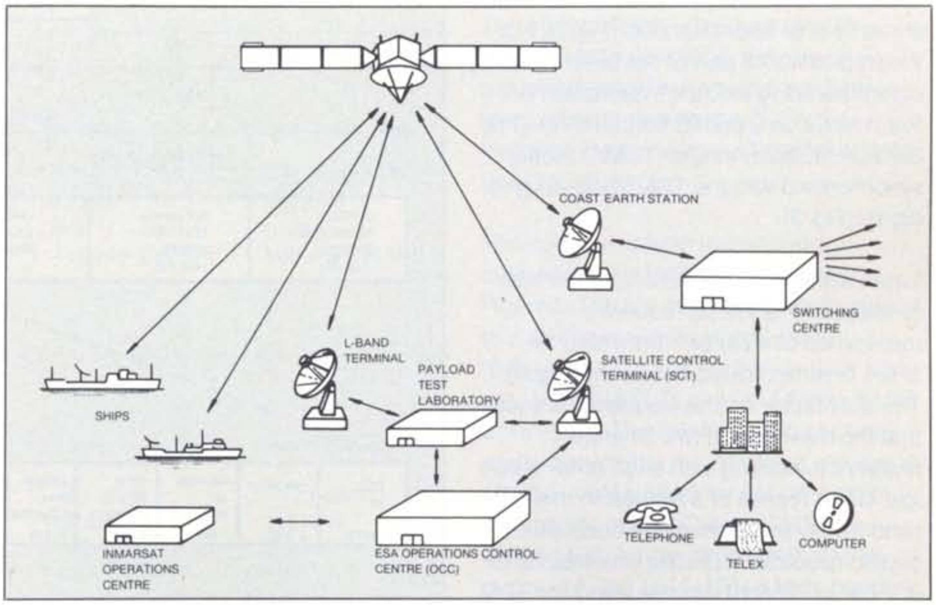


Figure 1 – Outline of the maritime satellite system for one satellite (Marecs)

Figure 2 – Shore-to-ship channel format

Figure 3 – Ship-to-shore channel format

Figure 4 – Ship-to-shore request carrier format

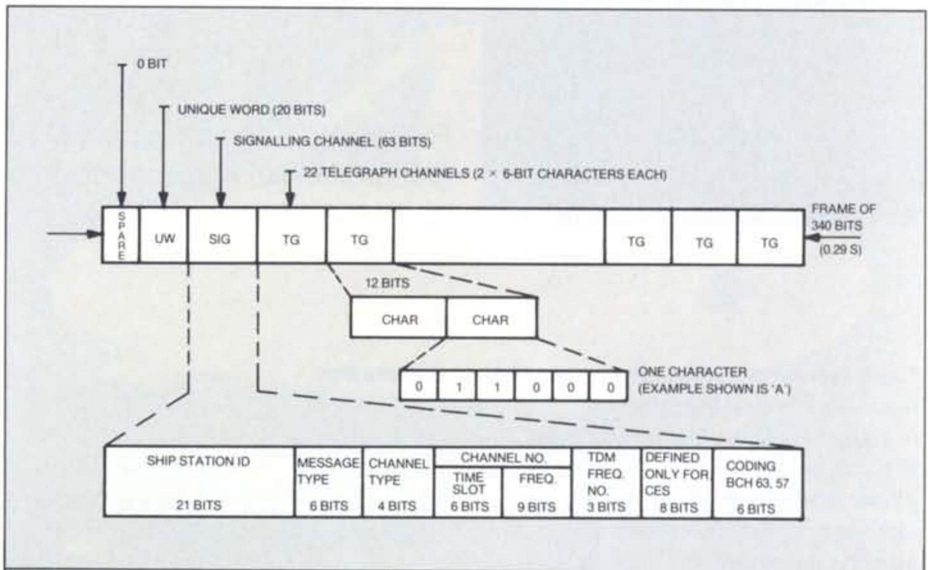
- relaying of low-bit-rate distress messages, and
- broadcasting of messages such as weather forecasts and national news summaries to groups of ships.

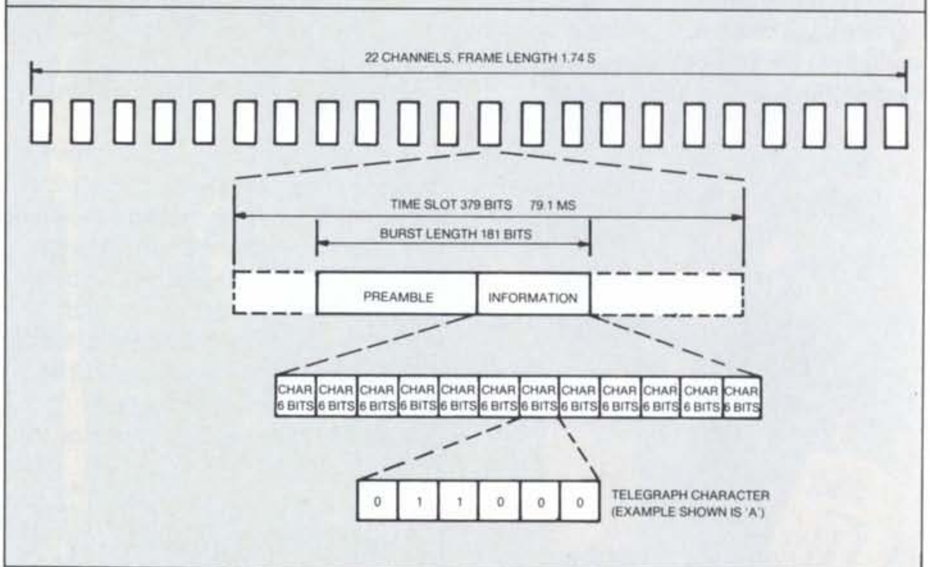
The initial space segment to provide these services will consist of two Marecs satellites (Marecs-A and -B), three Marisat satellites and maritime payloads carried by Intelsat-V satellites.

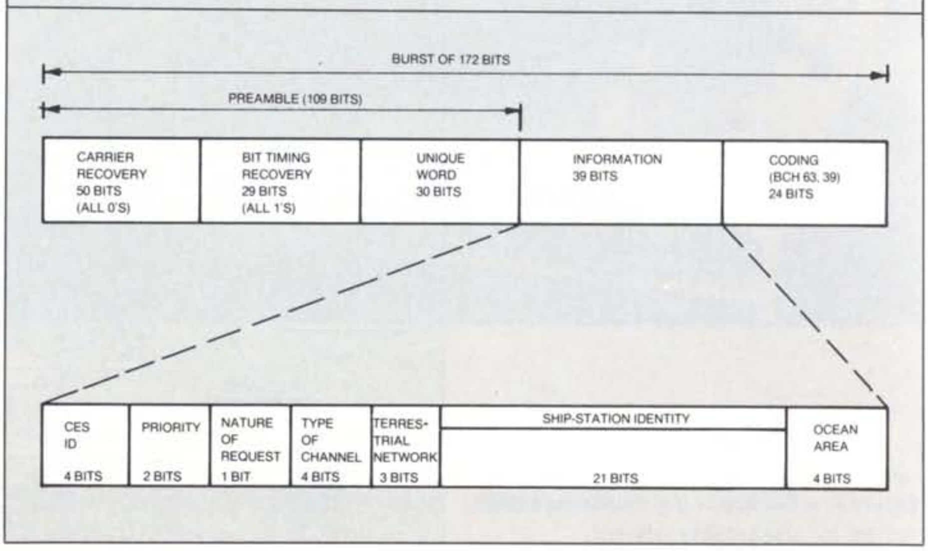
An outline of how the system will operate is shown in Figure 1, in this case for one of the Marecs satellites. It shows the satellite control terminal for telemetry, tracking and command operations and payload monitoring, the ESA Operations Control Centre (OCC), several coast earth stations connected to international switching centres, and the Inmarsat Operations Centre.

The organisation of this multiple-access telecommunications system has to allow the ship at sea to call a coast earth station, and vice versa, and must provide for the transmission of telex and telephony signals. In practice each ship terminal monitors, on a continuous basis, a 1200 bit/s signal or Time-Division Multiplex (TDM) channel transmitted by a particular earth station. This channel carries system-access information and 22 shore-to-ship telex channels (Fig. 2). For the ship-to-shore part of the telex communicating link, the information is transmitted on a paired frequency in Time Division Multiple Access (TDMA) mode, synchronised with the TDM shore-to-ship signal (Fig. 3).

When a ship requires service, either telex or telephony, a 172 bit request is transmitted at 4800 bit/s from ship-to-shore on a dedicated frequency (Fig. 4). The duty factor on this frequency is such that the likelihood of two different requests interfering with each other is very low. Upon receipt of a request in this random-access fashion the coast earth station allocates a precise channel, as for a shore-originated request using the TDM







shore-to-ship channel.

The telephony service is of the Frequency Division Multiple Access (FDMA) type with a single channel per carrier. All the resources or 'capacity' of the system is allocated on a demand-assigned basis, the various coast-earth-station requests being coordinated by one of the stations which is nominated to serve as the Network Coordination Station (NCS).

The Marecs communications subsystem
The Marecs satellite communications subsystem consists of two transponders, one serving the ship-to-shore link, known as the forward transponder, and a transponder servicing the shore-to-ship link, known as the return transponder. In defining these transponders to cope with the type of communications system needed for Marecs, flexibility has been one of the main criteria, partly because the exact characteristics of the system were not specified when definition began, but also because of the new services that might still need to be implemented in the future.

Compatibility has also been an important consideration, both with existing mobile satellite systems (e.g. Marisat) and with other satellite systems, in particular the Intelsat satellites (problems of mutual interference).

Careful attention has therefore been paid to the design of the Marecs frequency plan. For the coast earth station-to-satellite (or feeder) links, the upper part of the C-band frequencies (4 and 6 GHz) allocated to fixed satellite services has been adopted. For the mobile-to-satellite links the CCIR radio regulations provide dedicated frequency bands at 1.5 and 1.6 GHz (L-band). This, however, is a small spectrum (7.5 MHz for each link, later increased to 14 MHz by the 1979 World Administrative Radio Conference), and efficient use of the frequencies allocated is therefore an important consideration.

Together these considerations and criteria have led to the adoption of wideband transponders, as opposed to channelised transponders. In the return link, however, a dedicated high-gain channel has been included, to give improved reception of very weak signals for the search-and-rescue services, such as those transmitted by free-floating buoys or Emergency Position-Indicating Radio Beacons (EPIRBs).

The transponders employed are also quasilinear in operation; the use of saturated amplifiers would have been more efficient powerwise, but the frequency spectrum could not have been used so efficiently.

The communication transponder frequency plan for Marecs is shown in Figure 5. The link from coast-earth-station to ship (forward link) is at C-band (6420.25–6425 MHz) for the up-path and at L-band (1537.75 to 1542.5 MHz) for the down-path. The link from ship to coast-earth-station (the return link) is at L-band (1638.6–1644.5 MHz) for the up-path to the satellite and at C-band (4194.6–4200.5 MHz) for the down-path. In the return link, the 1644–1644.5 MHz band in

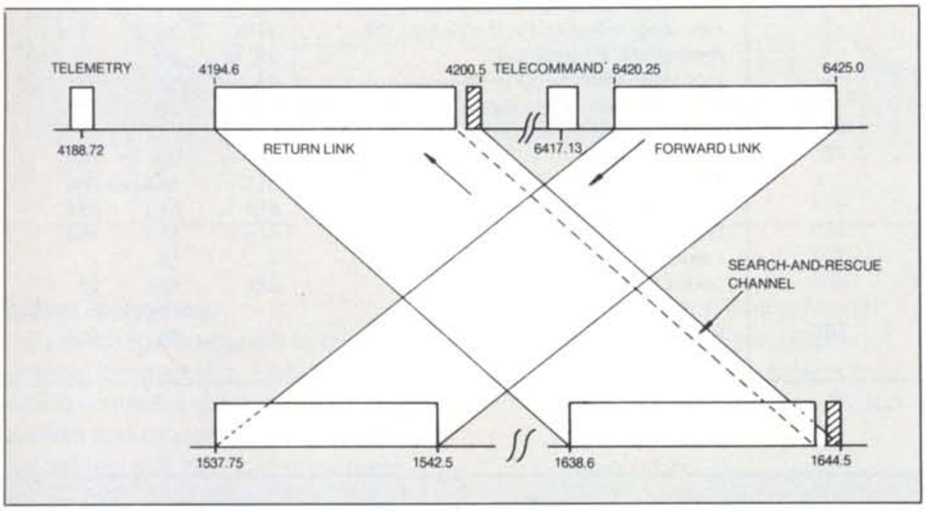


Figure 5 – Communications transponder frequency plan

Table 1 – Forward link performance

	Specified	Expected in orbit
G/T (edge of coverage)	−17 dB/°K	−15 dB/°K
Useful EIRP	34.2 dBW	34.4 dBW
C/I (worst-case; equi-spaced multicarrier loading)	14 dB	15 dB
Amplitude/frequency response	1.4 dB over 4.75 MHz	1 dB over 4.75 MHz

Table 2 – Forward link performance

	Specified	Expected in orbit
G/T (edge of coverage)	−12.1 dB/°K	−12.1 dB/°K
Useful EIRP	14.5 dBW	14.6 dBW
C/I (worst-case; equi-spaced, equal amplitude)	21 dB	21 dB
Amplitude/frequency response over 5.9 MHz	1.4 dB	1 dB

Table 3 – Forward link budgets

Up-link: Shore station-to-satellite (6.42 GHz; 5° elevation)	SCPC telephony carrier	TDMA
Nominal shore station EIRP per channel, dBW	60.0 + X	58.0 + X
Margin for level setting and stability, dB	1	1
Free-space loss, dB	200.9	200.9
Atmospheric loss and pointing loss, dB	X	X
Polarisation loss (1.5/3 dB), dB	0.3	0.3
Satellite G/T, dB/°K	−17	−17
Up-link C/N_0, dBHz	69.4	67.4
Shore station C/I_0, dBHz	73	71
Interference from other systems, dBHz	79	60
Resultant up-link $C/(N_0 + I_0)$, dBHz	67.5	59.0
Down-link: Satellite-to-ship (1.54 GHz; 10° elevation)		
Satellite EIRP per channel, dBW	19	17
Free-space loss, dB	188.4	188.4
Atmospheric absorption, dB	0.2	0.2
Propagation margin, dB	0.6	0.6
Ship terminal G/T, dB/°K	−4	−4
Down-link C/N_0, dBHz	54.4	52.4
Up-link $C/(N_0 + I_0)$, dBHz	67.5	59.0
Satellite LO noise, dBHz	74.5	72.5
Satellite intermodulation C/I_0, dBHz	59.3	57.3
Resultant C/N_0, dBHz	53	50.5

Table 4 – Return link budgets

Up-link: Ship-to-satellite (1.64 GHz; 10° elevation)	SCPC telephony carrier	TDMA RA carrier	Search- and -rescue signal
Nominal EIRP, dBW	37	37	6.5
EIRP stability margin, dB	1	1	–
Atmospheric absorption, dB	0.2	0.2	0.2
Propagation margin, dB	0.6	0.6	7
Free-space loss, dB	188.9	188.9	188.9
Satellite G/T, dB/°K	−12.1	−12.1	−12.1
Up-link C/N_0, dBHz	62.8	62.8	27
Down-link: Satellite-to-shore (4.2 GHz; 5° elevation)			
Satellite EIRP per channel, dBW	−7	−7	−30.8
Free-space loss (4.2 GHz; 5° elevation), dB	197.2	197.2	197.2
Atmospheric absorption, dB	0.2	0.2	0.2
Propagation margin, dB	0.5	0.5	0.5
G/T degradation due to excess antenna noise, dB	1.3	1.3	1.3
G/T (clear sky-including polarisation and tracking loss), dB/°K	32	32	32
Down-link C/N_0, dBHz	54.4	54.4	30.6
Satellite intermodulation C/I_0, dBHz	61.3	61.3	39.6
Satellite LO noise, dBHz	67.5	67.5	45.8
Interference from other systems, dBHz	–	53	–
Up-link C/N_0, dBHz	62.8	62.8	27
Resultant C/N_0, dBHz	53	50	25.2

the up-path, which corresponds to the 4200–4200.5 MHz in the down-path, is reserved for the relay of low-bit-rate distress messages transmitted by EPIRBs. The telemetry and telecommand frequencies noted in the figure are those used when Marecs is on-station, VHF transmissions being used during the transfer and drift-orbit phases after launch.

The main characteristics of the two forward-link transponders are summarised in Tables 1 and 2. The link budgets for the system are presented in Tables 3 and 4.

The capacity of the Marecs satellite is equivalent to 35 telephony channels in the forward direction, and 50 in the return direction.

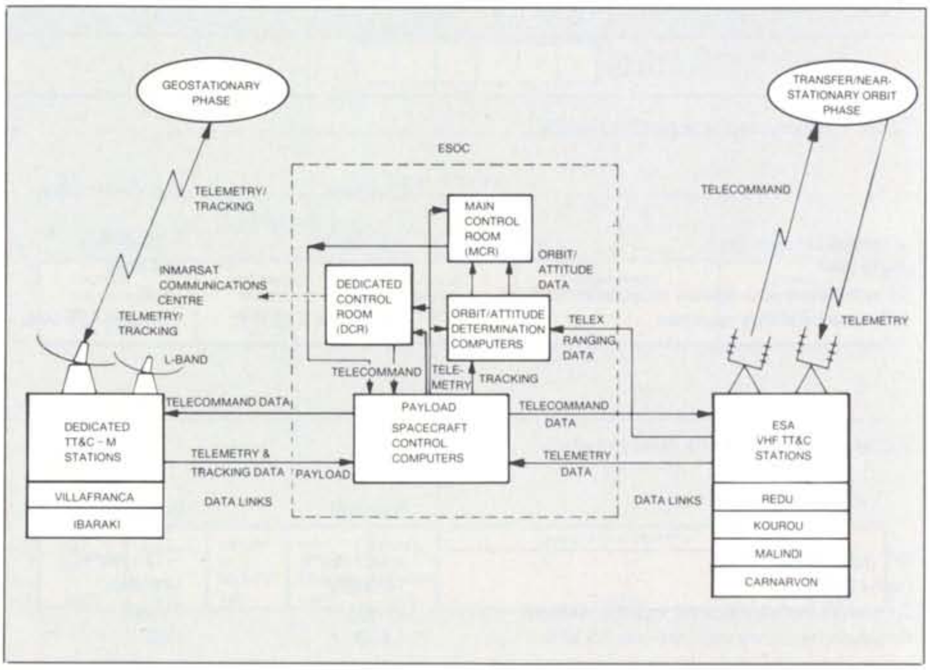
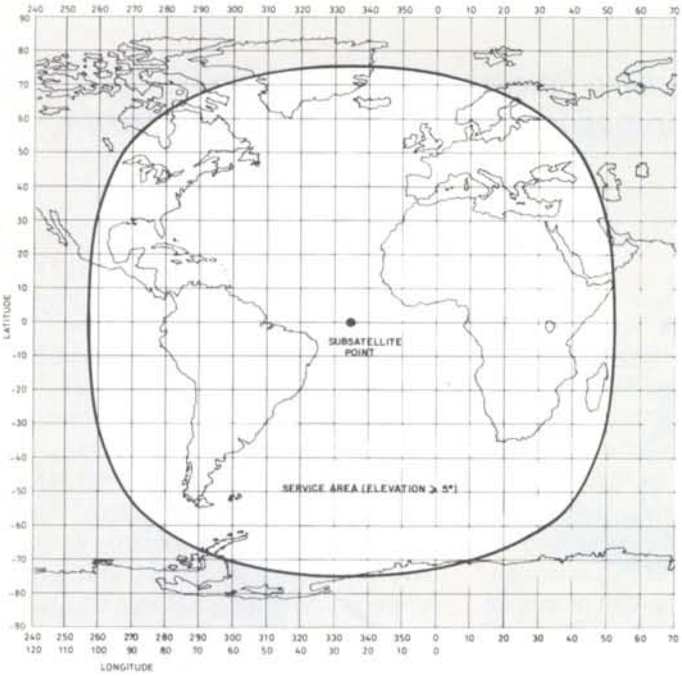
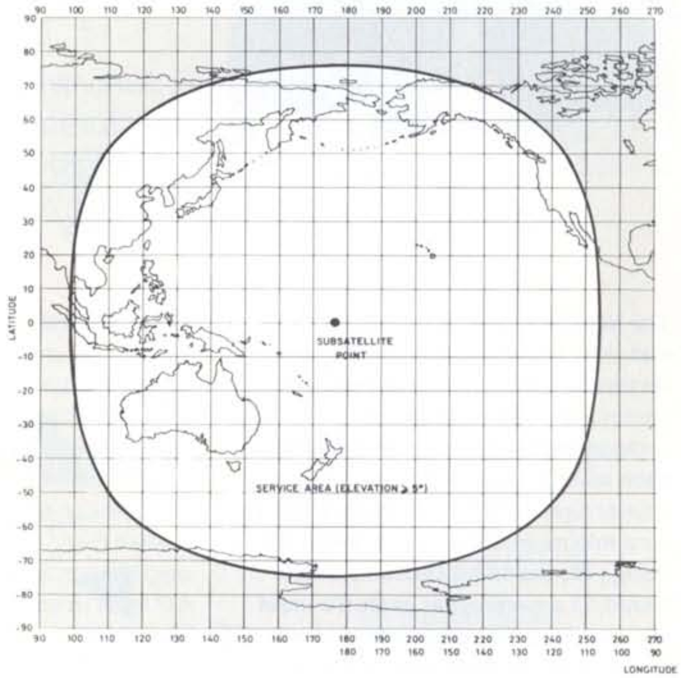


Figure 6 – Block diagram of the Marecs ground segment

Figure 7 – Coverage area for Marecs-A from 26°W, (5° elevation angle)

Figure 8 – Coverage area for Marecs-B from 177.5°E (5° elevation angle)





System deployment

The Marecs space segment to be provided to Inmarsat by ESA under the leasing contract is defined as the Marecs satellites and associated ground-support facilities required for tracking, monitoring and controlling the spacecraft during the transfer and drift orbits, as well as when the satellites are on-station. In addition to the Marecs-A and -B satellites, it includes (Fig. 6):

- The ground network required for transfer- and drift-orbit telemetry, tracking and command (TTC) operations.
- The ground network required for on-station operations (e.g. TTC, commissioning, acceptance-testing, and routine monitoring of the payload) consisting of:
  - C- and L-band earth stations located at Villafranca (Spain) able to control one satellite, over either the Atlantic Ocean Region (AOR) or the Indian Ocean Region (IOR).
  - A VHF station located at Redu, (Belgium), as a back-up for Villafranca
  - C-band, L-band and VHF earth stations located at Ibaraki (Japan), able to control up to two satellites located over the Pacific Ocean Region (POR)
  - A communications network, connecting these facilities to the Operations Control Centre (OCC).
  - The Operations Control Centre itself.

The Inmarsat global system assumes the provision of two satellites per ocean area, one being an in-orbit spare. Optimisation of the orbital positions is quite complex, involving both the coverage areas (e.g. the most used maritime routes, and active offshore exploration areas), and also the access from the various coast earth stations. With many of the optimal orbital positions already occupied by Intelsat satellites, there are potential interference problems with the feeder links, requiring careful frequency coordination between the various systems. Following negotiations with Intelsat, Marecs-A is to be located at 26°W over the Atlantic, and Marecs-B at 177.5°E over the Pacific (Figs. 7 and 8).

The Marecs Space Segment

E. Jurkiewicz, Maritime Satellites Project Division, Directorate of Application Programmes, ESTEC, Noordwijk, Netherlands

The Marecs satellites represent ESA's first entry into the role of providing a service to the international maritime community. The contractual arrangement with Inmarsat requires each satellite to provide an uninterrupted communications service for a minimum of five years, while the design life including consumables is based on a seven-year span. To meet this new long-life requirement special accelerated life tests together with extended reliability modelling and the use of enhanced redundancy schemes have been necessary in the design and building of the Marecs spacecraft.

The spacecraft systems

The Marecs spacecraft uses the basic service module developed for the European Communications Satellite (ECS), including all the supporting subsystems, to support the dedicated maritime communications payload module (Fig. 1). The complete spacecraft weighs approximately 1014 kg at launch, 432 kg of which are solid ABM propellant and 85 kg hydrazine fuel. The spacecraft is approximately 2 m wide and 2.5 m high, and has an octagonal body with a 2.0 m dish antenna mounted at one end and an ABM nozzle at the other.

Once the spacecraft arrives in its drift orbit, two fold-out solar arrays (Fig. 2) are deployed from the north and south faces of the body and oriented to face the Sun. Each array is 1.3 m wide and 5.2 m long and is attached to the body by a yoke and a drive mechanism, giving a total tip-to-tip span of 13.8 m. The arrays can generate 114 W when stowed and, once deployed, 955 W at beginning of life and 789 W (solstice) at end of life.

On station, the communications system uses 425 W and the other subsystems 190 to 220 W, depending upon the season. Approximately 80 W are required for battery charging at the equinoxes. Two 28 cell 21 Ah nickel-cadmium batteries are carried in order to maintain full satellite operation during eclipses.

Operational attitude is controlled by a fixed-momentum wheel system that maintains the antenna boresight within 0.2° of the Earth's centre. The wheels are driven by signals from an infrared earth sensor and limit rotations about the satellite–Earth direction to less than 0.35°. A hydrazine-fuelled reaction control subsystem provides for orbit and attitude manoeuvres and momentum-wheel loading using 16 catalytic thrusters in two redundant branches. Fuel is stored in two redundant pairs of bladder tanks which have a total capacity of 90 kg. Thermal control on the satellite includes the use of heat pipes on the radiator on which the high-power communications equipment is mounted and on-board-controlled heaters.

The overall spacecraft design is based on a seven-year operational lifetime. The supporting reliability analysis shows that the probability of the spacecraft maintaining a full service once in orbit is better than 0.87 over five years and better than 0.78 over its seven-year lifetime. High confidence in the availability of the requisite DC power from the solar arrays is based on in-orbit measurements that have been made with OTS. The propellant allocated to maintain attitude and orbital station contains a 100% contingency, which can be made available to extend the service beyond seven years.

Extensive activities have been embarked upon in pursuit of long lifetime, covering such areas as: high-reliability long-life component procurement; supporting life tests; circuit design, subsystem and system design taking into account component aging and drift rates over the extended mission duration; provision, storage and management of the on-board consumables (e.g. propulsion fuels); solar-array degradation;

Figure 1 – Exploded view of the Marecs spacecraft

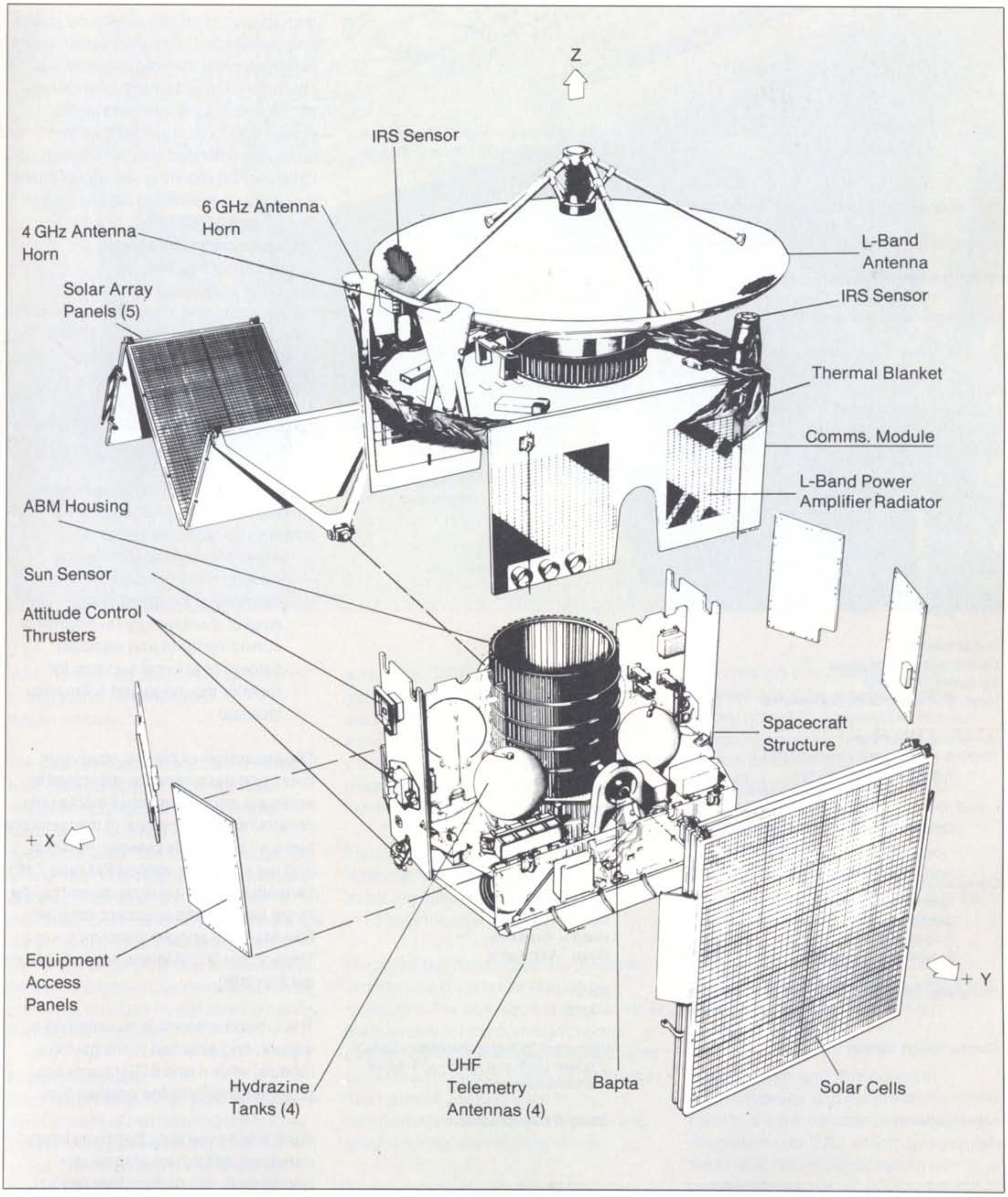


Table 1 – Key satellite characteristics

Launcher compatibility		Ariane (Marecs can also be adapted to a Space Shuttle PAM-D or Russian SL-type launch)
Total mass at separation from launch vehicle		1014 kg
Apogee boost motor propellant		432 kg
Despin and station-acquisition propellant		33 kg
Satellite mass at the beginning of life		572 kg
DC power generated by solar arrays: nominal/worst case (end of 7 yr life)		775/748 W
DC power margin: nominal/worst case:		
Beginning of life(equinox)		316/297 W
End of 7 yr life (equinox)		177/48 W
Stabilisation		Three-axis stabilised on station. Spin stabilised during injection and transfer orbit
Station-keeping accuracy		±0.2° E–W; ±3.0°N–S
Design life and on-board consumables		7 yr
Overall reliability:		
Launch and injection phase		0.888
5 yr operational phase (meeting all performance requirements)		0.870
Operational frequencies		
Tracking, telemetry and command (TTC):		
Injection and transfer orbit:	Command	179.3 MHz
	Telemetry	137.2 MHz
On station:	Command	6417 MHz
	Telemetry	4188.7 MHz
Communications:		
Ground station-to-satellite		6420.25–6425 MHz
Satellite-to-ship		1537.75–1542.5 MHz
Ship-to-satellite		1638.6 –1644.5 MHz
Satellite-to-ground station		4144.6 –4200.5 MHz
Orbital position (specified by Inmarsat)	Marecs-A	26°W
	Marecs-B	177.5°E
Communication capacity		Minimum of 35 duplex channels in daylight or eclipse mode and search-and-rescue channel (ship-to-shore).
Antenna coverage:		Global to within 5° elevation

degradation of protective external paints; and the effects of cosmic radiation on the performance of the solid-state devices. To characterise and define mathematically the reliability of the long-life satellite system and to be sure that it will be adequate, extended reliability models had to be evolved requiring new inputs related to the above-mentioned effects.

The spacecraft subsystems

Structural subsystem

The basic concept of the mechanical configuration and structural design is that of a modular approach in which the satellite is divided into a payload module (PM) and a service module (SM) (Fig. 3). The service module can be used as a bus to meet alternative payload requirements for future missions.

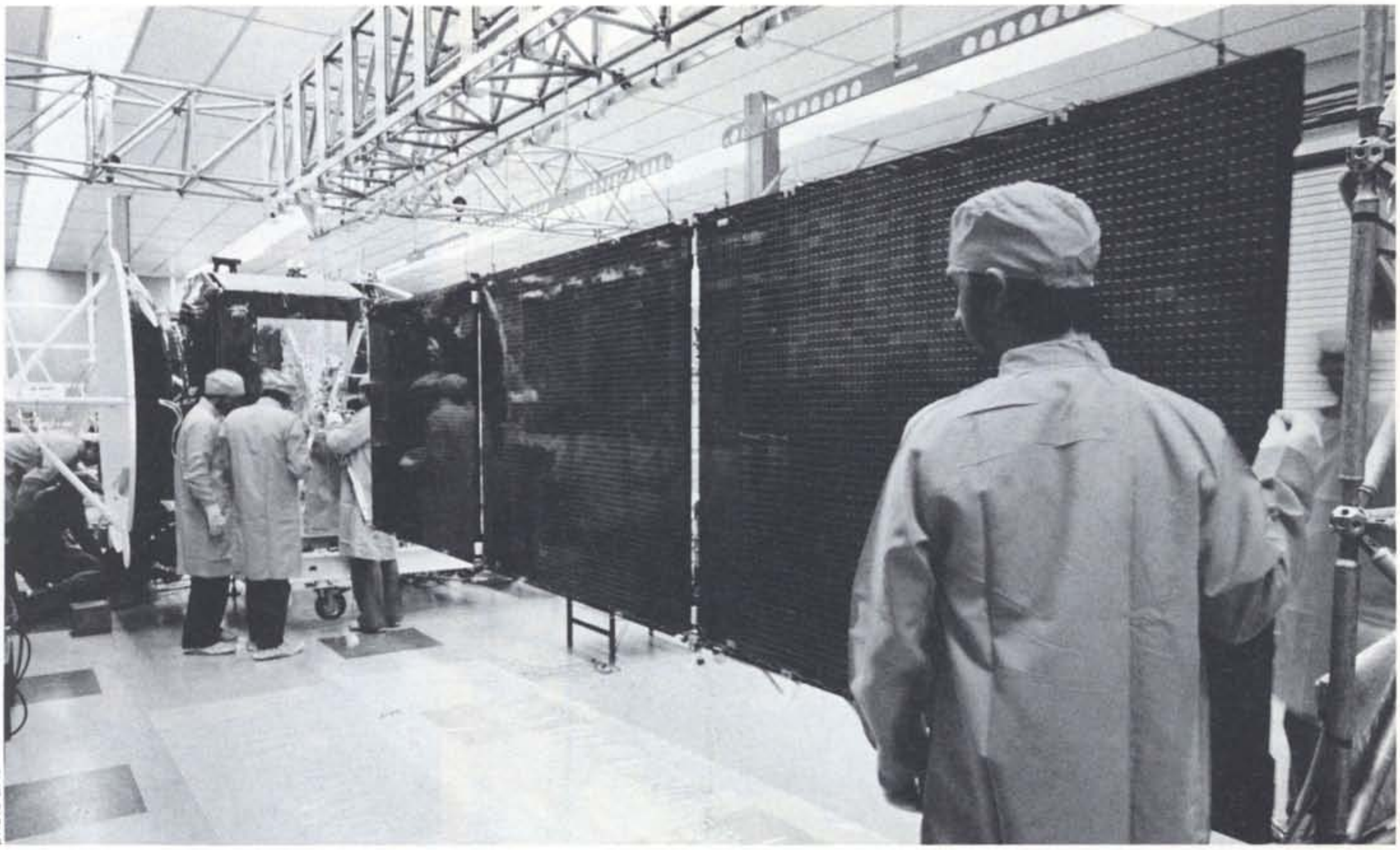
The spacecraft has a roughly hexagonal cross-section, which achieves an optimum compromise between:
- allowable payload dimensions
- maximum of floor area
- simplicity of structural design
- ease of manufacture (avoidance of curved surfaces and sections)
- flatness of external surfaces for radiator mounting and solar-array stowage.

The separation of the two equipment floors and the antenna is minimised to achieve a good moment-of-inertia ratio, constraints being the size of the hydrazine tanks and flywheels between the floors and the size of the various PM radiators beneath the dish-antenna assembly. The thrust tube is sized to accept either an ESA Mage 1S apogee boost motor or a Thiokol Star 30B (Marecs-A and B will use the Star 30B).

The L-band antenna is mounted on a support ring attached to the payload module, while 4 and 6 GHz horns are attached directly to the payload floor.

Each solar-array wing has three hinged panels made from an aluminium honeycomb with carbon-fibre facing

Figure 2 – Solar-array deployment test for Marecs-A



skins. The panels are held at four points during launch and released pyrotechnically.

The payload-module structure consists of a flat hexagonal floor area, with two radiators mounted on the north and south faces carrying high-power dissipating units. The payload equipment is mounted on the top and bottom faces of the upper floor and is distributed to meet balance requirements. The floors are constructed from a sandwich of two aluminium outer skins and an aluminium honeycomb core. Equipment-attachment points are provided by self-locking inserts bonded into the floor.

Power subsystem

Electrical power is obtained during the sunlit phases of operations from the two independently steerable, rigid solar-array wings. The innermost panel of the north wing is a 'dummy' and does not carry solar cells. Control of array pointing and transfer of the power into the spacecraft are effected by bearing and power transfer assemblies (BAPTAs). The pointing signals for the BAPTA control electronics are generated by solar-array-mounted Sun sensors (SASS).

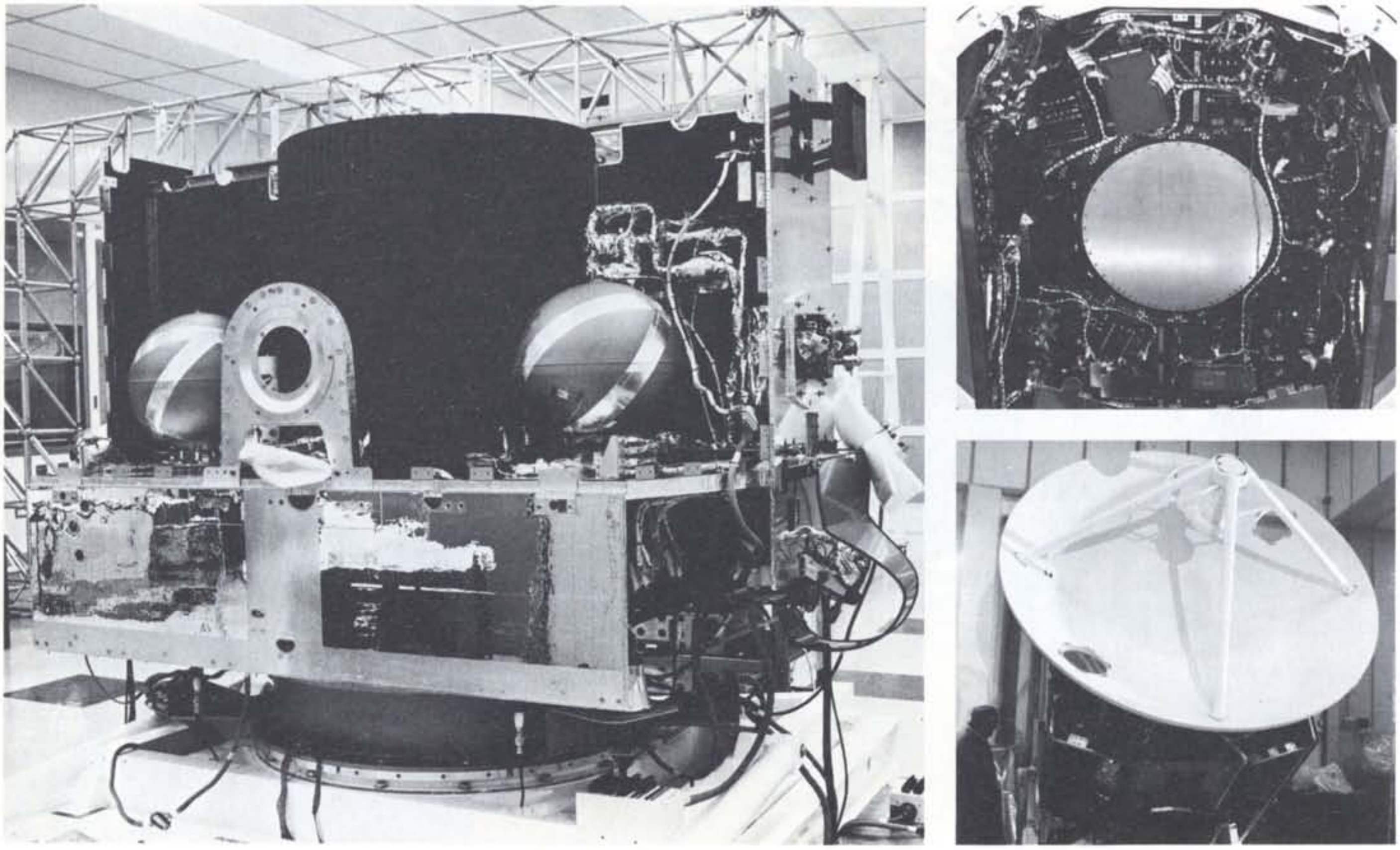
Power is regulated by the power subsystem, using a sequential-switching shunt regulator, to 50 V +2.5%, 50 V −1.5% at the user's input.

In eclipse, two nickel-cadmium batteries provide power via boost-discharge regulators. The batteries are sized to allow full operation of the communications payload during the longest eclipses, while not exceeding a 55% depth of discharge. The batteries are also used to complement the outputs of the spinning satellite arrays during transfer orbit.

To achieve the required long-life performance, overcharging of the batteries has to be avoided and the battery operating temperature kept low. Provision is also included within the satellite for trickle charging and reconditioning the batteries during solstice seasons. A separate power bus provides power for heater operation during the on-station sunlit phase. Protection is provided against short-circuit failures on the main bus and the heater bus, and against overcharging/discharging and overheating of the batteries. There is provision for disconnecting nonessential loads should abnormal loading conditions occur.

The collection and distribution of electrical power and the protection of the main bus is the function of the electrical integration unit (EIU), which also includes the spacecraft instrumentation conditioning circuits.

Figure 3 – Marecs flight spacecraft structure, payload and L-band antenna



An auxiliary power supply (APS), feeds units within the power subsystem. Units that use the APS are designed so that single-component failures do not shortcircuit the APS outputs.

The battery-control unit provides for overall battery power management. The electrical distribution unit distributes power and signals to the communications payload and the AOCS, TTC and thermal subsystems.

Attitude and orbit control subsystem (AOCS)

The primary functions of the AOCS are:

(a) To provide the attitude determination and control required for transfer orbit by:

- Processing attitude data from the Earth and Sun elevation sensors (ESS) as the spacecraft spins about its yaw axis.
- Adjustment of the spacecraft's orientation through operation of the pitch thrusters by ground command via the spin phase and thruster drive electronics (SPTE).
- Passive nutation damping throughout this phase.

(b) Following ABM firing, to perform the transition from spin-stabilised to three-axis stabilised conditions via:

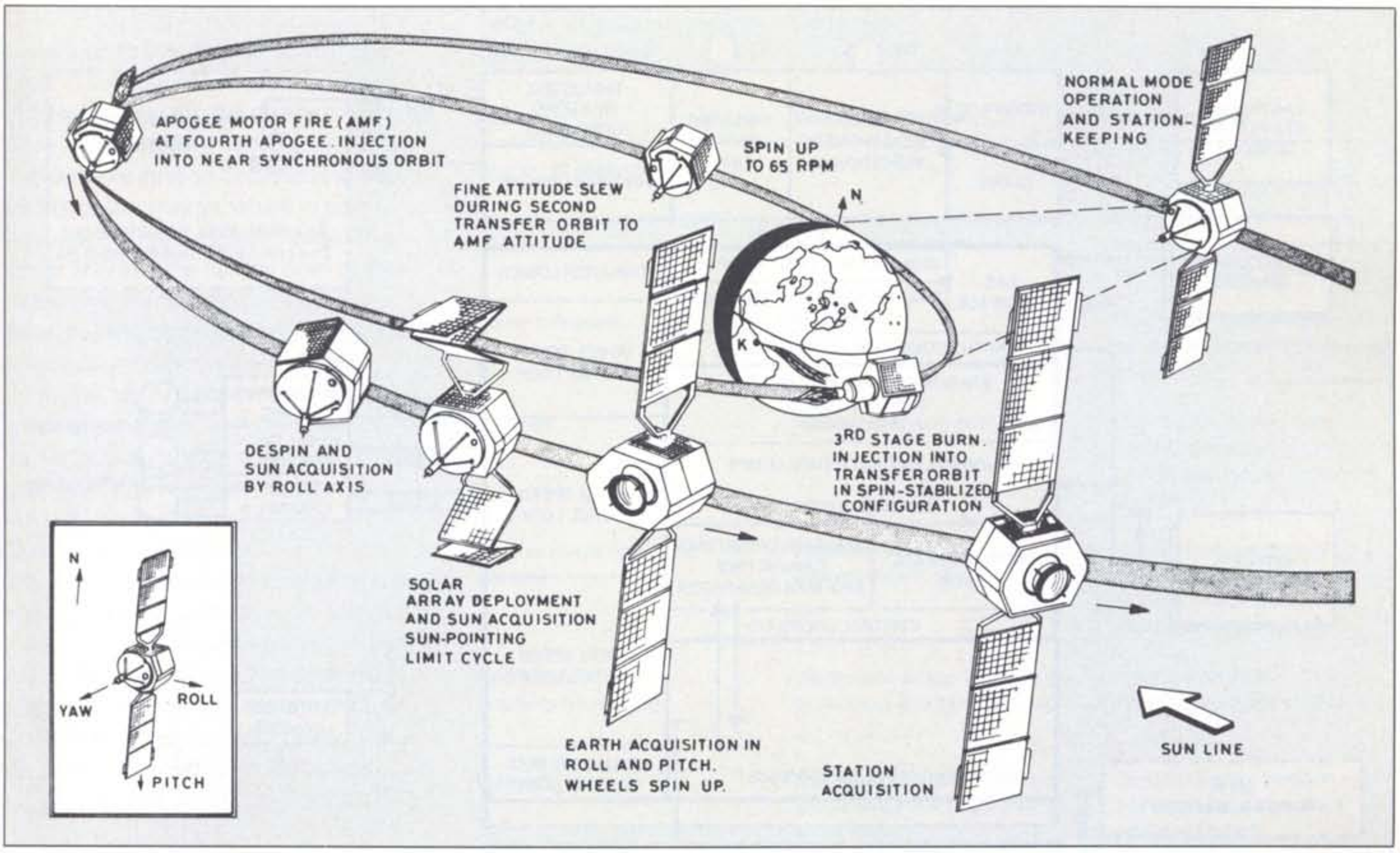
- Despin using roll and yaw thrusters.
- Sun acquisition using the hydrazine thrusters controlled by processing signals from the Sun acquisition sensors. When this has been achieved, the solar arrays are deployed and rotated towards the Sun.
- Earth acquisition when the spacecraft–Earth and spacecraft–Sun directions are orthogonal.
- Spin-up of momentum wheels.
- Station acquisition, which consists of a series of manoeuvres to obviate launch vehicle and ABM injection errors and to reach the preselected orbital location.

As a result of this phase, the on-station operational communications link can be established within 21 days of launch, with the satellite at its correct orbital position.

(c) To control the attitude and orbit of the satellite in its three-axis-stabilised configuration, the following operations are performed:

- Automatic normal mode operations, using infrared-earth-sensor data to control the speed of the momentum wheels.
- Automatic momentum off-loading by thrusters to maintain wheel kinetic momentum in the correct range.
- Station keeping using ground-commanded hydrazine thrusters to correct east-west orbital drift, while maintaining normal operations.
- Orbit-inclination control, if required,

Figure 4 – Main events in the Marecs launch sequence



through ground commands to maintain inclination within the 3° range.

A typical transfer-orbit-injection and final-station acquisition plan is shown in Figure 4.

The AOCS subsystem (Fig. 5) consists of sensors, actuators and the necessary control and drive electronics. Standby hardware redundancy is used to provide the reliability needed for seven years of operation. Redundant units are automatically activated by on-board failure detection and protection circuitry or by ground command.

Telemetry, tracking and command subsystem (TTC)

The TTC subsystem performs three main functions:

(i) The multiplexing together and transmission to Earth of the data necessary to establish the status and performance of the on-board equipment (telemetry function).

(ii) The provision of on-board facilities for angular tracking from ground stations using the telemetry carrier, and range measurements from ground stations (tracking function).

(iii) The reception, demodulation, decoding, validation and distribution of messages sent from the ground stations to control or change the operational status of the satellite and its subsystems (command function).

The telemetry function

During the transfer orbit (and for on-station backup) the telemetry signal is transmitted at VHF and during the on-station phase at SHF (C-band) via the payload. On the ground, the signal is demodulated, decoded and the data recorded and processed. The execution of commands is verified by the telemetry.

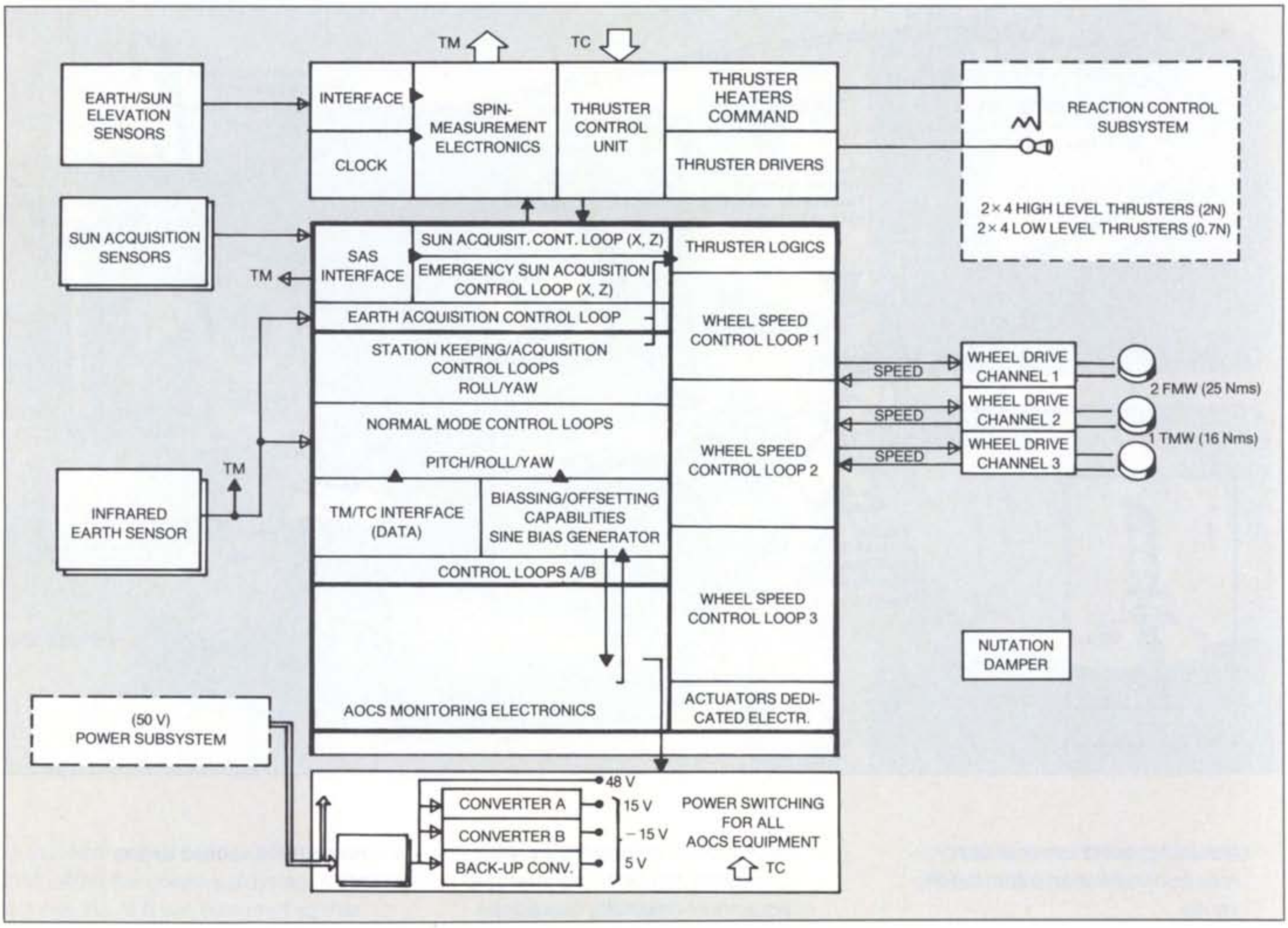
Each satellite has an identification code built into the telemetry format. Two formats are provided: one for transfer orbit including high-bit-rate data from the attitude and orbit control subsystem, the second for on-station operations, including communications equipment data.

The tracking function

Tracking is also performed at VHF frequencies during the transfer and drift-orbit phases and at C-band during the on-station phase.

Range is established using a tone ranging system. The uplink (VHF or C-band) is modulated by ranging tones. These tones are received by the spacecraft and retransmitted. The range is derived from the phase delay between

Figure 5 – The Marecs satellite's attitude and orbit control (AOCS) subsystem



the uplink tones transmitted and the downlink tones received on the ground.

The telecommand function
The commands to be transmitted to the satellite are first encoded into a particular form (message) before modulating an RF carrier. Transfer-orbit commands are transmitted at VHF frequencies and on-station commands at C-band frequencies. Each spacecraft has individual address words for command-message initiation and validation.

Thermal-control subsystem
The task of the thermal-control subsystem is to provide a suitable operating environment for the on-board equipment. It is basically of passive design with some active control for specific units such as the solid-state power amplifiers, the travelling-wave-tube amplifiers, the batteries, and the reaction-control subsystem.

The overall temperature of the spacecraft is controlled by fitting multilayer superinsulation blankets over the majority of the external surface, specific control radiator areas covered with second surface mirrors, and a high-emittance coating on all internal surfaces to maximise internal radiative heat exchange. Certain high-power dissipation units (TWT, TPA, TPS/PSU and shunt electronics) are mounted on separate radiators located on the north and south walls of the spacecraft.

Heat pipes are used on the solid-state power amplifier radiator for enhanced thermal control. Other units, such as batteries and flow control valves, are controlled by heaters switched automatically by thermistors.

ABM ignition
The function of the ABM is to impart a preselected velocity increment to the spacecraft when near to the apogee of its transfer orbit in order to inject it into quasi-stationary orbit. Limited increases or decreases in the total impulse imparted can be made by varying the propellant loading in the ABM motor.

ABM operation is initiated by an ignition system that consists of an igniter and a safe/arm device. A mechanical safing pin is removed manually prior to launch. Later in the countdown an electrical command is sent to the device to arm the ABM. At the moment of firing, an independent ignition command ignites a small booster charge, which in turn activates the main igniter charge. The igniter fires into the central bore of the motor propellant grain to initiate the selfsustaining combustion process. The combustion products are expelled through a single axisymmetric nozzle, which is concentric with the spacecraft's spin axis. Combustion continues until all propellant has been consumed.

Solar-array deployment
The solar arrays are folded against the spacecraft throughout launch and during transfer orbit. After Sun acquisition by the AOCS, they are released by severing restraining cables with two pyrotechnic guillotines, operated sequentially. The circuits are connected to the power supply by 'arming' telecommands.

BAPTA release
During the launch and transfer-orbit phases, the BAPTAs are caged by a mechanism that protects their bearings from possible vibration damage. They are released by ground command after array deployment and commanded to initiate rotation of the shafts so that the arrays face the Sun. The relevant firing circuits are connected to the power supply by the arming commands, which arm both the array-release and BAPTA-firing circuits.

Pyrotechnic subsystem
The pyrotechnic subsystem generates current pulses on telecommand and routes them to the satellite's pyrotechnic devices. The subsystem also contains arming circuits so that the devices can be isolated individually from the power supply until immediately before their moment of operation. At launch, the entire subsystem is isolated from the power supply by 'separation' switches, which close only when the spacecraft separates from the launch vehicle.

Table 2 – Design areas that have received special attention

Area	Reason for attention	Implementation
Spacecraft platform		
Reaction control system (RCS)	Reliability of thrusters and heaters for the long mission	Material/component screening, appropriate heater redundancy, life tests, purified hydrazine
Power subsystem	Overloads	Provision for disconnection of nonessential loads until overload cleared
Batteries	Reliability/capacity over 7 yr life	Tight manufacturing control. Careful charge/discharge control. Uniform and low temperature in operation
External paints on L-band antenna	Degradation of white paint absorptivity with time	Layout minimises thermal coupling with spacecraft. Antenna design takes paint degradation into account.
Electrostatic charging/discharging	Interference source, degradation of electrical and thermal surfaces	Protective measures incorporated, validated by tests
Materials	Outgassing, causing coating of critical areas or voltage-plasma breakdown	Careful materials selection, high-temperature bake-out, validated by tests
Payload		
High-power microwave devices	Reliability under high current densities and high peak power (due to multicarrier operation)	Careful procurement source inspection, judicious circuit application, realistic life-testing
Radio-frequency (RF) transmission path	Multipaction and passive intermodulation due to high peak power and multicarrier	Appropriate circuit and connector design techniques, with comprehensive testing
Solid-state devices	Space radiation effects on device life/performance	Appropriate design techniques, external shielding
On-board oscillators	Long-term stability of on-board oscillators	Careful crystal screening. High-temperature bake-out and burn-in. Life testing

The pyrotechnic subsystem is used to initiate ABM ignition, solar-array deployment, and BAPTA release.

Because of the critical nature of the ABM firing operation (when the spacecraft is near a chosen apogee in transfer orbit) and the need for exact timing, the command to the pyrotechnic subsystem is provided by a time-tag unit situated in the TTC subsystem and preset by telecommand. Should a failure occur in this unit, the ABM can be fired by direct command from the ground.

The Marecs Communications Payload

D.E. Campbell, Maritime Satellites Project Division, Directorate of Application Programmes, ESTEC, Noordwijk, Netherlands

The Marecs payload has been designed to provide a communications service to mobile stations by using the allocated band of the radio-frequency spectrum efficiently while minimising the likelihood of interference both by and to services occupying adjacent bands. Due account has also had to be taken of the constraints imposed by the capabilities of the spacecraft, of which the communications payload forms only a part.

The Marecs communications payload, a functional schematic of which is shown in Figure 1, provides maritime communications links between ships and coast earth stations. These links are provided by two redundant communications transponders and their associated antennas. A forward transponder provides shore-to-ship links, and a return transponder ship-to-shore connections.

The communication transponders are also used to: relay Emergency Position Identification Radio Beacon (EPIRB) signals from ship-to-shore; to receive telecommands from shore stations to control communications and service-module operations; and to transmit telemetry, range and telecommand verification data via the return transponder.

There are three antennas – a 6 GHz horn antenna, a 4 GHz horn antenna and an L-band dish antenna – the functions of which are to:
- receive signals in the 6 GHz frequency band (C-band) for the shore-to-satellite up-link
- transmit signals in the 1.5 GHz band (L-band) for the satellite-to-ship down-link
- receive signals in the 1.6 GHz band (L-band) for the ship-to-satellite up-link, and
- transmit signals in the 4 GHz band (C-band) for the satellite-to-shore down-link.

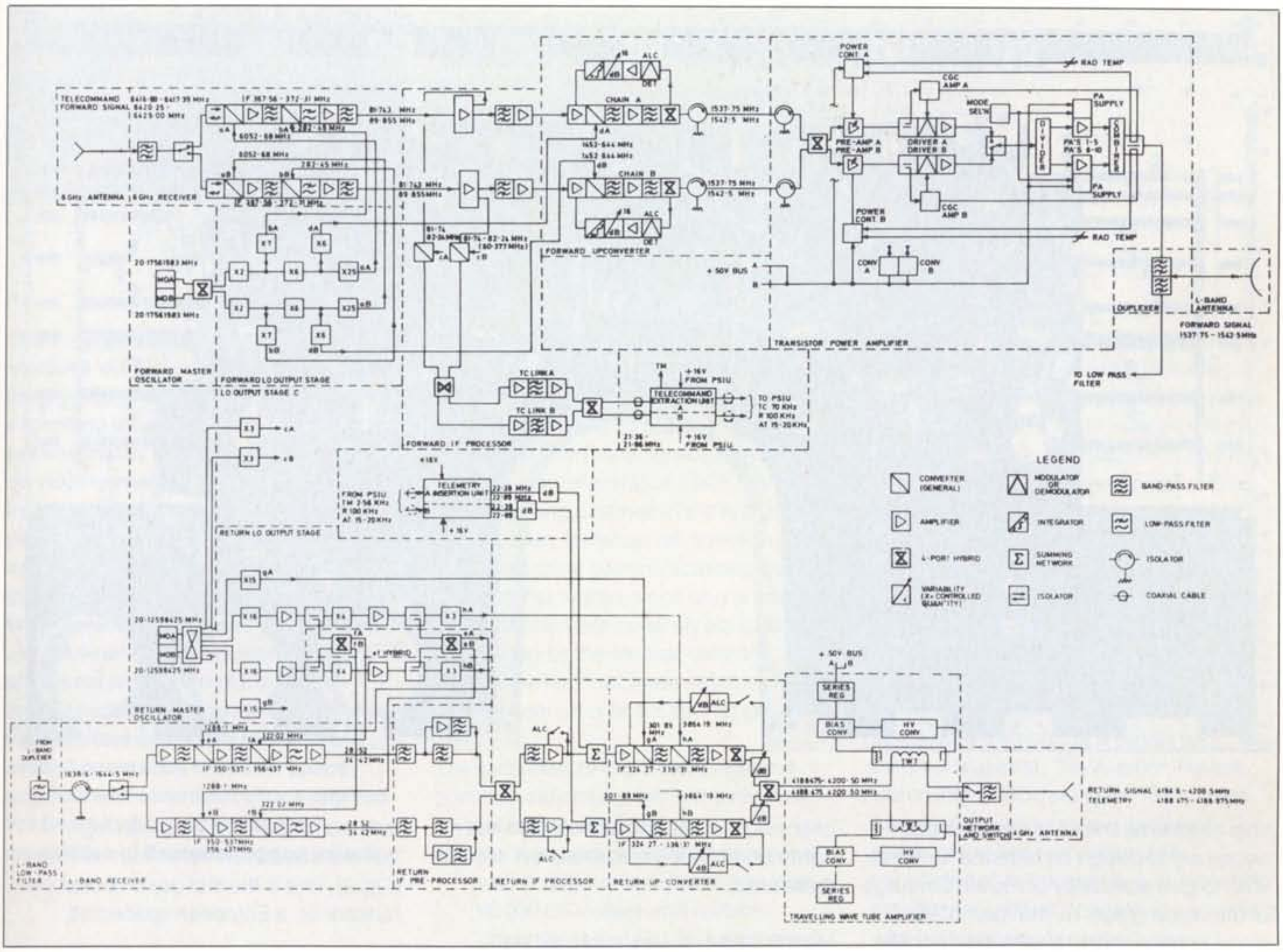
In the forward transponder the received C-band carriers are low-noise amplified and downconverted in two steps in the 6 GHz receiver to approximately 85 MHz. The IF processor then further amplifies and separates the communications and telecommand signals before bandpass filtering and amplification of the communications signal. This is then upconverted in a single step to about 1.54 GHz, filtered and level-controlled to provide the input to the L-band transistor power amplifier. The output of this amplifier is then fed via the duplexer (which separates the transmitted and the received signals) to the L-band transmit/receive antenna.

In the return transponder the signals received from the ships, after separation from the transmitted forward-link signals in the duplexer, are low-noise amplified, filtered and downconverted in two steps to approximately 30 MHz. The IF pre-processor then provides additional filtering of spurious signals and undesired mixing products before the communications signals are combined with the telemetry carrier in the IF processor. The IF pre-processor also provides a telecommandable additional gain of nominally 15 dB for the Search-and-Rescue (SAR) channel required for the transmission of low-level signals from EPIRBs. The composite signals are then double upconverted to approximately 4.2 GHz in the upconverter and further amplified before being fed to the TWTA for final amplification and transmission via the 4 GHz horn antenna.

Equipment redundancy

All equipment, with the exception of the antennas, the L-band duplexer, the 4 GHz

Figure 1 – Functional schematic of a Marecs transponder



output network and the combining hybrids, incorporates redundant sections that can be switched as required by telecommand. This is 100% redundancy except for the power-output stage of the transistor power amplifier, where redundancy is provided by the selection for parallel operation of from four to six out of ten available power amplifier modules (PAMs).

Transistor power amplifier (TPA) operational configurations

In order to obtain the RF output required (ca. 75 W) it is necessary to operate six of the final power amplifier modules in parallel. To provide the specified reliability it has been found necessary to use a total of ten PAMs in the TPA. These PAMs are grouped into two clusters of five, each with its own five-way divider/combiner. Thus, for normal operation, three modules from each cluster are selected to give the total of six. This is termed a '(3+3)' configuration. There are a total of 100 possible (3+3) configurations of the 10 modules.

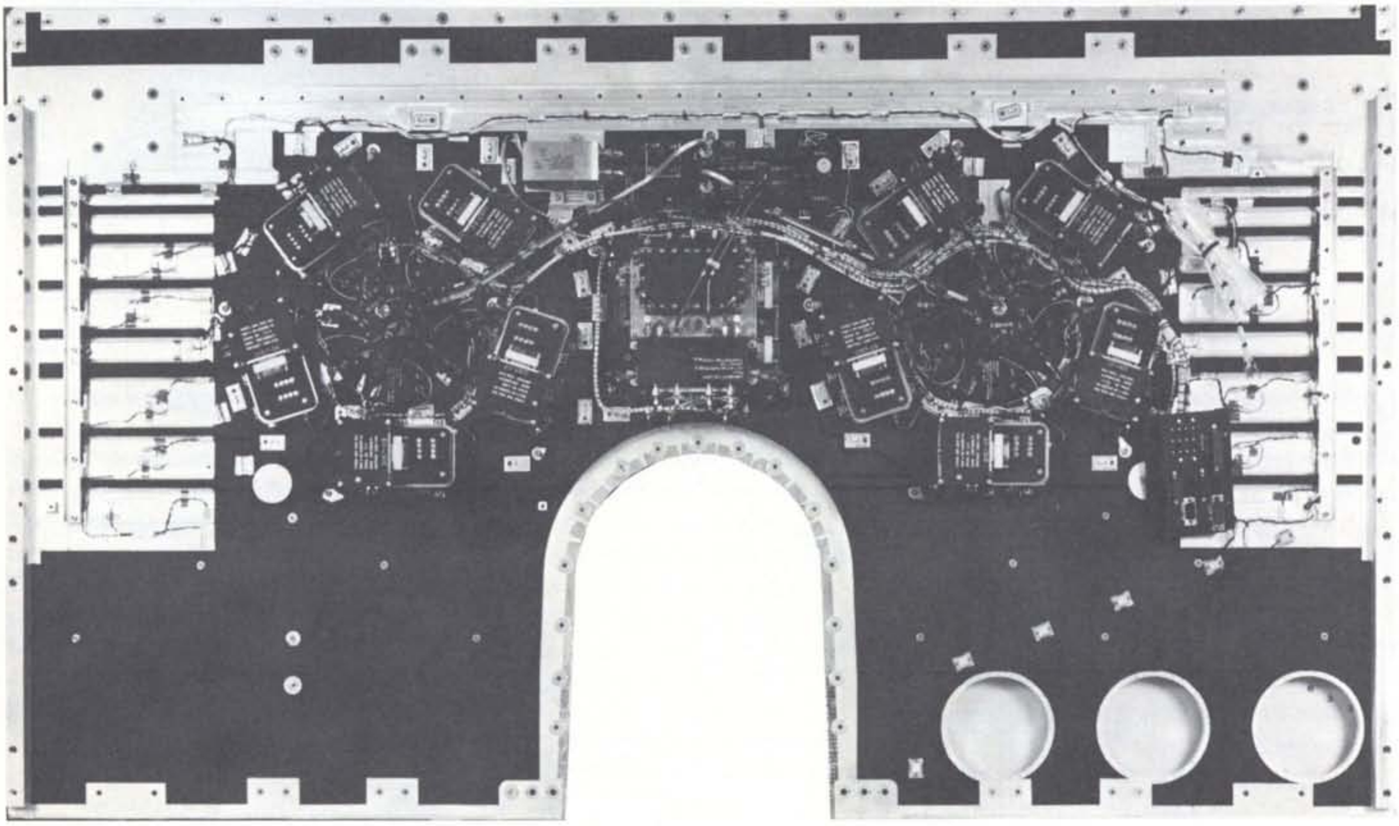
The design of the TPA allows operation with differing numbers of PAMs in parallel operation, e.g. (1+1), (2+2), (2+3) etc. However, due to the range of thermal dissipation involved, it is not possible to guarantee the necessary thermal environment for all of these configurations and in-orbit operation is limited to (2+2), (2+3), (3+2) and (3+3) configurations.

Link-based design features

In any radio-frequency communications link the capacity of the link depends on a number of parameters such as transmit power, transmit and receive antenna gains, receiver noise figure, etc. In the case of a link between an earth station and a spacecraft, the spacecraft transmit power, and transmit and receive antenna gains, are limited by the physical constraints of allowable mass and size of the spacecraft.

High antenna gains are attained by using small beam widths and are thus essentially only feasible when the position of the earth station is accurately known. For Marecs this cannot be considered to be the case for the satellite-to-ship and

Figure 2 – Marecs TPA power units mounted on a heat-pipe radiator to achieve a benign thermal environment with high thermal dissipation



ship-to-satellite links. Hence it has been necessary to design an antenna for these links to give essentially complete coverage of the visible globe, i.e. that part of the globe corresponding to elevation angles greater than 5° for the ship-based antenna.

The satellite-ship distance and the slant distance through the atmosphere increase with distance on the Earth's surface from the subsatellite point. The L-band antenna pattern has been designed to compensate for the variation in radio-frequency attenuation due to this by providing higher gain at the edge-of-coverage than at other points in the coverage. This has the effect of minimising the area of the globe receiving excess radio-frequency flux density and thus economising in the use of power transmitted from the spacecraft. It also compensates for the effect of amplitude diversity in the signals received from the ships. Because of the uncertainty of orientation of the shipborne antennas, right-hand circular polarisation is used for these links.

High transmit powers imply, for the spacecraft, a high degree of efficiency in converting the DC power generated by the solar array into radio-frequency power. The amount of DC power available is determined by the size of the solar array and the capabilities of the power-conditioning subsystem.

The TPA in the nominal (3+3) configuration produces ca. 75 W of radio-frequency output power for a DC consumption of 358 W. The carrier-to-intermodulation ratio (C/I) in a 50 kHz bandwidth for a multicarrier signal with equal-amplitude, equally-spaced carriers is in excess of 14.5 dB.

The high radio-frequency power units of the TPA are mounted on a heat-pipe radiator in order to maintain the temperatures of the units with high thermal dissipation within narrow limits (Fig. 2). This is the first use of a heat-pipe radiator on a European spacecraft.

Owing to the higher gain feasible – resulting from narrow antenna beams and better position control capability – for the coast earth stations, the requirements for the satellite antenna gain and transmit power in the satellite to coast earth-station link are not so high. Thus for instance, the satellite uses a TWTA producing about 1 W of output power and an antenna giving a gain of approximately 17.2 dBI at the edge-of-coverage to provide the same communications capacity as for the satellite-to-ship link.

Future Developments in Maritime Satellite Communications

A. Steciw, Directorate of Application Programmes, ESA, Paris

The economic viability of maritime satellites will be somewhat fragile in the early years and any means of expanding the revenue base for the system should be welcome provided the services currently offered are not impaired. The introduction in future years of lightweight maritime and aeronautical mobile terminals might therefore be of particular importance, as their availability for small vessels and aircraft would probably lead to a very significant expansion of the overall mobile communications market. These new services could be provided by a second-generation maritime space segment with communications payload hardware that is well within the capabilities of European space industry.

Introduction

Maritime mobile services will be provided by the Inmarsat organisation from 1982 onwards via a leased space segment. Voice, telex, and data services will be offered using ship stations with high-gain antennas and destined in the main for large vessels. Inmarsat will benefit initially from a maritime communications market that is rather limited, since only a few hundred ships are currently equipped for and served by the Marisat satellites, despite the fact that these satellites have already been in orbit for several years.

The weakness of the current maritime communications market is the result of several contributing factors:

- the high cost of the Marisat service, with a ship terminal costing at least 60 000 US dollars and a voice channel tariff of 10 US dollars per minute;
- the current mobile-terminal standard leads to a need for bulky, sophisticated equipment, which discourages the larger community of small vessels from becoming users of the service;
- the reluctance of users to equip their ships for the Marisat service, knowing that the Inmarsat organisation would soon offer a larger scale service with better guarantees of service continuity.

The inauguration of the first-generation Inmarsat service will undoubtedly stimulate expansion of the maritime communications market, but market penetration of mobile terminals of the current maritime mobile standard will probably be limited to a few thousand units (6000–7000 terminals), including those on vessels of over 10 000 tons. The introduction of low-G/T* maritime mobile terminals suitable for installation on small vessels, down to 300 tons or less, would probably lead to a much larger market (estimated at 40 000 to 50 000 units).

Another expansionist factor that Inmarsat might consider when planning its second-generation space segment is an aeronautical communications service (air-traffic-control communications, airline companies and perhaps passenger communications). The Aviation Review Committee (ARC), set up in 1978 by the Aerosat Council to review the future needs of the aviation community, concluded at its last meeting in June 1981 that the only option capable of competing with high-frequency ground-based communication systems would be the sharing with another service of a satellite capability. Furthermore, the Committee has included in its future work programme a detailed investigation of the feasibility and value of such a sharing with maritime mobile services.

There is good reason to believe that Inmarsat might eventually agree to offer its mobile communications service to the aviation community. The Inmarsat Council has already approved the use of its space segment for communications with three Saudi-Arabian aircraft, on a pre-emptible basis. Although this initial

* 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 by the satellite.

Figure 1 – Typical above- and below-deck equipment for a ship-borne earth station

photo inmarsat

photo inmarsat

service will be provided on a very limited scale to a small number of aircraft equipped with high-gain antenna terminals, it can be considered a positive step towards the setting-up of a future aeronautical satellite service.

From the discussions that have taken place in the Aviation Review Committee, it would seem that one of the stumbling blocks to the setting-up of an operational aeronautical satellite service might be the cost of the airborne terminals. Just as for the small maritime user, the adoption of a cheap, low-G/T terminal is likely to be a prerequisite to the setting up of an aeronautical service.

The maritime service

The Inmarsat Preparatory Committee has already identified three basic terminal standards that could be embodied in a second-generation system:

- Standard A (G/T = −4 dB/K), which is currently used for the Marisat service, and which will continue to be used with that system to provide high-quality voice and data transmissions;
- Standard B (G/T = −12 dB/K), and
- Standard C (G/T = −19 dB/K).

From an installation point of view, Standards B and C in particular are very attractive, since the size and weight of the associated terminals could be significantly reduced compared with those meeting the current standards. Furthermore, these terminals are likely to cost much less than Standard-A terminals (in the order of 30 000–40 000 US dollars for Standard C).

Services envisaged for Standard-B terminals include:

- telephony (good speech quality)
- data transmission
- facsimile, and
- telegraphy.

With a Standard-B terminal, all of these services could be accommodated within a normal Inmarsat communications channel (Standard-A channel), with a bit rate of 4.8 kbit/s. Vocoders, possibly in conjunction with forward-error-correction techniques such as convolutional encoding, would provide a speech quality with Standard-B terminals estimated to be fair to good.

The introduction of such vocoders into the maritime satellite service might lead to technical problems that would need investigation; e.g. the influence on speech quality of the band limitations, and variations in speech level due to the interconnection between the terrestrial network and the ship-to-shore link.

Standard-C terminals would provide the same basic services as Standard-B, but with reduced speech quality.

Another standard that might deserve consideration is a −24 or −26 dB/K G/T terminal that could be installed on very small ships (possibly less than 300 tons). This type of terminal would, in principle, provide only telegraphy and perhaps digital speech-transmission links, using low-bit-rate vocoders (below 1 kbit/s). Its cost would probably be in the order of 20 000–30 000 US dollars.

The aeronautical service

The main system requirements for an aeronautical satellite service as defined by the Aviation Review Committee are summarised in Table 1.

To meet the data-transmission performance required with this type of terminal, a satellite EIRP* three to four times that of an Inmarsat Standard-A communications channel would be needed. Voice transmission would require more satellite power, and could be achieved by using low-bit-rate vocoders.

According to the Aviation Review Committee, the communications capacity defined in Table 1 would be sufficient to meet air-traffic-control requirements for the North-Atlantic region until the 1990's.

The airspaces that could be served from a maritime satellite positioned between

Table 1

Airborne terminal G/T	−26 dB/K
Airborne terminal EIRP	<17 dBW
Service to be provided over the North-Atlantic region:	
– Data transmission (for air-traffic-control purposes)	150 bit/s (ground-to-air) 500 bit/s (air-to-ground)
– Voice transmission (for emergency purposes)	good intelligibility

* EIRP = *Effective Isotropically Radiated Power*

10°W and 30°W, in addition to those of the entire Atlantic region, would include those of South America and Africa, which currently suffer from a lack of reliable air-to-ground communications. The total capacity needed to provide air-traffic-control, airline and en-route flight-information communications in these airspaces would probably be in the order of 1 voice and 4 data channels.

Possible satellite concepts

The traffic expansion and new services identified above would require a higher satellite EIRP. Depending on the particular mission objectives, this requirement could be met either by increasing the power of the L-band amplifier of the Marecs transponder, or by employing a multibeam antenna on the satellite that would provide a higher gain at L-band. To identify and analyse new satellite concepts that might be adopted by Inmarsat for its second-generation space segment, three scenarios, based on different traffic, terminal-characteristic, and mission requirements, have been defined; each includes a crude definition of the main satellite characteristics:

Scenario 1

Satellite EIRP (L-band)	40 dBW
Total bandwidth	7 MHz
Global-coverage antenna gain	17 dB
RF power	200 W

This first scenario is very conservative, since it assumes that only Standard-A terminals are used. The only difference with respect to current Marecs mission requirements is that the satellite capacity has been increased from 35 to 120 channels. This could easily be achieved using a global-beam transponder with a high-power amplifier providing 200 W at L-band.

Scenario 2

Satellite EIRP (L-band)	47 dBW
Total bandwidth	8 MHz
Number of beams	7
Minimum coverage gain	24 dB
Antenna concept	multifeed
RF power per beam	85 W

In this second scenario, maritime and aeronautical low-G/T terminal services are provided, but with a limited capacity:

- Standards-A and B — 100 channels (high to good speech quality, depending on standard used)
- −24 dB/K maritime and aeronautical terminals — 20 channels (voice and data)

The introduction of low-G/T terminal services in this scenario implies the use of a multibeam antenna. Up to seven beams would be required, with a total RF power of 85 W per beam. A conventional multifeed antenna would probably provide sufficient performance.

The system implications of introducing new services for low-G/T mobile terminals need to be carefully investigated, the access of the mobile and shore-based earth stations to the satellite and the overall system organisation being of particular importance. It is essential that the introduction of the new services be accomplished without need for significant modifications to existing users' terminals.

Scenario 3

Satellite EIRP (L-band)	56 dBW
Total bandwidth	20 MHz
Number of beams	40 to 50
Minimum coverage gain (L-band)	31 dB
Total RF power	25 dBW

Scenario 3 offers the same basic services as Scenario 2, but with a much higher capacity:

- Standards-A and B — 100 channels
- Low-G/T maritime service — 200 channels
- Aeronautical service — 10 channels

The satellite EIRP requirement here is very stringent and cannot be met with conventional transponder technology. It would be necessary to use a phased-array antenna providing up to 40 beams. The traffic increase over the next decade is unlikely to justify the adoption of such an advanced satellite concept by Inmarsat for its second-generation space segment. However, phased-array antenna techniques could possibly be used to implement the satellite concept of Scenario 2 if it were found to be more practicable and advantageous to do so.

Conclusions

By the terms of a recommendation adopted during the International Conference on the establishment of Inmarsat, that organisation is charged with examining the consequences of using satellites in a multipurpose configuration, specifically for aeronautical and maritime use. Any eventual adoption of these services by Inmarsat would also be the result of a policy decision. This being the case, Inmarsat could be expected to exploit any opportunity that they perceived to be of commercial benefit. The introduction of new services for low-G/T maritime and aeronautical mobile terminals might be of particular importance in this regard. The various options open to Inmarsat for its second-generation system can be summed up in terms of the three possible scenarios that have been outlined, based on specific sets of assumptions as to traffic, system and mission characteristics. Each scenario is matched by a particular satellite concept, distinguished by the configuration of the associated payload.

Studies have recently been carried out by the Agency in order to define these scenarios more exactly, from both the missions and system viewpoints, and to analyse the corresponding satellite configurations in greater detail. They have been planned so as to allow for the possibility of Phase-A industrial work being started early in 1982. This target is necessary to allow European industry to make adequate preparations for meeting the competition that the setting up of a second-generation space segment by Inmarsat will engender.

The Inmarsat Organisation

K.P. Galligan, Directorate of Application Programmes, ESA, Paris

In January 1980, the Inmarsat Organisation officially took over its headquarters in London. The inauguration of this establishment was the climax to preliminary discussions that had commenced as early as 1966 in the very different forum of the International Maritime Consultative Organisation, IMCO, and was the signal for the start of intense activity on the part of Inmarsat to establish its own space segment.

The beginnings

The potential for satellites to provide a high-quality alternative to medium and high-frequency radio for communications and navigation purposes was recognised at an early stage, and in February 1966 studies were started by IMCO. This work, conducted by a Panel of Experts, comprised an examination of the technical and economic problems associated with the establishment of a satellite system, as well as the outline of an institutional framework for the creation of an organisation to effect such establishment.

These early studies indicated that the potential and viability of satellites, notably in the area of communications, was such that it was thought useful to convene an International Conference to consider the creation of an international maritime satellite system.

At sessions of this conference held in April 1975, and February and September 1976, the States represented, basing their work on the report of the Panel of Experts* and other comments from interested Governments and Organisations, developed and approved the institutional framework for an International Maritime Satellite Organisation, Inmarsat**.

It was notable that among the provisions contained in the document concerning the establishment of Inmarsat was one which provides that the new organisation should operate on a commercial basis, which is in contrast to the regulatory nature of the organisation that led to its creation (IMCO).

As is normal, provision was included for the entry into force of the Inmarsat Convention. It was established that a period of thirty-six months would be allowed for such entry into force and that 95% of the initial investment shares should be taken up.

Preparatory work

Much useful work had been done as a result of the Inmarsat conferences. Much remained to be done, however, and, in view of the comparatively long period which could be foreseen before entry into force of the Agreement, it was decided to set up a committee whose task was to prepare the way so that Inmarsat might come into being in as efficient a manner as possible. The Preparatory Committee's work was completed in May 1979, culminating in a report to the Inmarsat Council***. It is probably fair to say that the activities of this committee and of the three panels treating technical, economic/financial/marketing and organisational matters, respectively, was to a degree complicated by the fact that certain space-segment facilities were foreseen to be available at around the time Inmarsat would be set up****.

Inmarsat's creation and activities

On 18 May 1979, Teleglobe Canada signed the Inmarsat operating agreement bringing the investment shares above the 95% level for entry into force of the Convention and, according to the provisions thereof, Inmarsat came into being on 16 July of that year.

A first meeting of the Inmarsat Council took place in July 1979 at which decisions

---

* Study on the Establishment of a Maritime Satellite System – Report of the IMCO Panel of Experts Marsat/Conf./3.30 October 1974

** Convention and Operating Agreement on the International Maritime Satellite Organisation (Inmarsat), September 1976

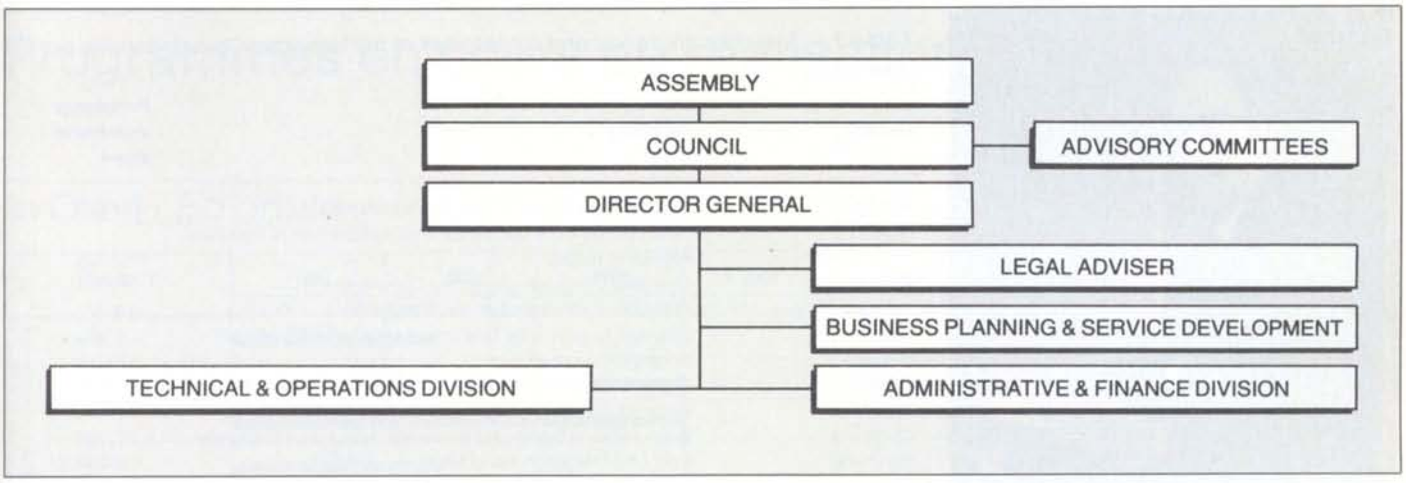
*** Final Report to the Inmarsat Organisation. Inmarsat Preparatory Committee, Fifth Session, Document Prepcom/V/6/Add. 1, 29 May 1979

**** Maritime Mobile Satellites – A Review of Institutions and Activities, K. Barbance and K. Galligan, ESA Bulletin No. 20, November 1979

Figure 1 – The structure of Inmarsat

Figure 2 – Mr. Olof Lundberg, Director General of Inmarsat

Figure 3 – Members of the Inmarsat Council and staff of the Directorate (July 1981)



concerning the practicalities of setting up the new organisation were taken. At a subsequent Council meeting, Mr. Olof Lundberg was chosen as the new organisation's chief executive (Director General).

Mr. Lundberg took up his post in January 1980 faced with the task of building a new organisation from scratch, whilst at the same time needing to procure in as timely a fashion as possible the space segment upon which the future profitability of Inmarsat would depend.

photo inmarsat

photo inmarsat

A task of vital importance was to provide Inmarsat with a staff to procure and run the space segment. An indication of the progress in this area is that now, from the modest beginning in 1980, a staff of around 50 people has been recruited.

Progress has also been rapid in the procurement of a space segment. In May 1980, after issuing a request for proposals, Inmarsat received proposals for the lease of elements of a space segment from Intelsat, Marisat and the European Space Agency. An intense period of evaluation and negotiation followed and in November of that year the first lease contract was signed, with ESA. Contracts were later signed with both Marisat and Intelsat. These three contracts provided Inmarsat with an operational and a spare satellite in each ocean region, with satellites starting to become available at the beginning of 1982.

Whilst important, the space segment was not the only area in which procurement had to take place. Inmarsat will not itself own or operate communications earth stations. However, it is responsible for communications system management and to this end specialised facilities for system management have been procured, together with a communications network control capability.

Figure 4 – Chairman of the Council of Inmarsat, Mr. L.P. Embratel

photo inmarsat

Table 1 – Member countries and signatories of the Inmarsat Convention (as per July 1981)

Country	Signatory	Percentage investment share
Algeria	Ministere des Postes et Telecommunications	0.05000
Argentina	Empresa Nacional de Telecommunicationes de la Republica Argentina (Entel)	0.60425
Australia	Overseas Telecommunications Commission	1.67854
Belgium	Regie des Telegraphes et des Telephones	0.60425
Brazil	Empresa Brasileira de Telecomunicacoes S.A. (Embratel)	1.67854
Bulgaria	Shipping Corporation	0.27218
Canada	Teleglobe Canada	2.61848
Chile	Empresa Nacional de Telecommunicaciones S.A. (Entel)	0.05000
China	Beijing Marine Communications and Navigation Company	1.23728
Denmark	Post and Telegraph Administration	1.67854
Egypt	Telecommunications Organization	0.05000
Finland	General Directorate of Posts and Telegraphs	0.60425
France	Direction Generale des Telecommunications	2.88698
Federal Republic of Germany	Bundesministerium fur das Post und Fernmeldewesen	2.88698
Greece	Hellenic Telecommunications Organisation (OTE)	2.88698
India	Overseas Communications Service Govt. of India	1.67854
Iraq	Republic of Iraq	0.05000
Italy	Ministero delle Poste e Telecomunicazioni	3.35693
Japan	Kokusai Denwa Co. Limited	7.00267
Kuwait	Ministry of Communications	2.01416
Liberia	Republic of Liberia	0.05000
Netherlands	Netherlands PTT Administration	2.88698
Norway	Norwegian Telecommunications Administration	7.88217
New Zealand	Post Office Headquarters	0.36295
Oman	Sultanate of Oman	0.05000
Philippines	Philippine Communications Satellite Corporation (Philcomsat)	0.05000
Poland	Ministry of Foreign Trade and Shipping	1.67854
Portugal	Companhia Portuguesa Radio Marconi	0.20620
Singapore	Telecommunication Authority of Singapore	1.67854
Spain	Compania Telefonica Nacional de Espana	2.01416
Sweden	Swedish Telecommunications Administration	1.87992
UK	British Telecommunications	9.89631
USA	Communications Satellite Corporation (Comsat)	23.37543
USSR (including Byelorussian and Ukrainian SSRs)	Morsviazsputnik	14.37543

A parallel development to that of the Inmarsat organisation has been seen in the area of institutions and membership of the investors in that organisation. From the original 26 members whose signature of the operating agreement gave birth to the organisation, membership has now risen to over thirty administrations and operating agencies.

The Inmarsat Council now meets approximately four times per year, and it has created two bodies to advise it on technical and financial matters.

Prospects
Inmarsat's first-generation space segment is being created out of elements that are disparate in nature. Their appeal to Inmarsat was that, apart perhaps from the reasonably favourable terms on which they could be procured, the facilities would be available at a much earlier date than if procured by Inmarsat itself. Their acquisition, however, has imposed a relatively heavy burden of harmonisation on the organisation itself. Nevertheless, it is hoped that Inmarsat's projections, notably in the financial area, will, like the fittings of earth stations to ships, exceed expectations.

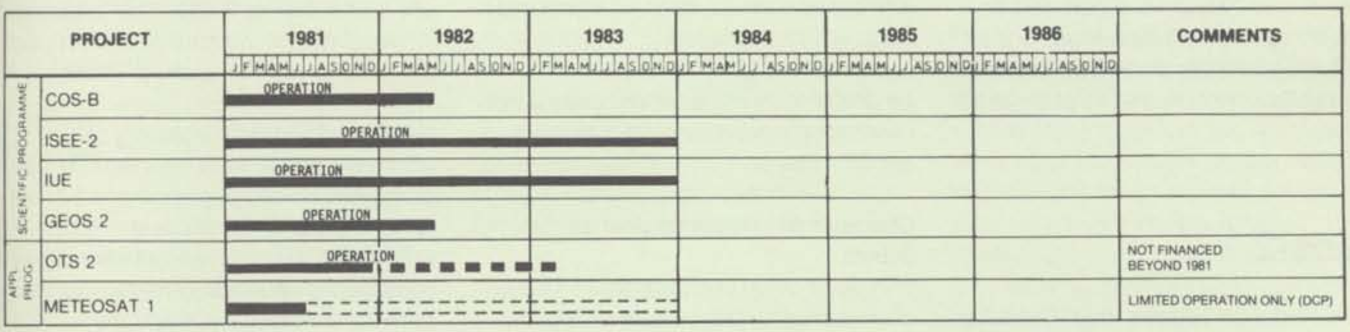
The lease contracts provide for service via Marecs, Intelsat-V and Marisat satellites for a seven-year period. Thus in 1988 Inmarsat must have available to it a second-generation space segment. Investment decisions concerning the second generation must be taken within the next two to three years. The prospect of such decisions raises a number of intriguing questions for system designers and spacecraft development agencies. Not least amongst these are the size and shape of the next generation, how the procurement will be managed and whether the space segment will be leased or bought.

However, it is hoped that the successful launch of Marecs will be a first step in providing the climate in which this relatively new organisation will thrive and in which the maritime telecommunications-satellite market will become increasingly profitable.

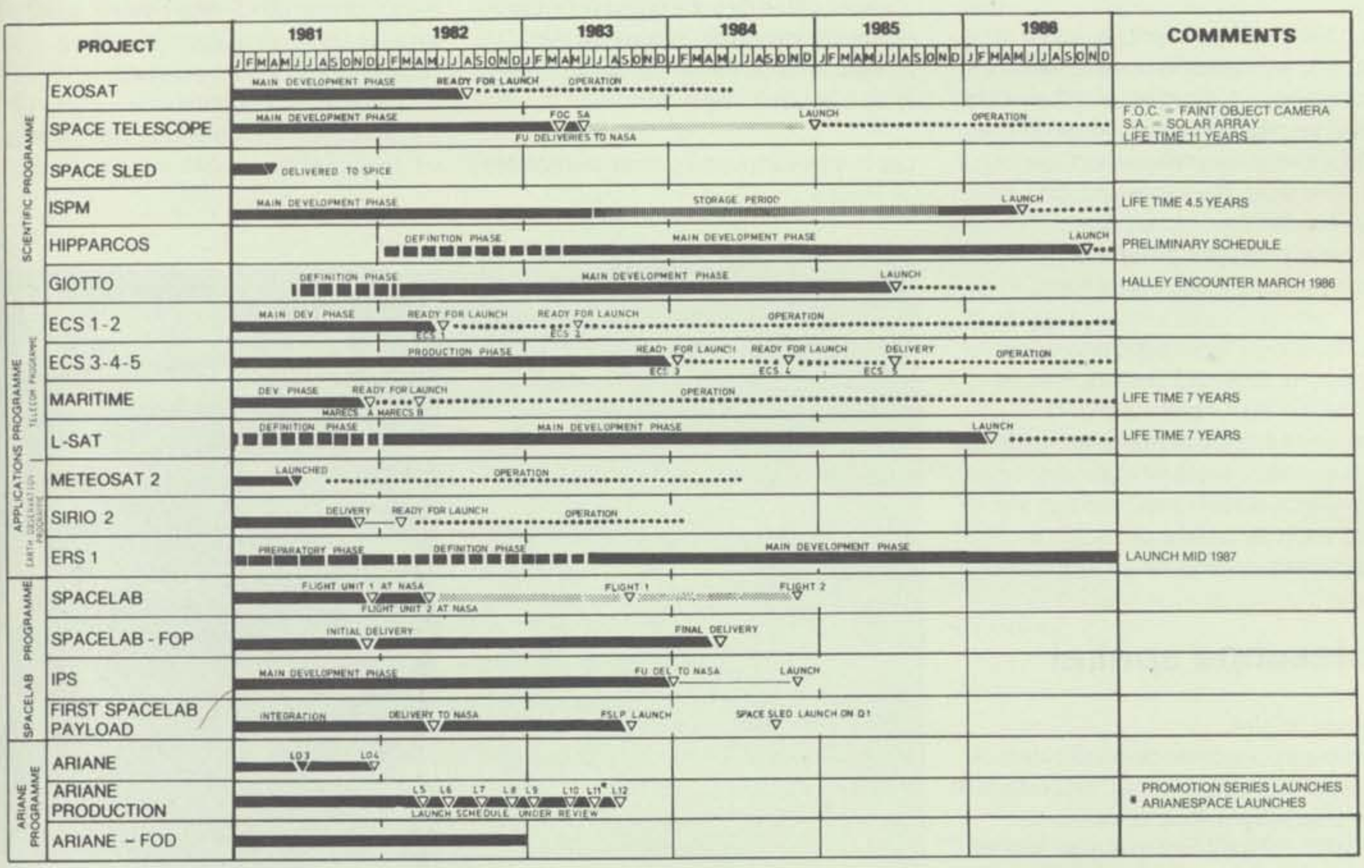
Programmes under Development and Operations*

Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



*Reporting status per 1 September 1981/Bar chart valid per 1 October 1981

** Situation des projets décrits 1er septembre 1981/Planning 1er octobre 1981*

ISEE-2

La situation de la charge utile d'ISEE-2 n'a pas changé récemment, en ce sens qu'une seule expérience (l'analyseur rapide de plasma) ne fonctionne toujours pas. Comme les deux autres satellites de la mission (ISEE-1 et 3) sont également dans un très bon état de fonctionnement, la NASA s'est assuré la poursuite des satellites ISEE et l'acquisition des données au moins jusqu'à l'automne de 1983. Le Comité du programme scientifique de l'ESA a également approuvé l'extension du programme ISEE en 1982. L'acquisition des données a souffert du lancement de la Navette en février et avril 1981 mais, à part cela, le pourcentage de restitution et de chevauchement des données entre les trois satellites a toujours été très élevé: 60 à 70%.

Geos-2

Au cours des six derniers mois, Geos-2 a continué de fonctionner à raison de 12 heures par jour; toutefois une couverture de 24 heures sur 24 a pu être assurée trois jours par mois.

A signaler les événements suivants: on a procédé, le 24 mars, à une manoeuvre d'inversion de 180° et, entre le 5 et le 11 juin, à un déplacement en longitude de 37° Est (point magnétiquement conjugué au Nord de la Scandinavie) à 25° Est (position très proche du point d'intersection entre les équateurs géographique et géomagnétique).

Six des sept expériences embarquées continuent de fournir des données de bonne qualité. Le satellite restera positionné comme actuellement à 25° Est de longitude jusqu'à ce que l'Association scientifique EISCAT annonce que son installation de radar à diffusion incohérente commence à fonctionner.

Télescope spatial

Réseau solaire

Les essais du modèle de qualification du mécanisme de déploiement secondaire se sont poursuivis et tous les essais de vibration ont été accomplis avec succès. Les essais thermiques sous vide et les essais d'endurance ont ensuite commencé.

Le modèle de qualification du mécanisme de déploiement principal a subi avec succès les essais de qualification complets et on prépare actuellement son expédition à British Aerospace pour l'intégration au niveau système.

Des recherches sur les défaillances de la nappe de réseau solaire utilisée pour la qualification se poursuivent. Des échantillons supplémentaires de la nappe du réseau solaire, représentant des conceptions différentes pour l'interconnexion des photopiles, ont été soumis à des essais thermiques cycliques (30 000 cycles de −100° à +100°), et les échantillons comprenant des interconnexions soudées à l'argent ont été soumis à ces essais.

La préparation des examens critiques de conception au niveau sous-système a bien progressé.

Chambre de prise vues pour astres faibles

L'intégration du compartiment d'électronique s'est achevée. L'ensemble a été soumis aux essais d'EMC, qui ont été exécutés avec succès.

L'intégration du premier compartiment d'électronique de vol a commencé chez Dornier System par l'intégration des équipements de traitement des données et du calculateur de bord.

Les activités de Matra ont été transférées de Paris à Toulouse.

Le modèle prototype de la structure porteuse est achevé et a été soumis à un étuvage sous vide. Celui-ci a cependant fait apparaître qu'environ un tiers des résistances chauffantes collées à la structure porteuse présente une exfoliation plus ou moins étendue. On étudie actuellement cette défaillance et l'on a mis en route une série d'essais supplémentaires pour déterminer la cause de ce phénomène.

Les retards intervenus dans la livraison des composants hybrides par le fournisseur américain pourraient avoir des répercussions sur le calendrier de la mémoire des données scientifiques.

Détecteur de photons

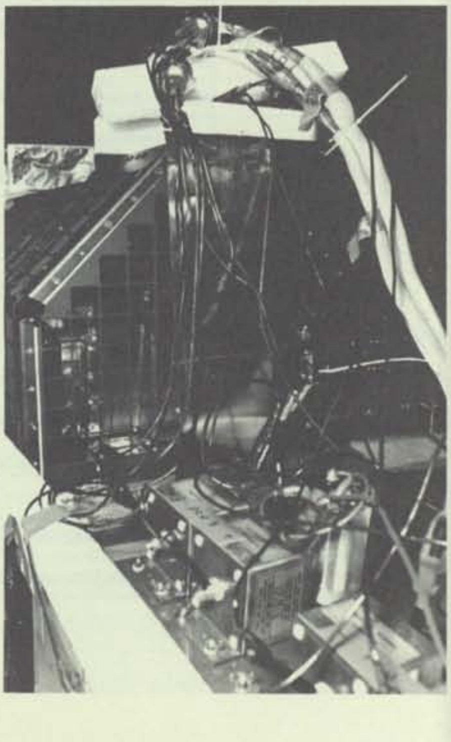
La mise à jour du modèle structurel/thermique, destiné aux essais thermiques sous vide du modèle prototype de vol de la chambre de prise de vues s'est poursuivie par l'exécution de modifications apportées à l'électronique et aux détecteurs. La fourniture de cet équipement est prévue pour septembre.

Le modèle d'identification est soumis à des essais pour optimiser l'électronique en vue d'assurer une observation et une identification correctes des photons.

Des progrès considérables ont été accomplis dans l'élimination des problèmes de décharges corona à haute tension, grâce à des essais sur des échantillons témoins représentant des conceptions de remplacement, pour les sections 'intensificateur' et 'tube analyseur'. Les travaux sur les épissures à haute tension progressent également.

Une modification a dû être introduite dans le mode de fonctionnement du tube analyseur en introduisant un câble à haute tension relié à ce dernier.

La fabrication des éléments du modèle de vol se poursuit.



Space Telescope camera module (FOC) electronic bay assembly undergoing EMC tests at ESTEC, Noordwijk

Essais EMC du compartiment d'électronique de la chambre de prise de vues du Télescope spatial à l'ESTEC, Noordwijk

ISEE-2

The status of the payload of ISEE-2 has not changed recently in that still only one experiment (Fast Plasma Analyser) is out of action. As the other two spacecraft of the mission (ISEE-1 and 3) are similarly in very healthy condition, NASA has secured ISEE spacecraft tracking and data acquisition at least until Autumn 1983. The ESA Science Programme Committee has also approved extension of the ISEE programme during 1982. Data acquisition suffered in February and April 1981 due to the launching of the Shuttle, but otherwise data recovery and overlapping between the three spacecraft has always been very high, ranging above 60–70%.

Geos-2

During the last six months Geos-2 has continued to operate on a 12 hour-per-day basis except for three days in each month when 24 hour-per-day operation was arranged.

Major events were a 180° inversion manoeuvre on 24 March and a longitudinal shift from 37°E (magnetically conjugated to Northern Scandinavia) to 25°E (a position very near the crossover point between the geographic and geomagnetic equators). This shift was carried out in the period 5 to 11 June.

Six of the seven experiments on board continue to return good-quality data. The satellite will remain at its present longitude of 25°E until the EISCAT Scientific Association indicate that their incoherent scatter radar facility is ready to commence operation.

Space Telescope

Solar array
The testing of the development-model secondary-deployment mechanism has continued and all vibration tests have been successfully completed. Thermal-vacuum and life testing have commenced.

The qualification model of the primary deployment mechanism has successfully completed qualification tests and is being prepared for shipment to British Aerospace for system integration.

The failure investigation for the qualification-sample solar-array blanket has continued. Additional samples of the solar-array blanket with a number of different cell-interconnection designs have been submitted to thermal cycling tests (30 000 cycles from −100°C to +100°C), and samples with welded silver-mesh interconnects have passed these tests.

Preparations for the Critical Design Reviews at subsystem level are well advanced.

Faint Object Camera
Integration of the electronics-bay assembly has been finalised. The assembly has been submitted to EMC testing, which has been completed successfully.

Integration of the flight electronics-bay assembly has started at Dornier System with the integration of the data-handling units and the on-board computer.

The Matra activities have been moved from Paris to Toulouse.

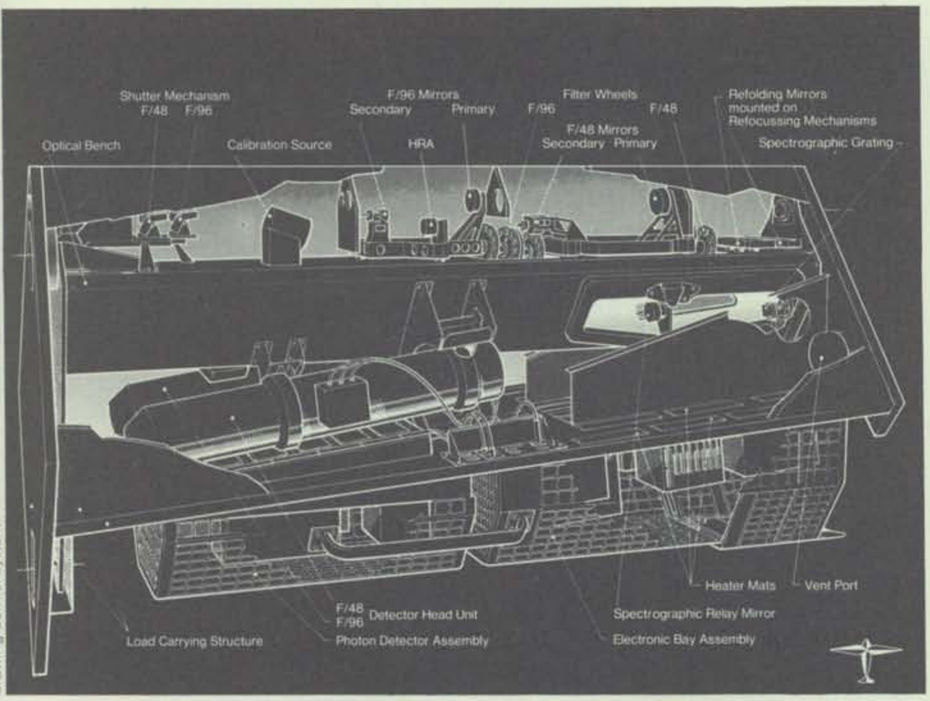
The protoflight model of the load-carrying structure has been completed and subjected to bake-out under vacuum. As a result of the bake-out, however, about one third of the heaters, bonded to the load-carrying structure, have shown some delamination. This failure is being investigated and a series of additional tests have been initiated to determine the cause.

Delays in the delivery of hybrid components from the US supplier could affect the schedule of the scientific-data-store unit.

Photon Detector Assembly
Updating of the structure/thermal model for use in Faint Object Camera protoflight model thermal vacuum testing has continued with modifications to the electronic and detector-head units. This item is due for delivery in September.

The engineering model is under test to optimise the electronics for photon observation and recognition.

Considerable progress has been made on the elimination of the high-voltage corona problems by successful tests on samples of alternative designs of intensifier and camera-tube assemblies. The work on high-voltage splices is also proceeding.



drawing dornier system

Vue écorchée de la chambre de prise de vues pour astres faibles (FOC)

Cutaway drawing of the Space Telescope Faint Object Camera (FOC)

Activités NASA

La NASA a procédé à des vérifications de masses pour tous les éléments du Télescope, notammen le réseau solaire, le détecteur de photons et la chambre pour astres faibles.

Les discussions sur les détails de la participation de l'ESA au Science Institute ont commencé avec la NASA à la suite du choix d'AURA pour mettre sur pied et faire fonctionner l'Institut.

Installation de coordination européenne

L'évaluation de quatre propositions pour accueillir l'installation de coordination européenne s'est achevée et le Comité du programme scientifique a porté son choix sur l'Observatoire européen de Garching (Allemagne) chargé des recherches astronomiques dans l'hémisphère austral (ESO).

Hipparcos

La phase de définition (dite phase B) du projet Hipparcos se subdivise en deux parties:

- *la phase B1, qui est une phase d'étude concurrentielle, doit durer 13 mois, et*
- *la phase B2, qui sera non-concurrentielle, ne devrait pas dépasser cinq mois.*

L'invitation à soumissionner pour la phase B1 a été lancée par l'Agence le 1er juillet: les maîtres d'oeuvre doivent soumettre leurs offres au plus tard le 20 octobre. Compte tenu des délais nécessaires pour les procédures d'évaluation, de sélection et d'approbation officielle, on s'attend à ce que la phase B1 commence début janvier 1982, ce qui est conforme au planning actuel du projet.

Les Avis aux expérimentateurs ont été lancés: ils comprennent la compilation du catalogue des entrées, le traitement des données scientifiques et la contribution à la liste des objets célestes à observer. La date limite des réponses aux deux premiers Avis a été fixée au 1er janvier 1982, tandis que les réponses au troisième avis devraient parvenir à l'Agence avant le 1er octobre de la même année.

Giotto

La phase B0 a démarré le 9 juin dans l'industrie. Une équipe composée d'ingénieurs de l'ESA et du consortium STAR – ce dernier ayant pour chef de file British Aerospace, Division de Bristol – a élaboré une conception de base au niveau système.

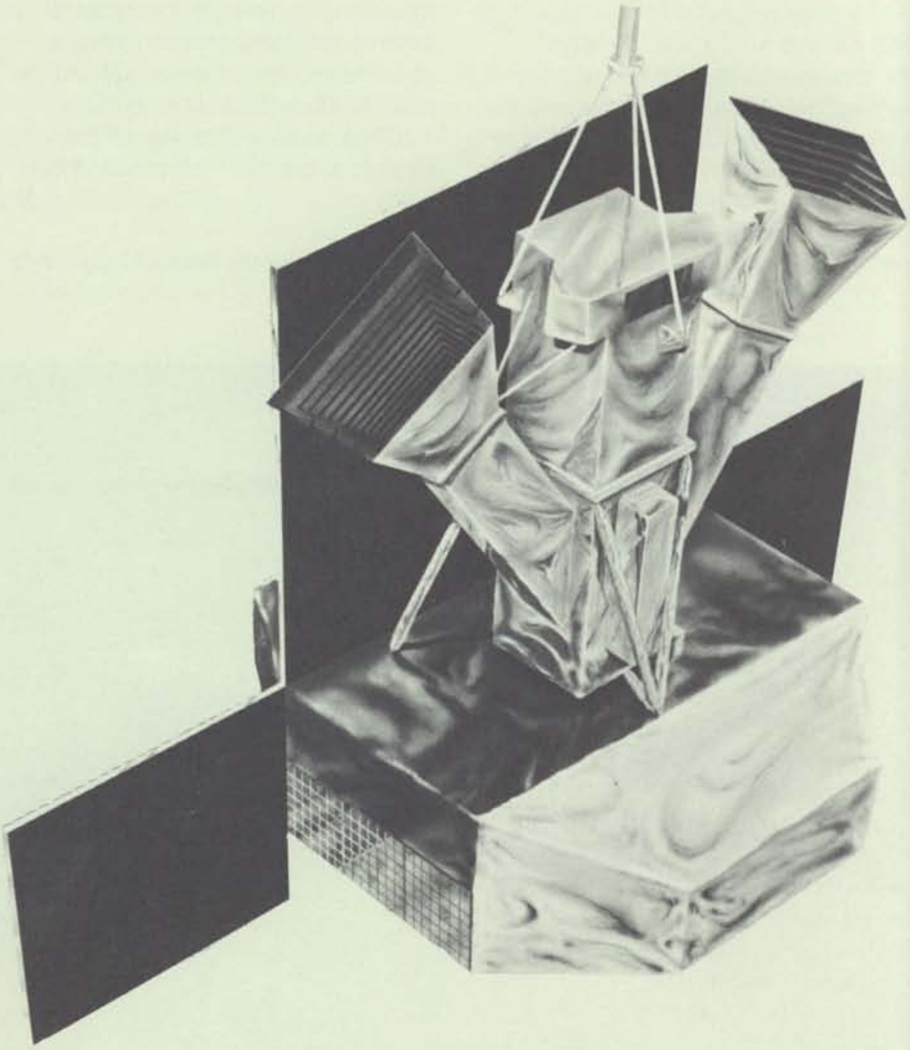
L'actuelle conception au niveau système fait appel à un satellite à double rotation d'une masse de 950 kg environ. Le corps cylindrique du satellite est équipé, à sa base, d'un bouclier de protection contre les impacts de particules et, en son sommet, d'une antenne contra-rotative à grand gain destinée à assurer les communications avec la Terre. L'injection du satellite sur l'orbite de rendez-vous avec la comète Halley se fera grâce au moteur d'apogée géostationnaire européen Mage-1S.

A la suite du succès de la phase B0 qui s'est achevée le 29 juin, la phase B1 a démarré avec la définition détaillée au niveau système et a conduit aux spécifications techniques des systèmes et sous-systèmes. Sur la base de ces spécifications, l'Agence a préparé les appels d'offres qui ont été addressés le 20 août aux soumissionnaires des sous-systèmes et des équipements.

Après la sélection de l'équipe industrielle, l'actuelle phase B1 sera complétée par une revue qui doit avoir lieu fin octobre.

OTS

OTS continue d'avancer allègrement dans sa quatrième année d'exploitation: tous les sous-systèmes embarqués fonctionnent parfaitement. Les températures enregistrées à bord du satellite redescendent légèrement après avoir atteint un sommet saisonnier lors de la solstice d'été. La quantité d'ergol restante dépasse 30 kg et l'énergie fournie par le réseau solaire continue de rester proche de la valeur prévue la plus



Artist's impression of the Hipparcos spacecraft

Vue conceptuelle du satellite Hipparcos

A change in the mode of operation of the camera tube had to be introduced, with the addition of a high-voltage cable to the camera-tube assembly.

The manufacture of flight-model units is in progress.

NASA activities
NASA have conducted mass audits of all Space Telescope elements, including the solar array, Photon Detector Assembly, and Faint Object Camera.

Discussions with NASA on the details of the ESA participation in the Science Institute have started, following the selection of AURA (Association of Universities for Research in Astronomy) to develop and operate the Institute.

European Co-ordination Facility
The evaluation of four proposals to host the European Co-ordination Facility has been completed and the Science Programme Committee has selected the European Southern Observatory in Garching, Germany.

Hipparcos

Phase-B (definition phase) of the Hipparcos project is divided in two parts:

- Phase-B1, which is a competitive study phase lasting 13 months, and
- Phase-B2, which will be noncompetitive and is planned to last no more than five months.

The Invitation to Tender for Phase-B1 was issued by the Agency on 1 July 1981, asking candidate prime contractors to submit their tender documentation on or before 20 October 1981. Taking into account the time required for evaluation, selection and formal approval, Phase-B1 is expected to commence in early January 1982, which is in line with current project planning.

Three Announcements of Opportunity have been issued: for the compilation of the input catalogue, for the processing of the scientific data, and for contribution to the list of celestial objects to be observed. Responses to the first two Announcements are expected by 1 January, whilst those to the third Announcement should be available by 1 October 1982.

Giotto

Phase-B0 started with industry on 9 June 1981. A joint engineering team drawn from ESA, and from the STAR consortium led by British Aerospace (Bristol Division), has established a baseline system-design concept.

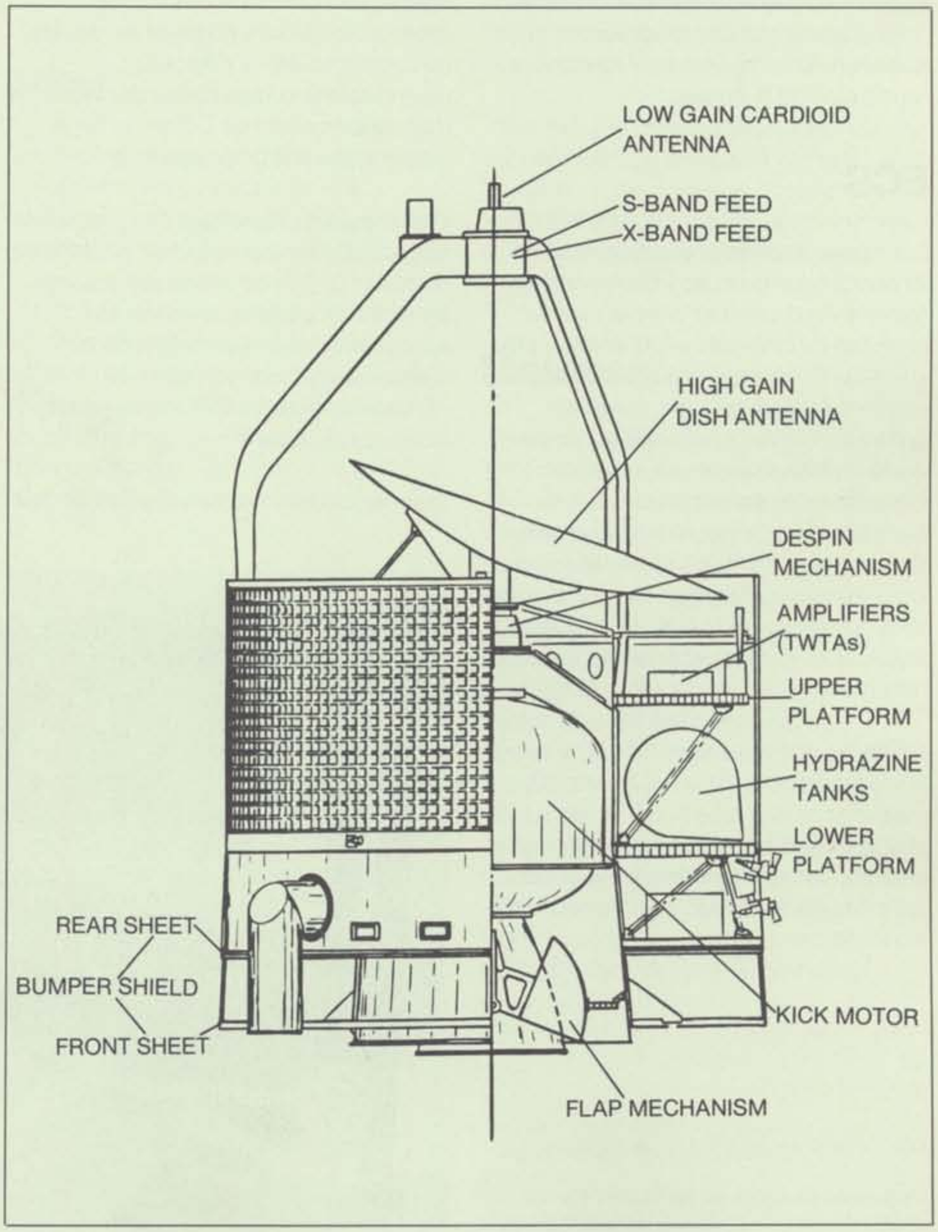
The present system design calls for a dual spin spacecraft of approximately 950 kg. The cylindrical spacecraft has a bumper shield at the bottom to protect it from impacting particles and a despun, high-gain antenna on top to maintain communications with the Earth. The spacecraft will be injected into its orbit to Halley by a Mage-1S motor.

After successful completion of Phase-B0 on 29 June, Phase-B1 was started with detailed system definition, leading to system and subsystem requirement specifications. On the basis of these specifications, Requests for Proposals were prepared and these were submitted on 20 August to interested subsystem/equipment bidders.

After selection of the industrial team, the present Phase-B1 will be completed by a review to be held at the end of October 1981.

Vue écorchée du satellite Giotto avec ses principaux éléments

Cutaway drawing of Giotto showing the major elements of the spacecraft



élevée. En conséquence, il est hautement probable que le satellite pourra encore fonctionner pendant deux ou trois ans.

Les expériences Stella et Spine continuent de se dérouler de façon satisfaisante. En particulier, la liaison Spine entre Frascati (Italy) et le RAE (Royaume-Uni) fonctionne maintenant de façon quaotidienne. Les stations suédoises se préparent à se joindre au réseau.

Eutelsat intérimaire exécute actuellement toute une série d'essais et d'expériences, dont les essais pratiques d'AMRT qui représentent une partie importante de cette activité préparatoire pour le système ECS.

Des démonstrations de transmission de données et de télévision à des conférences et des expositions ont fréquemment lieu par l'intermédiaire d'OTS tandis que des programmes de télévision sont régulièrement transmis à destination de la Tunisie.

ECS

Les essais du premier exemplaire de vol se poursuivent dans les installations de Matra à Toulouse. Les premiers essais complets de système intégré et les essais spéciaux de répéteur se sont achevés. Les résultats préliminaires des essais de système n'ont fait apparaître qu'un petit nombre de problèmes et le répéteur intégré a montré d'excellentes performances. De nouvelles modifications de structure ont dû être apportées pour loger le moteur d'apogée Mage-2 avant de procéder aux essais d'EMC et pour préparer les essais mécaniques prochains (vibration).

On pense que le lancement d'ECS-1 ne devrait pas avoir lieu avant la mi-1982, mais les progrès des travaux d'intégration et d'essais en cours pourraient permettre de procéder à un lancement avant cette date si le planning des lancements Ariane l'exigeait.

La fabrication d'ECS-2 avance normalement, mais les répercussions exactes des modifications du planning de lancement et des modifications du moteur d'apogée sur les coûts du satellite sont toujours l'objet de négociations détaillées.

L-Sat

L'achèvement de la phase principale B2 au début de juillet a été suivi par le démarrage d'une phase relais destinée à durer jusqu'à ce que l'on donne le feu vert à la phase C/D.

Les objectifs de cette phase relais sont, d'une part, de maintenir la continuité des activités industrielles et de celles de l'Agence entre l'achèvement de la phase de définition et le démarrage de la phase de réalisation et, d'autre part, de poursuivre l'exécution des tâches essentielles qui sont critiques en matière de calendrier, afin d'éviter des répercussions négatives éventuelles sur la date de lancement de L-Sat 1 et sur le coût d'ensemble du programme.

En particulier, cette phase comprendra la négociation de la proposition industrielle de phase C/D, la poursuite des activités de définition détaillée et les travaux critiques en matière de calendrier au niveau équipement, y compris la conception détaillée et le montage sur table de l'équipement.

Les propositions relatives à la phase C/D ont été reçues et évaluées au cours de l'été, tandis que se poursuivaient des négociations à différents niveaux au sein de l'industrie et entre le contractant principal et l'ESA. Une opération de réduction de coût est actuellement en cours.

Il a été ultérieurement décidé que l'industrie soumettrait à nouveau en deux temps, en septembre et en octobre, pour la phase C/D, une proposition complète qui tienne compte des différents commentaires détaillés présentés par l'Agence à la suite de la première soumission, en vue de parvenir à un prix global réduit.

L'activité prolongée de soumission/ négociation exigera un étirement du calendrier de la phase relais, de sorte que l'on prévoit de reporter à la fin de novembre le démarrage de la phase C/D.

Météosat

Secteur spatial

Météosat-2 a été lancé par Ariane le 19 juin à 12 h 32 TU, avec le satellite indien Apple. Le lendemain à 4 h 49 TU, le moteur d'apogée a été mis à feu pour permettre au satellite d'atteindre une orbite où il était quasiment géostationnaire. Après avoir dérivé pendant un mois, Météosat-2 a atteint sa position finale à 0° de longitude. Le satellite a été ensuite déclaré opérationnel

ECS checkout equipment at Matra, Toulouse

Equipement de vérification d'ECS chez Matra à Toulouse

OTS

OTS, now well into its fourth year of orbital operation, continues to function satisfactorily with all on-board subsystems working well. Spacecraft temperatures are now dropping slightly, after reaching a seasonal peak around the summer solstice. There is still more than 30 kg of propellant left and the solar-array power continues to remain close to the highest predicted value. Consequently there is confidence that the satellite can be operated for a further two to three years.

The Stella and Spine experiments continue to operate satisfactorily, in particular the Spine link between Frascati and RAE (UK) is now in use on a daily basis. The Swedish stations are preparing to join the network.

Interim Eutelsat is conducting a wide range of tests and experiments. TDMA field trials form an important part of this activity in preparation for the ECS system.

Demonstrations of data and television transmissions to conferences and exhibitions are frequently conducted via OTS, while TV programmes continue to be regularly transmitted to Tunisia.

ECS

The testing of the first flight unit is continuing at Matra's facilities in Toulouse. The first full integrated-system tests and the special repeater tests have been completed. The preliminary results of the system tests have shown only very few problems and the repeater tests have shown excellent performance. Further structural modifications required to accommodate the apogee boost motor (Mage-2) are now being implemented prior to EMC testing and in preparation for the forthcoming mechanical (vibration) testing.

The launch of ECS-1 may not take place before mid-1982, but the progress of the current integration and testing might allow an earlier launch should this be required to assist Ariane launch planning.

The construction of ECS-2 is proceeding well, but the final impacts of the launch-planning changes and ABM modifications on satellite costs are still the subject of detailed negotiation.

L-Sat

Completion of the main Phase-B2 in early July was followed by the start of a Bridging Phase, intended to last until the go-ahead is given for Phase-C/D.

The objectives of the Bridging Phase are, on the one hand, to maintain continuity of industrial and Agency activities between completion of the Definition Phase and full commencement of the Development Phase, and, on the other to pursue essential schedule-critical tasks to avoid any adverse impact on the L-Sat 1 launch date and overall programme costs.

In particular, the current phase will include negotiation of the Phase-C/D industrial proposal, continuation of the detailed definition activities and on the schedule-critical work at equipment level, including detailed equipment design and breadboarding.

The Phase-C/D proposals have been received and evaluated during the summer, in parallel with negotiations at various levels within industry and between the prime contractor and ESA. A cost-reduction exercise is currently underway.

It has subsequently been agreed that industry will resubmit a consolidated Phase-C/D proposal in two stages during September and October, taking into account the various detailed comments raised by the Agency in response to the earlier submission, in order to reduce the overall price.

The extended bidding/negotiation activity will necessitate a stretching of the Bridging Phase timescale, and it is currently foreseen that the start of Phase-C/D will be postponed until the end of November.

Meteosat

Space segment

Meteosat-2 was launched by Ariane on 19 June 1981 at 12.32 h UT, together with the Indian satellite Apple. The apogee boost motor was fired at 4.49 h UT the following day, enabling the satellite to reach quasi-geostationary orbit. Meteosat-2 satellite reached its station at 0° longitude after a one-month drift period. The satellite was declared operational and routine operations were started on 11 August 1981 at 13.00 h UT.

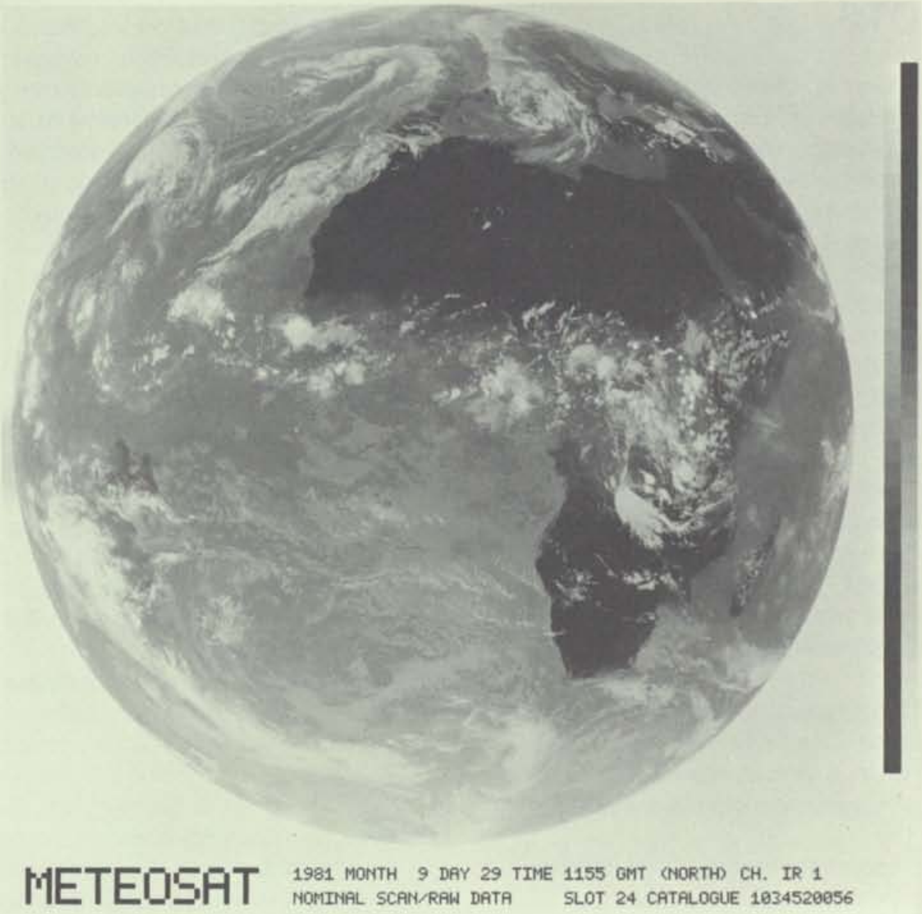
Imaging, dissemination and DCP (Data-Collection Platform) interrogation are working nominally, but so far it has not been possible to operate the satellite in its DCP reporting mode. This problem is

Module d'antenne d'ECS (unité de vol) avant intégration chez Matra à Toulouse

ECS antenna module (flight unit) prior to integration at Matra, Toulouse

Infrared image of the Earth's disc taken by Meteosat-2 at 11.55 GMT on 29 September 1981

Image infrarouge du disque terrestre prise par Météosat-2 le 29 septembre 1981 à 11.55 GMT



et a entamé sa phase d'exploitation de routine le 11 août à 13 h 00 TU.

La prise d'images, la diffusion des données et l'interrogation des plates-formes de collecte de données (DCP) fonctionnent normalement mais, jusqu'ici, il n'a pas été possible de faire fonctionner le satellite pour assurer la dernière fonction. Le problème est actuellement à l'étude. Entre-temps, Météosat-1 continue d'assurer sa mission de collecte des données.

Segment sol
Les travaux relatifs au remplacement du système de calculateur se poursuivent. Une configuration intérimaire du calculateur permet d'assurer la commande de Météosat-2, la prise d'images et la diffusion des données par l'intermédiaire du DATTS. Le soutien de Météosat-1 et de la mission DCP sont temporairement assurés par l'antenne prototype de PDUS, la station de Redu et un processeur principal.

Programme opérationnel
Les préparatifs de la prochaine session de la Conférence intergouvernementale prévue pour la fin de l'année se poursuivent.

Sirio-2

Le modèle de vol du satellite Sirio-2 a été intégré. Les essais électriques se sont achevés avec succès et le satellite sera soumis prochainement aux derniers essais de recette (vibrations et essais thermiques sous vide).

Les installations de contrôle et de commande du satellite à Fucino ont atteint les derniers stades de l'assemblage et des essais de recette.

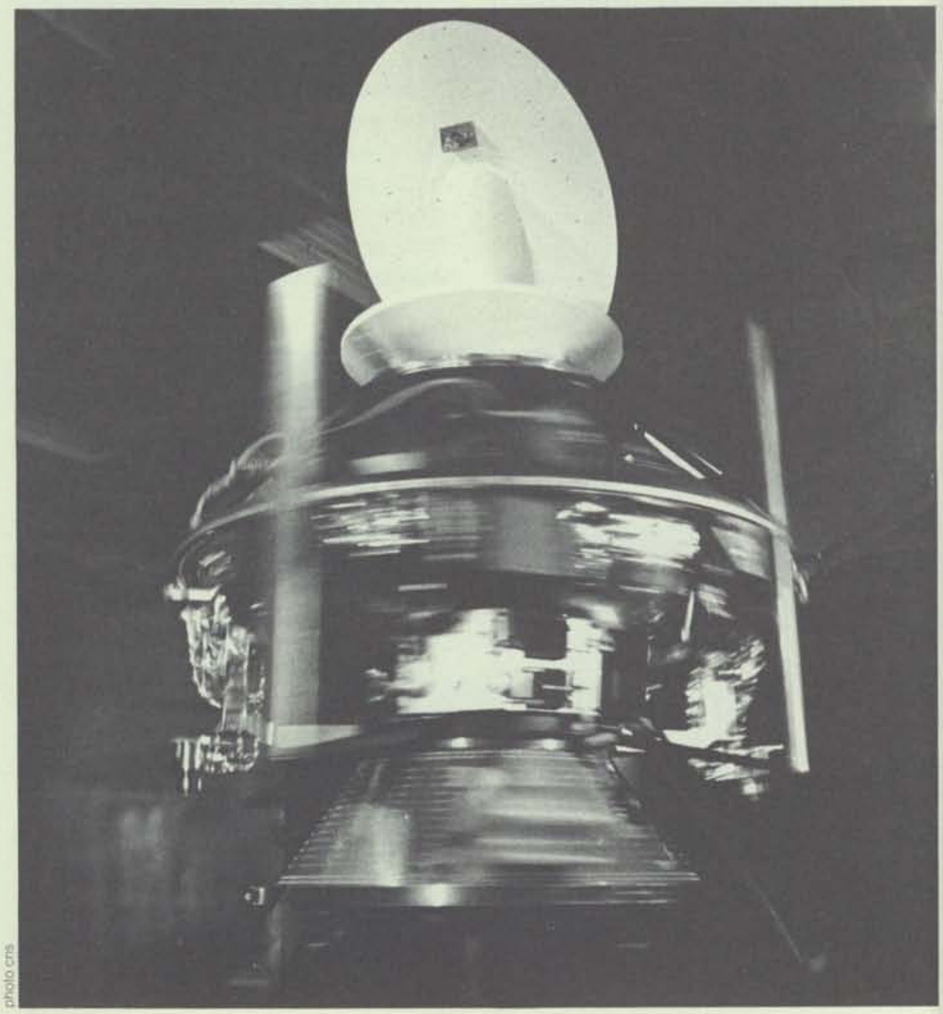


photo cns

Sirio-2 spin test, with the spacecraft's mechanically despun antenna at rest

Essai de rotation de Sirio-2 avec antenne contrarotative au repos

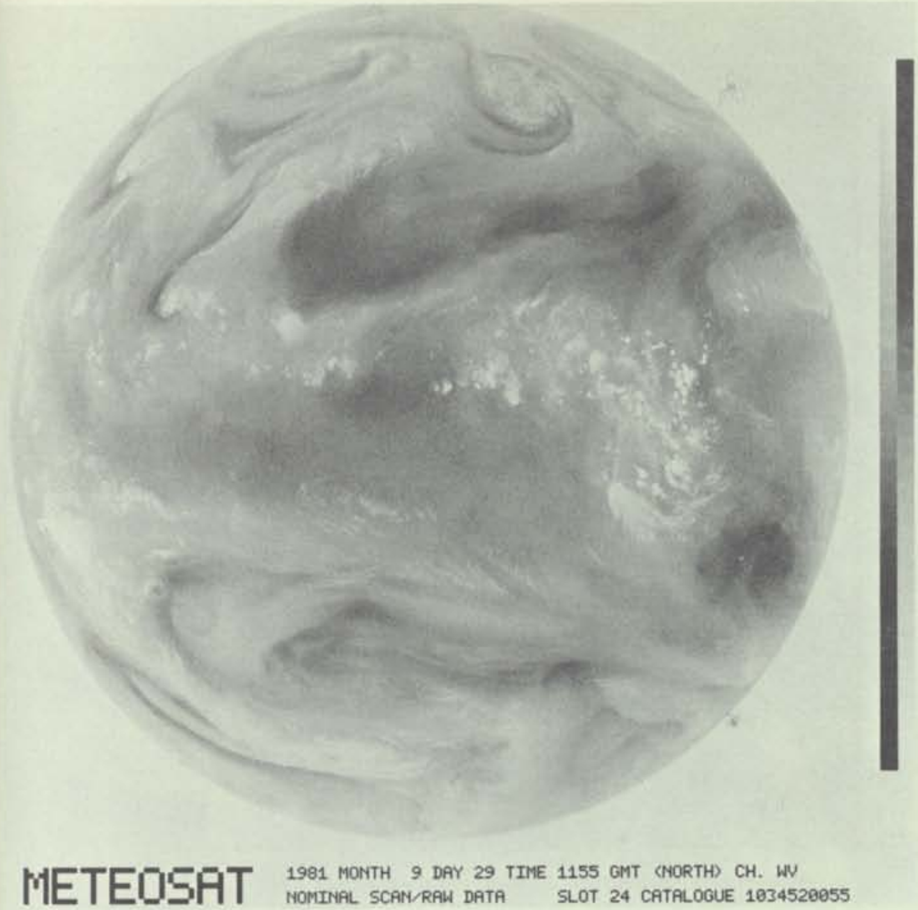


Image de Météosat-2 prise dans la bande d'absorption de la vapeur d'eau le 29 septembre 1981 à 11.55 GMT

Water-vapour channel image of the Earth's disc taken by Meteosat-2 at 11.55 GMT on 29 September 1981

being investigated and in the meantime Meteosat-1 continues to carry out this data-collection mission.

Ground segment

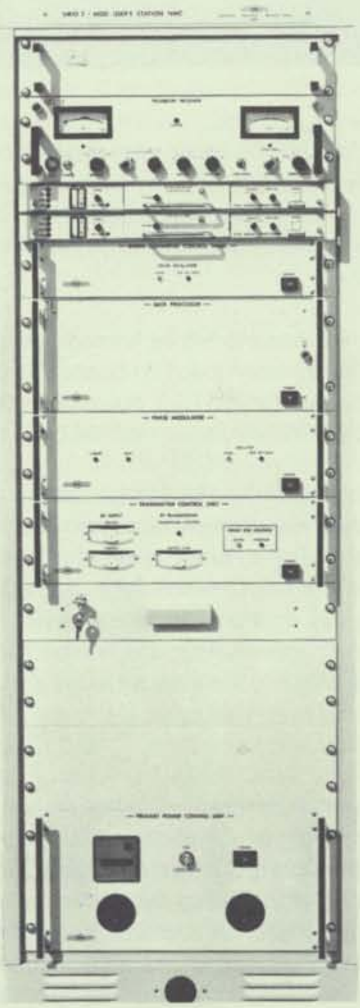
Work is continuing on the replacement of the computer system. An interim computer configuration is supporting Meteosat-2 spacecraft control, the imaging, and dissemination through the DATTS. Meteosat-1 and the DCP mission are temporarily being supported via the prototype PDUS antenna, the Redu station, and one back-end computer.

Operational programme

Work is continuing in preparation for the next session of the Intergovernmental Conference, scheduled for the end of the year.

Eléments d'une station typique de dissémination de données météorologiques (antenne et baie microprocesseurs)

Elements of a typical Sirio-2 meteorological data-distribution (MDD) user station (antenna and microprocessor rack)



Sirio-2

The flight model of the Sirio-2 satellite has been integrated, electrical tests have been successfully completed, and the satellite will be submitted to final acceptance tests (vibration and thermal vacuum) in the near future.

The satellite monitoring and control facilities at Fucino are in the final stages of assembly and acceptance testing. Three African sites, namely Brazzaville, Nairobi and Tananarive, have been nominated by ESA in collaboration with the World Meteorological Organisation (WMO) to accommodate the three prototype MDD stations during the two-year exploitation campaign. At the same time, consolidation of the Lasso exploitation scenario is progressing well.

Remote Sensing

The SAR 580 campaign started in early June and was completed on 24 July. It is still difficult to assess the value of the data that have been collected, but more than 80% of the foreseen experiment data have been acquired and are now being processed optically and digitally.

Trois sites africains, à savoir: Brazzaville, Nairobi et Tananarive, ont été désignés par l'ESA en collaboration avec l'OMM pour recevoir les trois stations prototypes MDD pendant la campagne d'exploitation d'une durée de deux ans. Parallèlement, la mise au point du scénario d'exploitation de Lasso progresse de façon satisfaisante.

Télédétection

La campagne SAR-580 a commencé au début de juin et s'est achevée le 24 juillet. Il est difficile actuellement d'évaluer la valeur des données qui ont été recueillies mais plus de 80% des données expérimentales prévues ont été collectées et sont actuellement l'objet d'un traitement optique et numérique.

La proposition de programme pour ERS-1 (satellite de télédétection de l'ESA) a été présentée au Conseil directeur du programme de télédétection (PB-RS) les 23 et 24 juin. Le coût total du programme dépassant les ressources financières de certains des Etats qui envisagent d'y participer, on a entrepris un exercice de réduction de coût pour atteindre un chiffre susceptible d'être accepté par toutes les délégations. Une nouvelle réunion du PB-RS aura lieu le 17 septembre, réunion à laquelle sera présentée une proposition révisée du programme.

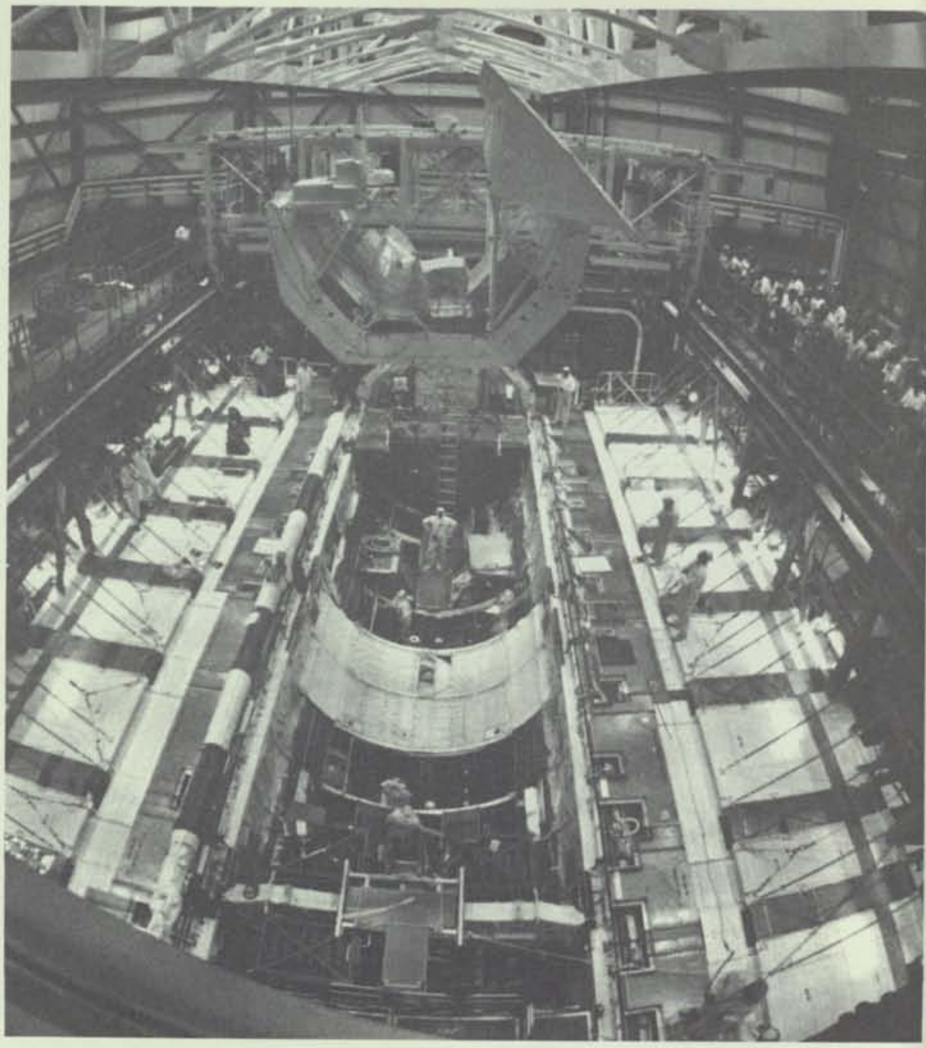
Parallèlement à la révision de la proposition de programme, la préparation de l'appel d'offres se poursuit.

Le programme préparatoire de télédétection approche de sa fin (décembre 1981) et plus de 80% des activités ont été terminées.

Spacelab

Le modèle technologique du Spacelab a été livré au Centre Spatial Kennedy en décembre 1980. L'équipement électrique de soutien au sol (EGSE), le logiciel de vol et le matériel de servitude au sol ont suivi en juillet 1981.

Le premier élément du Spacelab à être embarqué sera un modèle technologique de porte-instruments qui a été installé dans la Navette Columbia en vue de son lancement prévu pour le 9 octobre 1981. Ce porte-instruments devait emporter la charge utile OSTA-1 à cinq expériences et rester dans l'espace un peu moins de cinq jours. Le poids total du porte-instruments et des expériences est de 2542 kg.



Integration of the Spacelab orbital flight test (OFT) pallet with the OSTA-1 payload to be carried on the second Space Shuttle flight

Intégration du porte-instruments d'essai en orbite à la charge utile OSTA-1 destinée au deuxième vol de la Navette spatiale

Le deuxième modèle technologique du porte-instruments doit en principe être embarqué sur le STS-3, troisième essai en vol de l'Orbiteur, en janvier 1982.

L'accroissement des charges de l'Orbiteur a nécessité des renforcements de structure du matériel de vol, d'où une modification du calendrier d'intégration et d'essais. Toutes les modifications nécessaires pour les bâtis, le plancher du module et le cône du module ont été définies et sont en cours de mise en oeuvre.

L'examen de recette définitive du premier modèle de vol de Spacelab (SL-1) est désormais fixé à novembre, l'expédition au KSC étant prévue pour la fin de l'année. Cet envoi comprendra la section principale et les sections expérimentales du modèle de vol, le centre de contrôle complètement équipé et ses bâtis d'établis, ainsi que le sas.

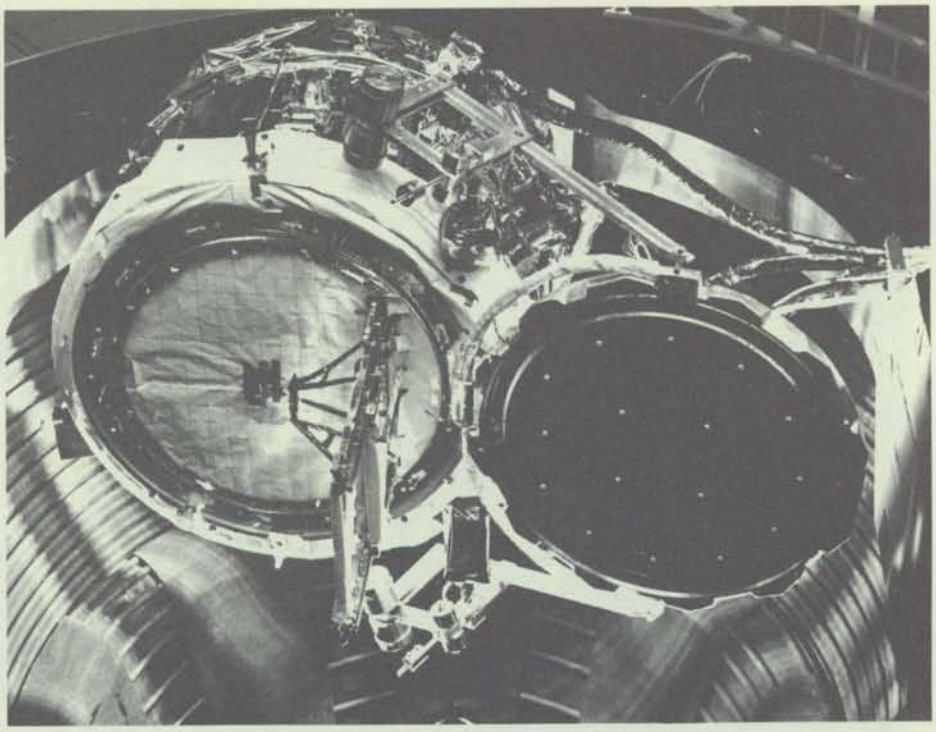
La livraison de la deuxième unité de vol, comprenant uniquement des porte-instruments et un igloo, est prévue pour mai 1982.

La révision par la NASA des conditions de charge a entraîné une modification de la conception du système de pointage d'instrument (IPS). Le maître d'oeuvre a, en outre, pris l'initiative de modifier certains des arrangements concernant les sous-traitants. L'offre à prix forfaitaire couvrant le système de pointage d'instrument modifié est attendue pour le 28 septembre 1981.

The ERS-1 (ESA Remote Sensing Satellite) programme proposal was presented to the Remote-Sensing Programme Board (PB-RS) on 23 and 24 June. As the total programme cost exceeded the financial resources of some of the Member States that intend to participate, a cost-reduction exercise has been performed to reach the target figure that is likely to be accepted by all Delegations. A further meeting of the PB-RS will take place on 17 September during which a revised programme proposal will be presented.

The preparation of the Call for Tender is continuing in parallel with the programme-proposal revision.

The Remote-Sensing Preparatory Programme is reaching its end (December 1981) and more than 80% of the activities have been completed.



Essai du modèle de vol du hublot du Spacelab dans la Chambre de simulation spatiale HBF-3 de l'ESTEC

Spacelab airlock (flight model) under test in the HBF-3 facility at ESTEC

Spacelab

The Spacelab engineering model was delivered to Kennedy Space Centre (KSC) in December 1980. The Electrical Ground Support Equipment (EGSE), flight software and services followed in July 1981.

The first Spacelab component to fly, an engineering-model pallet, has been fitted into the Columbia ready for the next launch from KSC. This pallet carries the OSTA-1 payload, comprising five experiments, and will stay in space for a little more than five days. The total weight of pallet and experiments is 2542 kg.

The second engineering-model pallet is scheduled to fly on STS-3, the third Orbiter test flight, in January 1982.

Higher Orbiter loads have required some structural reinforcement of the flight hardware, necessitating a change in the integration and test schedule. All necessary modifications for the racks and the module floor and the module end-cone have been determined and are being implemented.

The final acceptance review for the Spacelab flight unit (SL-1) is now scheduled for November, with delivery to KSC by the end of the year. This shipment will include the flight-unit core and experiment segments, the completely equipped control centre and workbench racks, and the airlock.

The planned delivery date for the second flight unit, comprising pallets only and igloo, is May 1982.

The revised NASA loads led to a need to redesign the Instrument Pointing System (IPS). In addition a change in the subcontractor arrangements has been initiated by the prime contractor. The fixed-price offer for the adjusted IPS programme is due by 28 September 1981.

FSLP

NASA has confirmed that modifications considered for the TDRSS satellite will not be carried out and that consequently the full data-relay capability will be available for the Spacelab-1 mission, enabling full operation of all experiments to be included in the flight operations. The launch date, previously foreseen for June 1983, has now moved to September 1983.

The European integration continues to make good progress at Bremen. Seven pallet instruments have been installed and tested, and similarly seven module instruments have been integrated. The Spacelab racks delivered to SPICE have now been reinforced to withstand the latest Shuttle loads, and integration of the rack equipment can proceed unimpeded.

Delivery of several major instruments is expected in the period September – October 1981.

The experiment 1 ES 332, formerly using acetonitrile as a medium for crystal growth, has had two non-toxic compounds approved as replacements by the NASA safety authorities. Development will now proceed using the non-hazardous material. The instrument hardware has successfully passed the interface tests at Bremen.

The 7th Investigator Working Group meeting of all experimenters involved in the First Spacelab Payload (FSLP) was held at Stirling University, Scotland from 1 to 3 September. The agenda of the meeting included a review of the programme, flight-operations questions, and other items such as the payload-specialist designation procedure. The meeting was attended by more than 100 scientists from Europe, the US and Japan as well as ESA and NASA project staff.

FSLP Investigator Working Group Meeting at Stirling University (UK) in September.

Réunion du Groupe 'Chercheurs' FSLP à l'Université de Stirling (R-U) début septembre.

FSLP

La NASA a confirmé que les modifications que l'on envisageait d'apporter au satellite TDRSS n'auraient pas lieu et que par conséquent on disposera de la pleine capacité de relais des données pour la première mission du Spacelab, ce qui permettra un fonctionnement intégral de toutes les expériences qui feront partie des opérations de vol. La date de lancement, initialement prévue en juin 1983, a été reportée à septembre 1983.

L'intégration en Europe continue de progresser de façon satisfaisante à Brême. Plusieurs instruments du porte-instruments ont été installés et essayés, et sept instruments du module ont été intégrés. Les bâtis du Spacelab livrés au SPICE ont maintenant été renforcés pour supporter les charges récemment spécifiées pour la Navette et l'intégration des équipements des bâtis peut se poursuivre sans entrave.

La livraison de plusieurs instruments importants est prévue pour la période septembre – octobre 1981.

L'expérience 1ES 332, dans laquelle il était précédemment prévu d'utiliser des acétonitriles pour la croissance de cristaux, a donné lieu à l'approbation, par les autorités de la NASA responsables de la sécurité, de deux corps non toxiques de remplacement. Les travaux de réalisation se poursuivent en utilisant des matériaux non dangereux. Le matériel des instruments a subi avec succès les essais d'interface à Brême.

La septième réunion du Groupe de travail 'Chercheurs' réunissant tous les expérimentateurs de la FSLP s'est déroulée à l'Université Stirling en Ecosse, du 1er au 3 septembre. L'ordre du jour de cette réunion comportait un examen du programme, des questions relatives aux opérations en vol et d'autres points comme la procédure de désignation des spécialistes 'Charge utile'. Plus de cent scientifiques venant d'Europe, des Etats-Unis et du Japon assistaient à cette réunion à laquelle participaient également des membres du personnel des bureaux de projet de l'ESA et de la NASA.

Le programme de formation à l'ESA

P. van Reyn, Département du Personnel, ESA, Paris

L'Article 14 du Statut de l'Agence spatiale européenne impose au Directeur général l'obligation d'élaborer 'un programme annuel afin d'assurer une formation continue du personnel; ce programme doit permettre d'une part de satisfaire les besoins de l'Agence dans l'ordre technique et administratif en utilisant le personnel de la manière la plus efficace et d'autre part, de développer les qualifications et le potentiel de chaque membre du personnel'.

En chiffres bruts, la formation du personnel à l'ESA s'est traduite par une progression de 68 500 UC en 1973 à 253 000 UC en 1980.

Ces chiffres illustrent une évolution constante du concept même de cette formation dont le tournant décisif s'est produit lorsque le nouveau Statut du Personnel, coïncidant avec l'institution de l'ESA, est entré en vigueur le 1er avril 1975.

Programmer la formation à l'Agence, organisation internationale de pointe, signifiait dès lors concilier la mise à jour constante de l'expertise de son personnel et la relative précarité de la situation du même personnel.

Au départ, on entendait par formation dans l'ESA, l'adaptation classique des connaissances et qualifications du personnel dans une grande variété de domaines:

- sciences de l'Espace et tous leurs développements récents;
- techniques spatiales: ingénierie des systèmes, stabilisation et contrôle d'attitude de satellites, cellules solaires, aéro-et thermodynamique, lasers, téléguidage, fibres optiques, calcul d'orbite, poursuite de satellites, météorologie, télédétection etc;
- droit international: négociation d'accords, contrats, propriété intellectuelle etc;
- informatique: logiciel, microproceseurs, systèmes de télé-informatique, calculateurs embarqués etc;
- gestion;
- secrétariat: direction, traitement de texte etc;
- cours de langues.

Programmer cette diversité en conciliant les intérêts de l'Agence et de son personnel, tel était donc l'objet de l'Article 14 du nouveau Statut. Certes, l'idée d'un programme de formation n'était pas nouvelle. On la retrouve dans les Statuts d'autres Organisations internationales et dès 1972, l'ESRO et l'ELDO avaient organisé une journée d'étude sur ce sujet avec des représentants des Communautés européennes, du CERN et de l'OCDE.

La conclusion essentielle et unanime de cet échange de vues était la difficulté, non pas tant de mettre en oeuvre un programme de formation, mais de le concevoir, systématiquement et dès le départ.

Comment l'employeur ESA a-t-il tenté d'assumer son rôle dans ce domaine au cours de la période 1975-1981? Quelles étapes ont marqué le processus de formation du personnel à l'ESA?

Première étape: prévision budgétaire
Cette étape a consisté à abandonner une pratique commune à bien des entreprises et organisations internationales, c'est-à-dire élaborer simplement pour l'exercice à venir un budget en fonction des dépenses de l'exercice précédent plus un pourcentage forfaitaire d'augmentation.

Pour échapper à cette routine, la solution idéale aurait été d'établir, dès le départ, les profils individuels qui constituent la panacée de tout programme de formation; on en retrouve des traces dans les législations nationales sur la formation; ils sont un des leitmotive des revendications des représentants du personnel.

Pour l'Agence, il aurait donc fallu dès 1975 établir 1500 profils individuels. Or un profil individuel de formation comporte au moins deux volets:

- les qualifications et le potentiel dont fait état l'intéressé lui-même;
- l'appréciation de la hiérarchie sur ces qualifications et sur ce potentiel, en relation avec la carrière possible de l'intéressé dans l'Agence.

Le premier volet est relativement simple à réaliser, bien que sa valeur soit assez subjective. Quant au deuxième volet, il relève de la divination tant que n'existe pas un programme de développement opérationnel de l'entreprise, assorti d'un minimum de précisions et de certitudes et couvrant un cycle de plusieurs années.

En conséquence, et par la force des choses, la première étape franchie à l'ESA s'avéra à la fois modeste et pragmatique. Elle a consisté à tenter de recueillir année par année, lors de la notation périodique, les souhaits des intéressés et les recommandations de leurs supérieurs. Le taux des réponses n'a jamais atteint 10% des notations! Quels qu'ils fussent, ces faibles résultats marquaient la première étape de l'établissement d'un véritable programme de formation à l'Agence; ils permettaient en effet de prévoir dans une certaine mesure les interventions nécessaires au cours de l'exercice budgétaire.

Le paradoxe fut que dès 1975, le nombre d'interventions de formation effectivement demandées en cours d'exercice a atteint 347, sans compter les cours de langues: la méthode empirique conserve malgré tout certaines vertus!

Deuxième étape: initiative du Directeur général

Dès la fin de 1975, le Directeur général avait exigé la mise en oeuvre d'un réel programme de formation, c'est-à-dire la prévision systématique par chaque Chef de Département, de toutes les actions individuelles à prendre au cours de l'exercice budgétaire suivant, dans le cadre d'un budget alloué à son personnel.

Ceci revenait en fait à combler, dans la mesure des crédits budgétaires, le vide constitué par les 90% dont nous avons parlé précédemment; et par une sorte d'acrobatie inversée, ceci permettait de chiffrer et de justifier les crédits budgétaires en question.

Pour inaugurer et lancer cette deuxième étape, un rapport avait été rédigé en novembre 1977, qui analysait les réalisations intervenues de 1974 à 1977 et formulait des recommandations pour l'avenir.

Ce rapport constatait le taux élevé des interventions de formation au cours des années précédentes, en comparaison avec les données obtenues d'autres organismes nationaux ou internationaux; il constatait aussi que tout le problème était de savoir si ce taux élevé répondait ou non aux exigences réelles de l'Agence et au développement du potentiel de son personnel.

A cet égard, le rapport concluait de manière significative que 'le but du Directeur général – à savoir une utilisation plus efficace des fonds alloués pour la formation – peut être atteint principalement par une modification dans la procédure d'établissement des programmes de formation annuels et par un changement radical de la mentalité de tous ceux qui sont intéressés par ce genre d'activités au sein de l'ESA'.

L'accent était ainsi mis sur la procédure et sur la mentalité de ceux qui devaient mettre en oeuvre le programme de formation; trois axes d'action étaient dégagés:

- une plus grande adaptation aux besoins de l'Agence;
- une procédure plus systématique et mettant davantage en oeuvre le dialogue;
- une meilleure utilisation des crédits prévus.

On retrouve ici la texture des deux volets des profils individuels, à la seule différence qu'au lieu de perspectives à moyen terme, il s'agissait toujours d'estimations limitées à une année.

Les efforts qui ont été faits dans ce cadre étroit se traduisent par la progression suivante (Tableau 1).

Tableau 1

	1977	1978	1979	1980
Augmentation des dépenses (%)	17	41	8,5	10
% de la masse salariale	0,33	0,7	0,7	0,8

Le bond en avant de 1978 résulte essentiellement du développement des cours internes dans les domaines de la gestion et dans les techniques utilisant l'expertise disponible à l'ESTEC et à l'ESOC. Cet exercice 1978 marque également le vrai début de l'élaboration d'un programme de formation selon la nouvelle procédure.

On relève d'autre part que durant les deux dernières années, 1979 et 1980, la masse des dépenses de formation est demeurée relativement stable compte tenu de la hausse des coûts. Il semble que l'on ait ainsi atteint le palier de 0,8% de la masse salariale qui constitue un taux remarquable.

La majorité des interventions a été accordée au titre de la catégorie I prévue par le Règlement, à savoir la formation estimée nécessaire à l'accomplissement des fonctions de l'intéressé, tandis que la

Figure 1 – Des cours de gestion sont organisés régulièrement à l'ESTEC à l'intention du personnel. (Ici: une séance de travail de groupe).

catégorie II présente un caractère plus facultatif et est laissée à l'initiative des bénéficiaires.

En réalité, les programmes qui ont été élaborés depuis 1975, et surtout depuis 1978, pour réaliser cette formation continue, prenaient pour cible des objectifs relativement nébuleux si l'on tient compte de la situation des projets et des budgets correspondants.

Mais le Règlement prévoit également une troisième catégorie d'interventions qui, elle, a trait au recyclage. Il s'agit d'un domaine bien plus critique d'actions 'à chaud', puisque cette fois il faut faciliter le reclassement de membres du personnel touchés par une suppression de poste. Ce reclassement doit s'opérer dans l'Agence ou en dehors de celle-ci; concernant du personnel forcé de quitter l'ESA, les interventions de formation ont laissé une certaine amertume. Aurait-on pu faire davantage? Aurait-on pu mieux planifier?

Troisième étape: révision fondamentale
En effet, malgré les progrès réalisés d'année en année, une nouvelle révision fondamentale de notre programme de formation s'impose; il faudra bien la réaliser en s'accommodant de la précarité des prévisions opérationnelles dont nous disposons.

Désormais, l'informatique sera mise à contribution par le Département du Personnel afin de privilégier d'une manière sélective et aussi statistique que possible, les actions individuelles à prendre, en tenant compte des qualifications et des aspirations du personnel ainsi que des interventions déjà obtenues, et enfin des perspectives telles qu'on peut les concevoir à l'heure actuelle, en inscrivant toutes ces données dans un cycle de trois à cinq années.

Une collaboration étroite avec les Directeurs et les Chefs de Département intéressés et avec les représentants du personnel sera indispensable pour lancer ce nouveau programme des années 1982/1983 et suivantes. Ce nouvel effort est impératif puisque la formation dans tous les sens du terme revêt une nécessité vitale pour l'Agence.

Conclusion
Peut-être ce qui vient d'être dit à propos du passé de l'ESA semble-t-il exagérément abstrait? Concrètement donc, la formation dans l'entreprise, étant une 'découverte' relativement récente, a connu depuis une vingtaine d'années un développement pour ne pas dire une vogue foudroyante dans les pays occidentaux. Pour l'employeur, l'obligation de formation y est devenue une charge légale d'une haute valeur morale; elle a ainsi permis des réalisations aussi efficaces que spectaculaires. Elle a également parfois constitué une ligne budgétaire des frais généraux singulièrement rentable, l'alibi de la mauvaise gestion du personnel, l'escapade touristique bonifiée au personnel méritant, le subterfuge des licenciements dits économiques, pour ne pas parler du dernier remède miracle contre le chômage.

En outre, la formation a engendré une prolifération d'organismes spécialisés; à côté d'institutions aussi vénérables que rigoureuses, se sont ouvertes de véritables 'auberges espagnoles' où l'apport est essentiellement le fait des participants eux-mêmes qui paient fort cher pour échanger leurs propres expériences dans des hôtels de grand luxe.

Pour l'ESA, Organisation internationale soumise à sa propre règlementation sur la formation, il a fallu échapper à tous ces travers et écueils qui guettent le secteur national et préserver ainsi le caractère original de notre programme de formation, en organisant nous-mêmes un grand nombre de cours et de colloques internes.

La troisième étape qui vient de s'ouvrir devra renforcer ce caractère original; elle mettra en oeuvre non seulement de nouveaux moyens d'information (catalogues, communications périodiques) et d'informatique (programmation sur la base de fiches individuelles) mais surtout une conviction renforcée à tous les échelons de la hiérarchie.

A ce prix, nous pourrons sans doute dans trois ou quatre années parler d'une quatrième étape.

Six Years of Gamma-Ray Astronomy with Cos-B

B.G. Taylor & R.D. Wills, Space Science Department of ESA, ESTEC, Noordwijk, Netherlands

ESA's Cos-B satellite has been operating in orbit for three times the duration foreseen when it was launched. This success, unprecedented in gamma-ray astronomy, coupled with the high standard of performance of the experiment, has resulted in a gamma-ray picture of the sky that was unforeseen in its detail and implication. Gamma rays have been detected from objects as diverse as molecular clouds, pulsars and quasars, while the Galaxy has been thoroughly mapped. The results are of fundamental importance to astronomers and cosmic-ray physicists alike and have demonstrated the great value of this relatively young branch of astronomy with such forcefulness that more powerful missions are planned within this decade.

Historical introduction

A series of feasibility studies aimed at selecting ESRO's (now ESA's) next scientific missions was concluded early in 1969. Two of these were alternative versions of a satellite for the study of cosmic gamma radiation, known as Cos-A (a joint X- and gamma-ray mission) and Cos-B (a gamma-ray only mission). Considerations by the scientific advisory bodies led to the elimination of Cos-A, and in July 1969 the Council formally approved Cos-B, together with Geos, as the next scientific programmes to be undertaken. Cos-B was the Organisation's first satellite dedicated to a single experiment, previous satellites being of the multi-experiment variety.

In May 1969 a group of five university and research institutes calling itself the Caravane Collaboration approached ESRO with a letter of intent proposing that they should jointly build the experiment conceived for the Cos-B satellite. In June 1970 one of the groups withdrew, since it was unable to obtain national funding, to be replaced by the Space Science Department, ESTEC. The other four members of the Collaboration (in alphabetical order of location) were:

- Max-Planck-Institut fur Physik und Astrophysik, Institut fur Extraterrestrische Physik, Garching bei München (D)
- Cosmic Ray Working Group, Leiden (NL)
- Laboratorio di Fisica Cosmica e Technologie Relative del CNR, Istituto di Scienze Fisiche, Università di Milano (I) (together with the Istituto Fisica, Università di Palermo (I))
- Service d'Electronique Physique, Centre d'Etudes Nucléaires de Saclay, Gif-sur-Yvette (F).

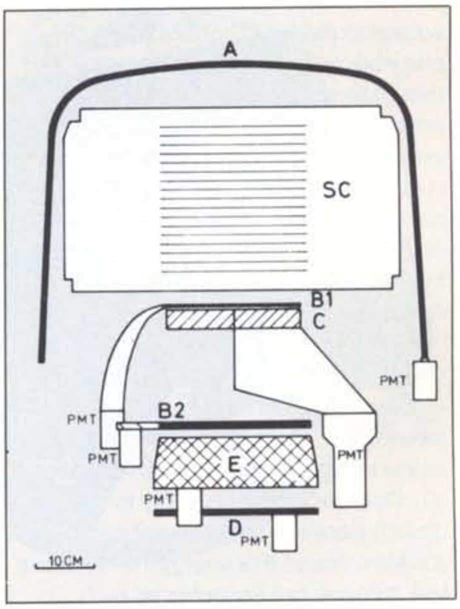
The Council approved the participation of the Caravane Collaboration in 1970. Following a competitive definition phase, the CESAR consortium, led by MBB as prime contractor, was selected in August 1971 for the Cos-B hardware development phase. A four-model satellite programme (conventional at that time) was followed, with the provision and testing of an engineering model, a prototype, a flight satellite and a flight spare. One notable event which occurred in April 1973 was the change of launch vehicle from Europa-II to Delta-2913.

Cos-B was launched from the Western Test Range, California, at 0147 h (GMT), 9 August 1975 and has provided scientific data since the start of routine operations on 17 August 1975. At that time the planned duration of the mission was two years, but the early scientific achievements were such as to warrant continuation of operations for longer. In the absence of significant degradation or failure in the spacecraft and payload subsystems, the mission has been extended several times and it is now foreseen that scientific measurements will continue into the first half of 1982, until the spark-chamber gas is exhausted.

Scientific objectives

Since the discovery of cosmic rays at the beginning of this century their origins and acceleration mechanisms have been the source of much theoretical speculation and experimental endeavour. Cosmic rays

Figure 1 – Sectional view of the Cos-B experiment



are composed mainly of protons together with other atomic nuclei and electrons. All are very energetic, with observed energies ranging from 10^9 electronic volts (eV) up to some 10^{20} eV, energies far beyond those generated in particle accelerators. They may be produced in part by explosive events (supernovae) and may be accelerated by stochastic processes (Fermi mechanism) and in, or near, exotic objects. Certainly cosmic rays will interact with the interstellar medium and with low-energy starlight and microwave photons to produce gamma rays observable in the range above 30 MeV. Since gamma rays are able to pass through the interstellar medium with little attenuation and are undeflected by electric or magnetic fields, study of the sky in the light of gamma rays may reveal the sources and distribution of cosmic rays, the distribution of matter and photon fields in the Galaxy and, through the study of spectra, the nature of the production mechanisms.

Gamma-ray astronomy is one of several branches of astronomy which can only be conducted from outside the Earth's atmosphere because the latter is transparent only in limited wavelength ranges. In this case an additional difficulty arises from the intense background of high-energy gamma rays which are generated in the atmosphere itself by interactions of incident cosmic rays. Even at the latitudes reached by scientific balloons this background is strong enough to mask all but the brightest sources of extraterrestrial gamma rays.

When the Cos-B mission was approved in 1969, a limited number of experiments had been flown on high-altitude balloons and in satellites as a first step in the investigation of the electromagnetic spectrum above 30 MeV. Perhaps the most significant data had been recovered from an experiment on NASA's OSO-III which identified the enhancement of gamma radiation from the galactic plane (the Milky Way) and especially from the galactic centre. Two other missions were due to be carried out during Cos-B's development phase, namely experiment S-133 on ESRO's TD-1 satellite (launched March 1972) and NASA's SAS-2 (launched November 1972). It was anticipated that the observation programme of Cos-B would be much influenced by the results from these missions, but S-133 suffered severely from particle-induced background, while SAS-2 operated for only seven months before a power-subsystem failure caused premature termination of the mission.

The major objectives of gamma-ray astronomy have changed little since Cos-B was conceived and may be broadly subdivided as follows:

- Measurement of the large-scale galactic emission
- Investigation of diffuse emission at high galactic latitudes
- Study of the local galactic emission
- Search for gamma rays from radio pulsars
- Search for extragalactic gamma-ray sources
- Search for galactic gamma-ray sources
- Investigation of variability of sources.

The experiment
Gamma rays with energies above about 20 MeV can be detected indirectly following their interaction with material in which they convert to two electrons (one positively charged, the other negatively) which share unequally the energy of the incident gamma ray. The electrons travel in essentially the same direction as the incoming gamma ray, and since they are charged and thus able to produce ionisation along their paths through a gas, their directions can be measured. Their energy, essentially the energy of the incoming gamma ray, can be measured through total absorption.

Figure 1 shows a schematic cross-section of the Cos-B experiment central detector package. The heart of the experiment is the spark chamber (SC) which is filled with neon and a small percentage of ethane to a pressure of 2 bar. Sixteen pairs of wire grids define 16 gaps, between the upper 13 of which 12 thin tungsten sheets measuring 24×24 cm^2 are placed to provide the gamma-ray conversion material. The electron pair passes through the gas and tungsten plates below the point of conversion. A high voltage of several kV applied across the pairs of grids within a microsecond causes spark discharges to occur along the ionisation trails, thereby marking the tracks of the electrons. The discharges draw currents through those grid wires that cross the tracks and the currents 'set' magnetic cores threaded on the ends of the wires, thereby recording the information for subsequent interrogation by the experiment electronics.

The field of view of the experiment is defined by the triggering telescope, a stack of scintillation (B1/B2) and Cherenkov (C) counters, located below the spark chamber. Light signals generated in these counters by passing electrons are detected by photomultiplier tubes. Due to the directional properties of the Cherenkov counters, only particles moving in a downward direction are accepted. Simultaneous detection of signals in B1, C and B2 causes the high-voltage pulse to be applied to the spark-chamber grids. The spark chamber and telescope are screened with an anticoincidence scintillation counter (A) viewed by nine photomultipliers. If this counter detects a signal in time coincidence with the telescope, indicative of the passage of a charged cosmic ray, triggering of the spark chamber is inhibited.

On leaving the triggering telescope, the electron pair enters the energy calorimeter, which consists of a caesium-iodide crystal (E) and a plastic scintillator (D). Detector E has the ability to totally absorb electrons up to an energy of some 300 MeV. Above this energy the electrons leak through but are detected by D.

Associated with the central detector, and constituting a significant part of the experiment, is the signal-processing and data-handling electronics. In addition, a small X-ray detector, known as the pulsar synchroniser, is included to allow time correlation of X- and gamma-radiation from sources. A set of electronics to detect and measure the time profiles of cosmic gamma-ray bursts (photon energies of about 100 keV) interacting in the anticoincidence detector is also provided.

One of the major preoccupations prior to launch concerned the ability of the instrument to reject charged-particle interactions which might simulate the detection of a genuine cosmic gamma ray. This was the more serious due to the orbit not being close to the Earth, where the detector would be screened from the background radiation by the Earth's magnetic field, and due to the low data rate. Given that a typical spark-chamber trigger may generate some 1000 bits of data, any serious underestimate of the trigger rate due to background-induced events would have been catastrophic. This preoccupation was one reason for the very comprehensive calibration programme, in which the engineering model of the payload was exposed to particle beams produced by accelerators at DESY (Hamburg), CERN (Geneva) and Neuherberg and to atmospheric gamma rays and cosmic rays in a high-altitude balloon flight from Sioux City (USA). The flight model was also tested and calibrated at DESY and CERN. With thresholds and triggering configurations chosen on the basis of these tests, the background trigger rate in orbit of about $0.2\,s^{-1}$ was close to predictions, while the careful calibrations to determine the instrument's response functions have been crucial in the analysis of the orbital data.

Figure 2 shows the characteristic parameters of the experiment for paraxial incidence of gamma rays. The sensitive area reaches a maximum of about 50 cm² at an energy of some 500 MeV. The

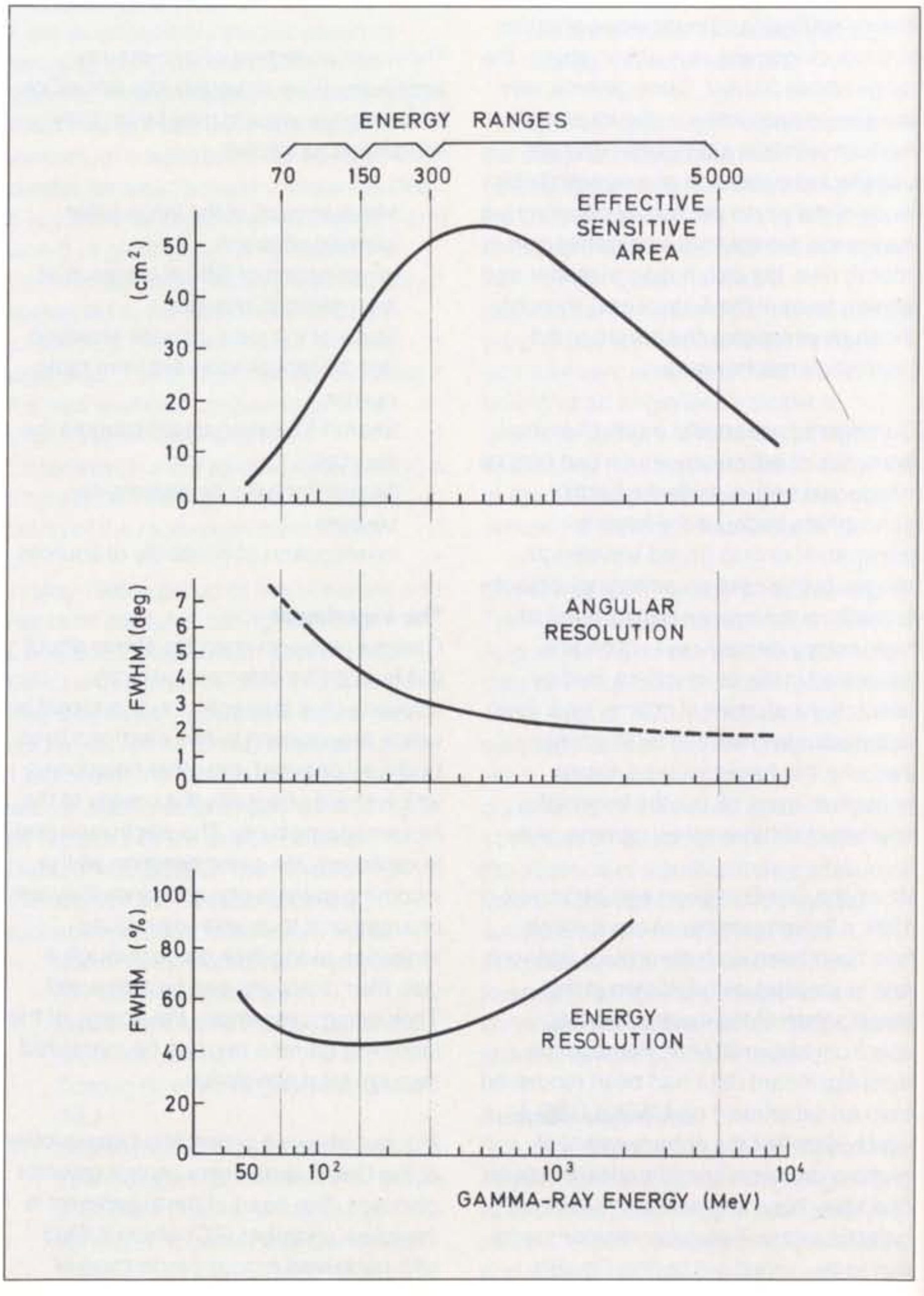
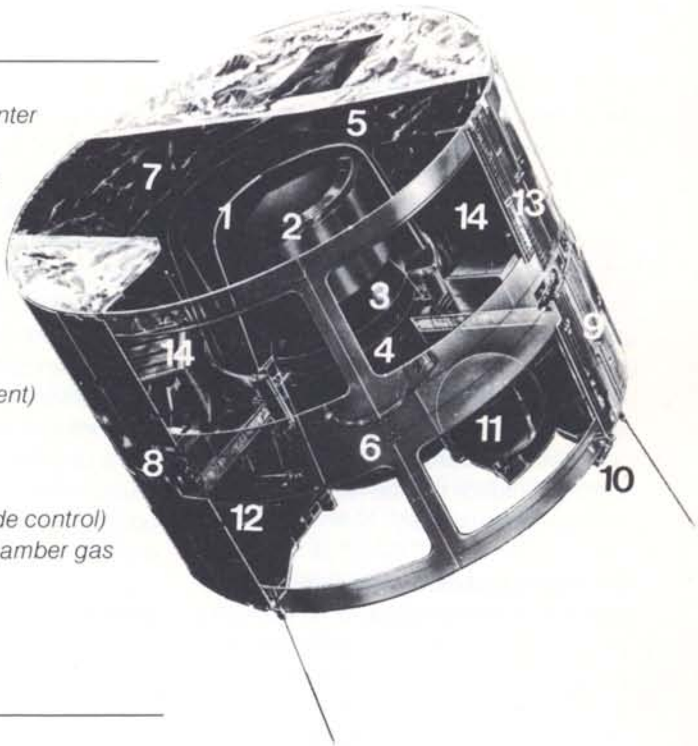


Figure 2 – Effective sensitive area, angular resolution and energy resolution of the Cos-B gamma-ray detector for gamma rays incident parallel to the experiment axis and satisfying the selection requirements applied in the analysis

Figure 3 – Sensitive area versus angle of incidence with respect to the experiment axis for the data-selection requirements applied in this analysis. The three curves refer to the geometric means of the energy ranges indicated in Figure 2

Figure 4 – Cutaway view of the Cos-B satellite:

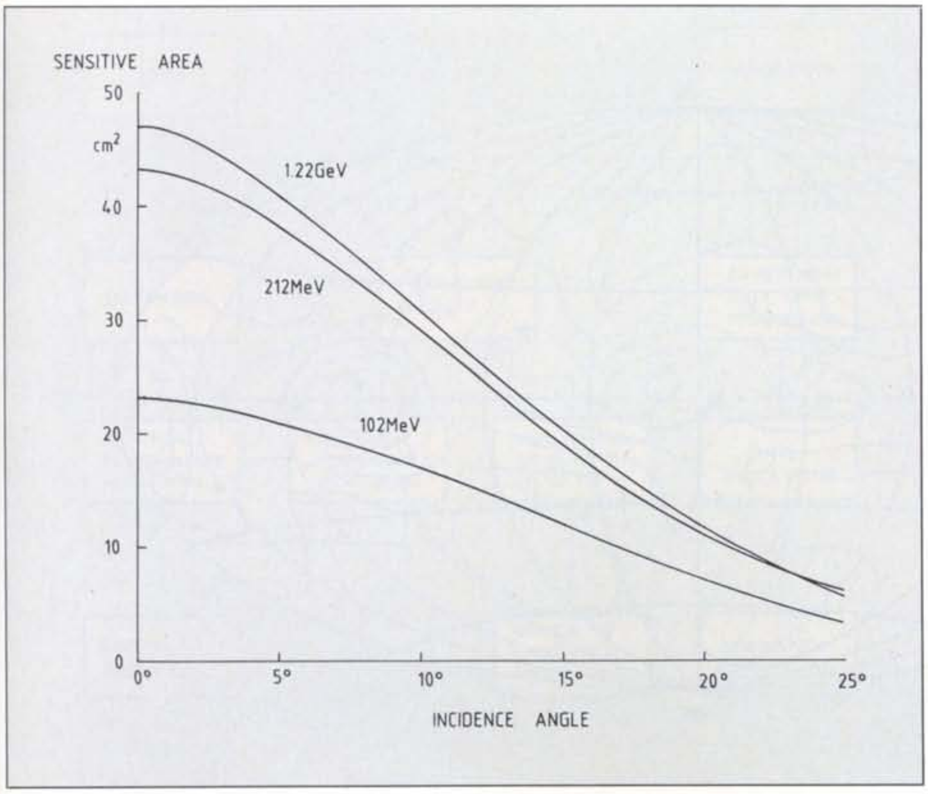
1. *Anticoincidence counter*
2. *Spark chamber*
3. *Triggering telescope*
4. *Energy calorimeter*
5. *Pulsar synchroniser*
6. *Structure*
7. *Superinsulation*
8. *Sun- and Earth-albedo sensors (attribute measurement)*
9. *Spin thruster*
10. *Precession thruster (attitude control)*
11. *Nitrogen tank (attitude control)*
12. *Neon tank (spark-chamber gas flushing)*
13. *Solar-cell array*
14. *Electronics*



angular resolution shown is derived from beam calibrations and confirmed by in-orbit observation of the strongest gamma-ray point source, the Vela pulsar. The best energy resolution of some 40% FWHM is achieved at about 100 MeV. The dependence of the sensitive area on incidence angle is shown in Figure 3. The majority of the scientific results have been derived from measurements within a cone of half angle of 18°.

The satellite and its orbit

If for no other reasons than budgetary considerations and reliability, the Cos-B satellite had to be simple in concept, within the state of the art and capable of being launched by a Europa-II or Thor-Delta vehicle into the desired orbit. An initial eccentric orbit with 100 000 km apogee, 90° inclination and 335° argument of perigee was chosen. This orbit permitted long uninterrupted observation periods, imposed few constraints on the coverage by the experiment on the celestial sphere, suffered little or no effect from the atmospheric gamma-ray albedo, and permitted real-time data recovery during most of the orbit from the ESRO ground stations so that no on-board tape recorder was required. The disadvantages of the orbit are the limited telemetry rate (via VHF at 320 bit/s maximum), traversal through the Van Allen radiation belts every orbit reducing the on-time to 30 h of the 37 h orbital period and exposure of the experiment to the high and variable intensity of low-energy cosmic rays and solar particles which raises the background counting rate and dead-time.



The satellite is cylindrical, 1400 mm in diameter and 1130 mm long, with the main experiment package occupying the central region (Fig. 4). The pulsar synchroniser is mounted on the equatorial equipment platform with its optical axis parallel to that of the main experiment. All experiment electronics units and spacecraft subsystems are mounted on the upper or lower surface of this platform in order to minimise the amount of material in the field of view and to reduce the probability of the experiment's being triggered by background-induced charged-particle interactions in these units. The total mass

Figure 5 – Relative sky coverage between 17 August 1975 and 7 September 1981 (galactic coordinates). The contour intervals are chosen to indicate the number of times a given direction has been observed within 20° of the pointing direction. Crosses indicate pointing directions

at launch was 278 kg of which 118 kg was contributed by the experiment units. The total power requirement was 60 W, of which 25 W was for the payload.

The satellite is spin-stabilised at about 10 rpm about its axis of symmetry, which coincides with the optical axis of the gamma-ray detector. A simple nitrogen-gas attitude-control system is used to point the experiment in the desired direction. Sun and Earth sensors are used for attitude measurements, from which the pointing direction can be reconstituted with a precision of 0.5°.

Operations and data processing

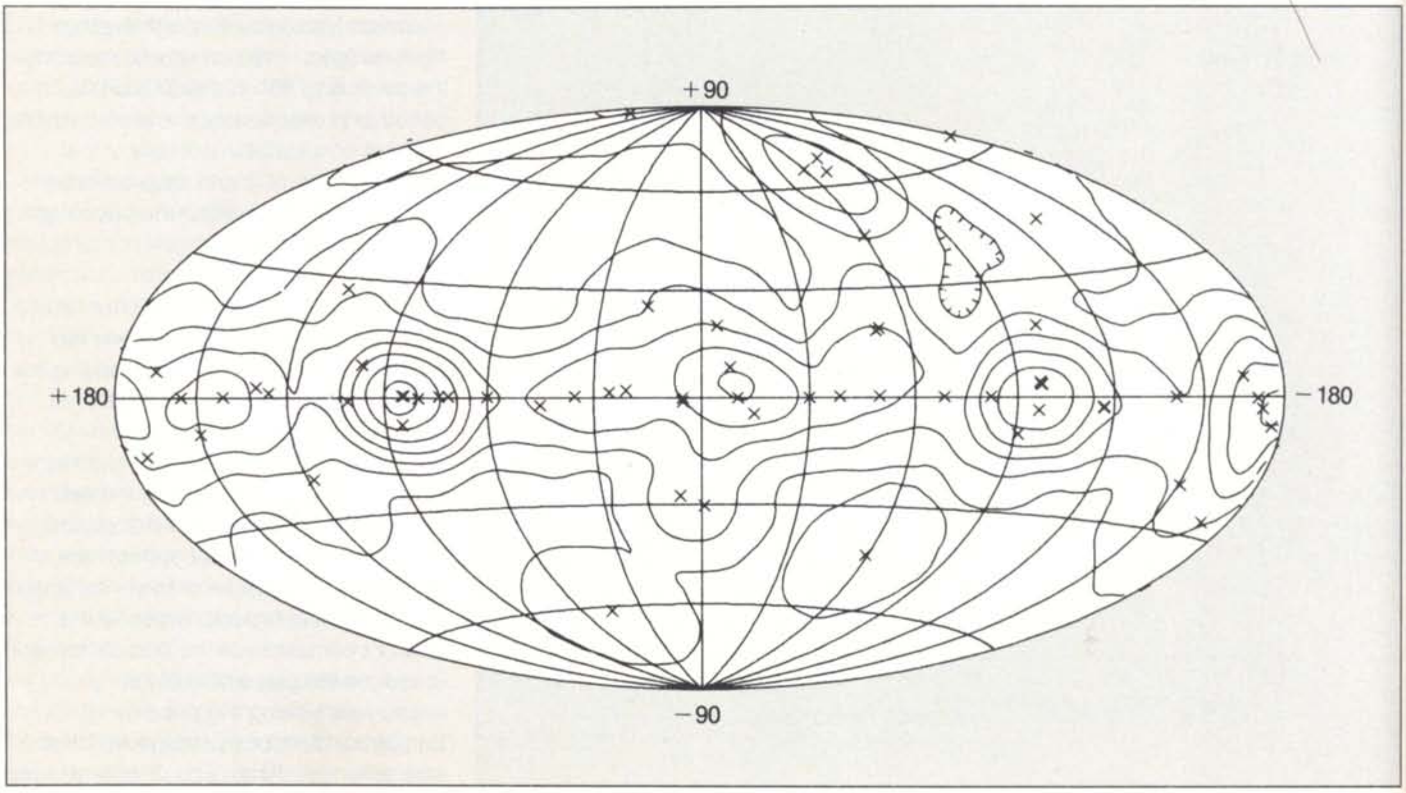
Observation programme

The choice of target for observation at any given time is constrained by the requirement that the solar array be illuminated and that the attitude-measurement sensors view the Sun and the Earth. The sky is observed by maintaining a fixed pointing direction for about one month during which data are accumulated from a circular field of about 25° radius. Special emphasis has been given in the observation programme to a comprehensive scan of the Milky Way. In addition, about a third of the time has been devoted to observations at higher galactic latitudes, especially in regions containing specific objects of general interest, such as radio pulsars, quasars and Seyfert galaxies. Scheduling of observations takes account of scientific priorities and, where possible, the known plans of other satellite, balloon or ground-based astronomy experiments. The sky coverage achieved up to September 1981 is shown in Figure 5.

In-orbit performance

Because the photomultipliers would be damaged if they were operated during passages through the Earth's radiation belts, the experiment high-voltages are switched off during that part of the orbit. Thanks to the choice of orbit, this falls within the interval when data acquisition is not possible. Every third orbit, about 45 min is devoted to calibration of the detectors. For this purpose, use is made either of cosmic-ray protons by relaxing the anticoincidence requirement in the event-selection logic or of an in-flight-test system with electronic stimulation and light-emitting diodes. Every sixth orbit, a calibration of the pulsar synchroniser is made using an ^{241}Am-Sr target source. The intervals between these various calibrations were initially shorter, but they have been increased in the light of the demonstrated stability of the detector performance.

For gamma-ray measurements, the experiment event-selection logic is operated in the 'narrow-angle' mode, i.e. triggers are accepted only if a coincidence is registered between any one quarter of the C counter and the corresponding quarter of the B2 counter. This mode was found during the pre-launch investigations to provide a reduced probability of triggering on locally-induced background without



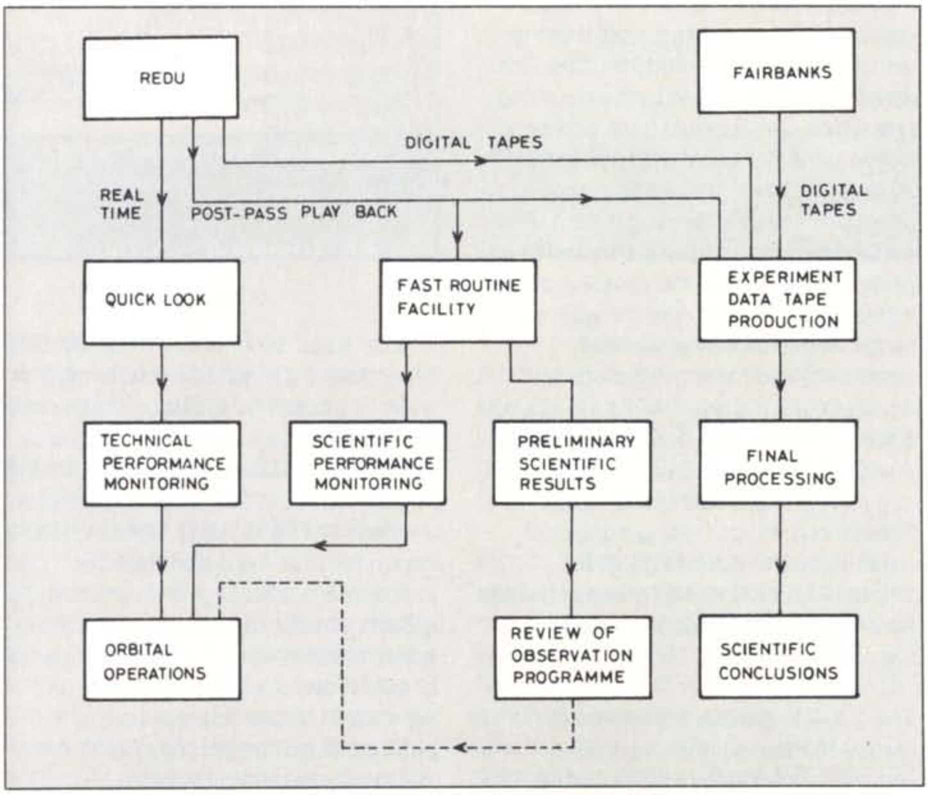


Figure 6 – Overall flowchart of data processing

seriously restricting the efficiency for recording good gamma rays. Although many background triggers are still registered, their rate is not so high that the time taken to transmit them will significantly reduce the observation time. Genuine gamma-ray events are separated from the background during the analysis of the data.

Continued satisfactory operation of the spark chamber during the long mission was made possible by equipping the satellite with a gas-flushing system for emptying and refilling the chamber. This has been used to forestall progressive deterioration of performance due to poisoning of the gas. As the rate of deterioration has decreased with time, it has proved possible to increase the interval between flushings from its initial value of 6 weeks to about 14 weeks.

Several anomalies in the measurements of certain housekeeping channels which were recognised soon after launch were quickly found not to be indicative of any malfunctions. However, an excessive counting rate in the anticoincidence-counter ratemeter did result in the threshold for gamma-burst detection being significantly higher than foreseen. This effect, whose origin remains unknown, got worse with time and after about six months in orbit it was recognised that fulfilment of this part of the mission was no longer possible. Unfortunately during the period when timing information could have been provided for triangulation of gamma-burst sources, none of these rare events were recorded by other spacecraft.

Less than nine months after launch one of two redundant relays in the 5 V power line failed. Since that time the satellite has operated with the alternate relay and the operations plan was modified to reduce its use. In the payload one of the nine photomultiplier tubes of the anticoincidence counter failed during launch and another failed after 29 months of operation. On both occasions it was possible to restore the performance of the instrument by compensatory increases in the high voltage on the remaining photomultiplier tubes. At other times alterations to the configuration of the electronics were made to correct for drifts in the performance of some experiment units.

Data acquisition and processing

Experience has shown that the satellite telemetry system can be operated at the maximum bit rate of 320 bit/s without significant loss of data quality. During the part of the 37 h orbit that the experiment is switched on (initially about 30 h) data are recovered by one of the Estrack ground stations at Redu (Belgium), and until August 1977 at Fairbanks, Alaska. Following closure of the Fairbanks station data acquisition has been about 25 h per orbit. All data are recorded in the ground station on digital magnetic tapes which are despatched at regular intervals to the Operations Centre (ESOC) in Darmstadt (Germany) where they form the basis of the final data processing. In addition, data recorded at Redu can be transmitted directly to ESOC, either in real time or, by playing back the digital tape, at the end of a pass. Real-time data are used for monitoring the correct functioning of spacecraft and experiment subsystems, especially during telecommanding operations. An overall flow chart of the data processing is shown in Figure 6.

From the data transmitted 'post-pass' to ESOC, a sample, equivalent on average to about 30% of all data acquired, is made available to the experimenters' 'Fast Routine Facility'. In this facility the scientific collaboration has set up a suite of programs for the complete scientific analysis of these data, using predicted orbit and attitude information provided by ESOC. This permits a thorough check on the scientific as well as the technical performance of the various experiment units, providing where necessary the possibility of a fast feedback to keep the equipment in the optimum operational mode. In addition, preliminary scientific conclusions can be reached, which can be taken into account in planning the future observation programme and in establishing priorities for the analysis of the final processed data. Such preliminary conclusions have been published in IAU circulars when it has been considered useful to alert other investigators to the possibility of correlative observations.

When all station tapes for a given observation period are received at ESOC they are submitted together to the final processing. The experiment data are reformatted and, where appropriate, converted from engineering to scientific units. The attitude-sensor data are used to derive the satellite attitude as a function of time, which is then merged with the experiment data together with the satellite position derived from ranging measurements and with relevant spacecraft housekeeping information. Copies of the resulting data tapes are sent to all the institutes in the Collaboration. Each group has specific specialisations and responsibilities in the first stages of scientific analysis though the more time-consuming duties (computerised recognition of track patterns in the spark-chamber pictures and visual scanning and manual correction of the selected pictures – see Fig. 7) are shared on a rotational basis. In the end, compressed data tapes, each containing the relevant information on all the gamma rays of one observation period, are produced and copies are distributed among the collaborating institutes. The scientists make individual analyses (sky maps, variation studies, pulsation searches), but the results and immediate interpretation are published jointly by the Caravane Collaboration members.

Highlights of the results

Gamma rays from the Galaxy

As can be seen from Figure 5, most of the observations have been devoted to the study of the galactic disc. The available processed data cover the whole range of galactic longitude, and so constitute the first complete, detailed, gamma-ray survey of the Milky Way.

Figure 7 – One of the dedicated minicomputer systems used for the detailed manual analysis of the spark-chamber pictures

Figure 8 shows a map of the measured galactic gamma-ray emission, together with longitude and latitude profiles. The emission is represented by the counting rate which Cos-B would have experienced due to gamma rays of energies between 70 and 5000 MeV, had it been pointing directly at any direction in the map. This parameter has not been converted to a photon flux because the variation of the instrument sensitivity over the wide energy range would cause the less well measured, lower energy photons to dominate the picture. The map is actually a sum of three maps derived in separate energy bands and individually smoothed to minimise the effects of statistical fluctuations without losing significant detail. However, not all significant structure is visible in the figures presented here because of limitations imposed by the scale available.

The Cos-B experiment is the first to resolve the 'line source' of gamma radiation along the galactic equator. The intense 'ridge' seen mainly within 60° on either side of the galactic centre has a width of about 1°, suggesting that most of the gamma rays are produced between 15 000 and 20 000 light years from the Sun (the Sun is about 30 000 light years from the centre of the Galaxy). The longitude dependence of the distant features indicates a relationship to large-scale galactic structures, consistent with the spiral model inferred from measurements of other tracers, while a small but significant latitude displacement of the peak emission corresponds well to the 'hat-brim' effect seen by radio

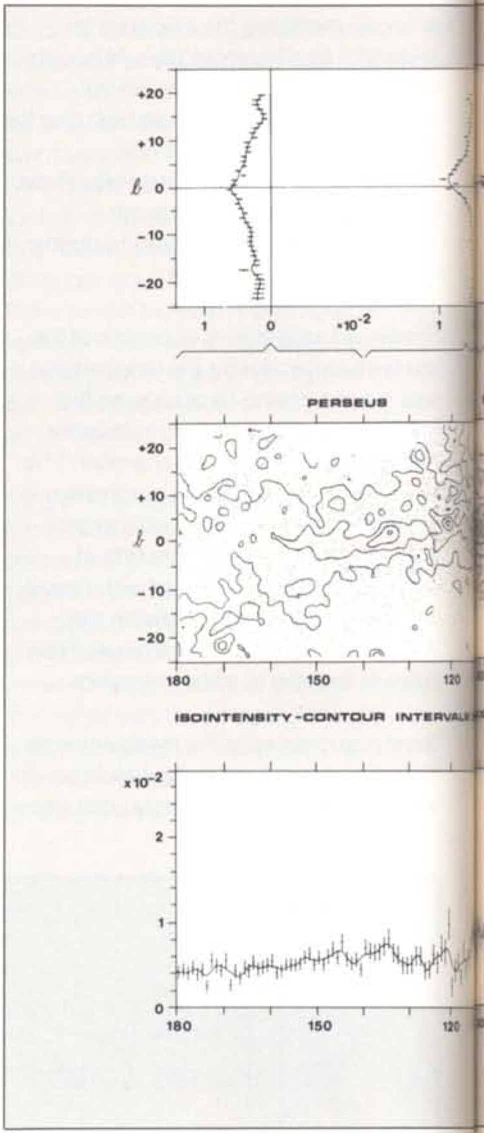
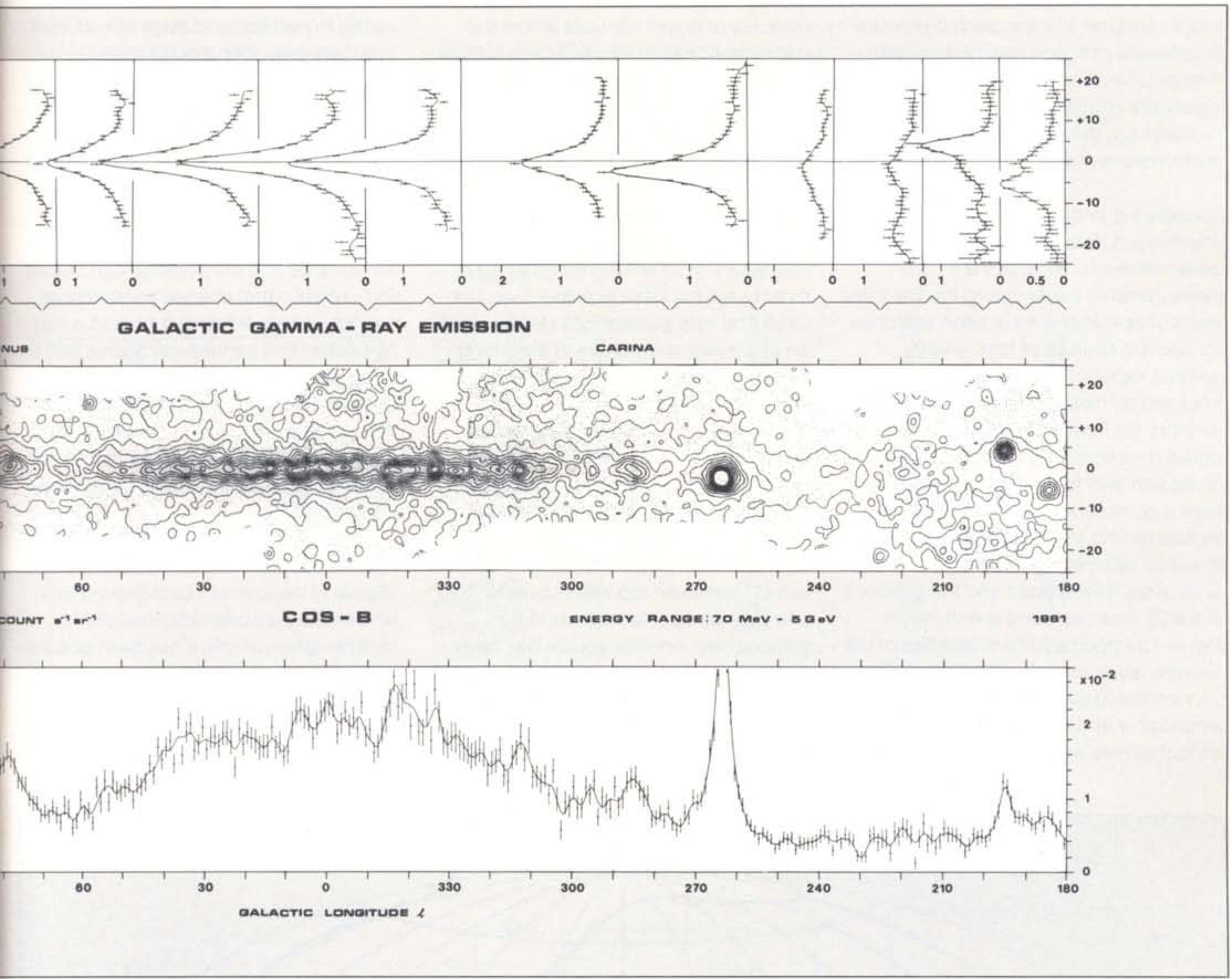


Figure 8 – Presentation in galactic coordinates of the structure of the galactic gamma-ray emission as measured by Cos-B. In the map the gamma-ray intensity is indicated by contour lines and a grey scale. Regions outside the accepted field of view are left blank. The profiles along longitude and latitude show the data points with statistical errors and the fitted surface (solid line). In the longitude profile the data are averaged over ±5° in latitude. For the latitude profiles the ranges for averaging over longitude are indicated by brackets. The map and the profiles show the parameter on-axis rate sr $^{-1}$. The contour levels are indicated at multiples of 3×10^{-3} on-axis counts s $^{-1}$ sr $^{-1}$.

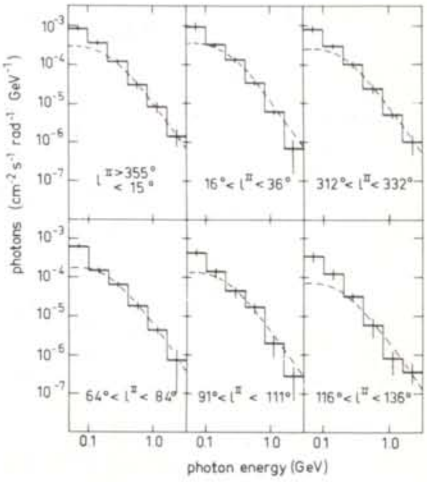
Figure 9 – Energy spectra of the gamma radiation from six regions of the galactic disc. The error bars represent both statistical uncertainties and fluctuation of the background. The dashed lines indicate the expected spectral shape due to neutral pion decay.



astronomers in the HI 21 cm line and considered to indicate a large-scale warping of the galactic plane.

This ridge is superimposed on a broader band of emission which is visible to a greater or lesser extent at all longitudes and which has clear local latitude asymmetries. These features are well correlated with the projections on the sky of two complexes of stars, gas and dust, known as Gould's Belt and the Dolidze Belt, which surround the solar system at distances between 500 and 1500 light years. This correlation provides support for the popular concept of gamma-ray production by the interaction of cosmic-ray protons and electrons with nearby interstellar clouds. The measured gamma-ray flux is generally consistent with the predictions of a number of authors.

From six observations, covering half the range of longitudes, the energy spectrum of the galactic radiation has been derived. Figure 9 shows that the shape of the spectrum does not vary significantly with longitude. The interpretation of this spectrum is of great astrophysical significance, since its shape indicates



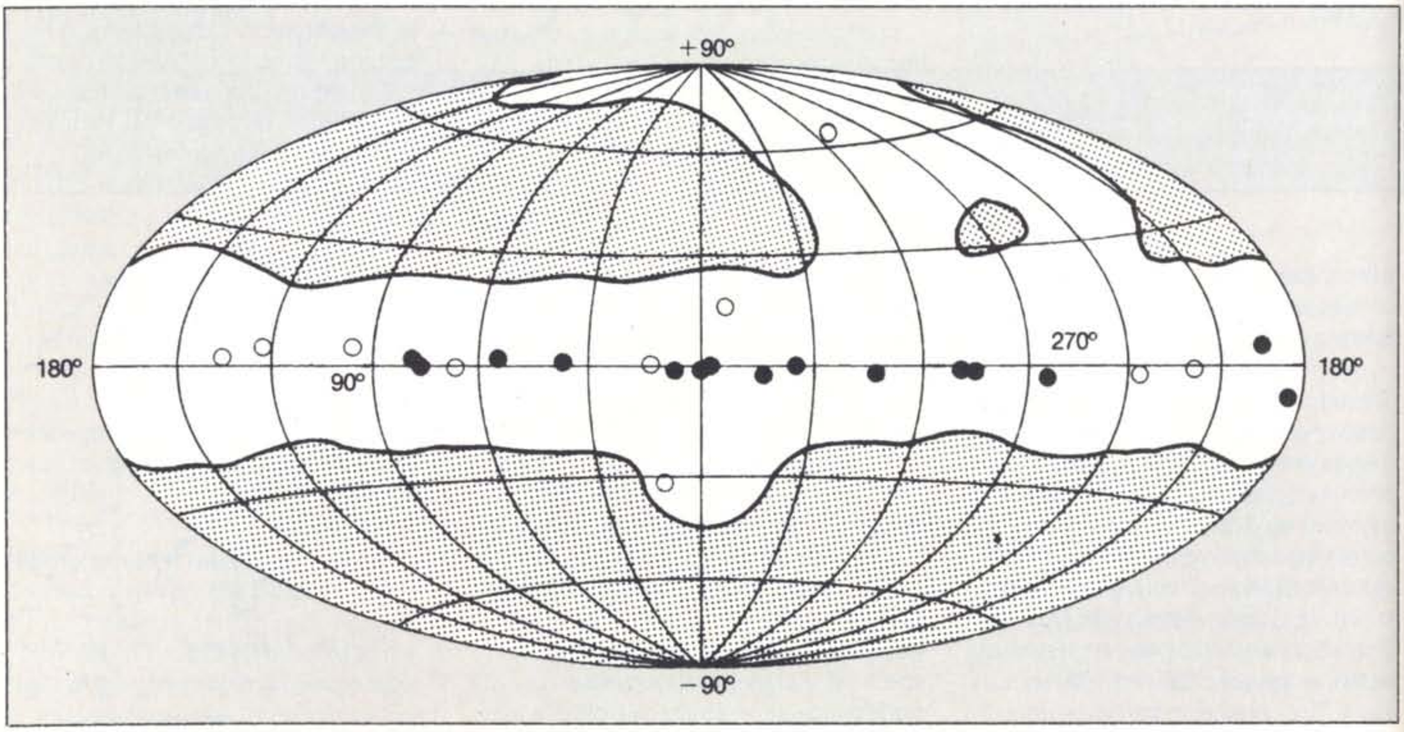


Figure 10 – Region of the sky searched for gamma-ray sources (unshaded) and sources detected above 100 MeV by spatial analysis. The closed circles denote sources with measured fluxes above 1.3 $\times 10^{-6}$ photon cm^{-2} s^{-1}. Open circles denote sources below this threshold.

that, in addition to the expected production in collisions of cosmic-ray protons with interstellar matter, there must be a significant contribution from radiation processes of the electron component of the cosmic radiation.

Localised gamma-ray sources

The merged data from about 30 separate observations, i.e. most of the measurements made during the first three years of operations, have been searched for discrete sources of high-energy gamma radiation. The data were analysed by means of a cross-correlation method: the frequency distribution of arrival directions of gamma rays was correlated with the distribution expected from a point source. Any significant feature having an extent less than about 2° will be detected by this method. The area of sky investigated and the positions of the 25 sources found are shown in Figure 10. Important characteristics of the sources are summarised in Table 1. Their concentration along the galactic disc is remarkable and significant, bearing in mind that they would be more easily detected at higher latitudes where the background of galactic radiation is lower. This indicates that at least the majority of the sources lie within the Galaxy, while their longitude distribution suggests a concentration towards its central regions.

However, identification of the gamma-ray emitters with objects known from astronomy at other wavelengths has in most cases not been possible. Two, the Crab and Vela pulsars (see below), have an unequivocal signature in the timing pattern of their radiation. A third source, that at the highest latitude, has been identified with high confidence with the quasar 3C273. This is the most distant gamma-ray source known (about 2500 million light years away) and hence the most powerful though its gamma-ray flux is so attenuated by the distance that it would have been too weak to detect had it by chance appeared close to the galactic disc. Another source has been associated with a nearby (500 light years) cloud complex known as rho Ophiuci (from the star of the same name which appears near it in the sky). With this variety in the nature of these few sources that have been identified it is not surprising that attempts to correlate the remainder with particular populations of galactic objects have led to no unique conclusion. Searches have been made at other wavelengths (notably radio and X-ray) for objects within the Cos-B positional error boxes, but these boxes are so large and the potential candidates so numerous that chance coincidences are not unlikely. What can be said is that no unidentified gamma-ray source has an X-ray luminosity more than a small fraction of the gamma-ray luminosity so the understanding of the physical processes in these objects will have to be found in interpretation of the gamma-ray measurements.

In a few cases, where a source is strong relative to the ambient background and where data had been acquired during multiple observations, it has been possible to estimate the flux from the source in separate limited ranges of energy. The spectra of four sources are compared in Figure 11. None of these spectra look

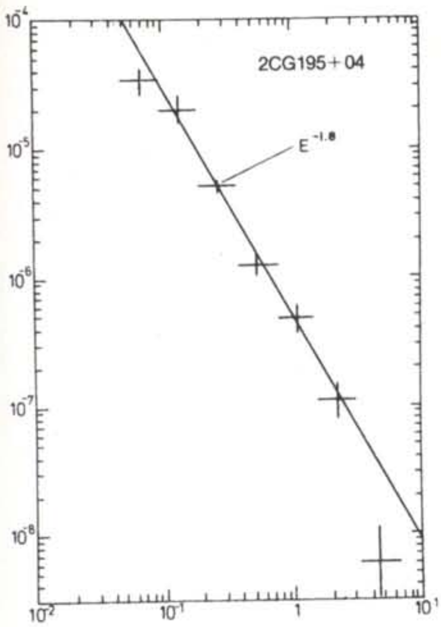
Figure 11 – Spectra of four gamma-ray sources:
(a) 2CG195+04 (unidentified)
(b) 2CG263 –02 (PSR0833 – 45)
(c) 2CG184 –05 (PSR0531+21)
(d) 2CG89+64 (3C273).

alike, though at least two of them (Crab and Vela) belong to similar objects. This fact carries a warning that even if it becomes possible to determine the spectra of all sources they might not be a useful means to classify them as types of emitting object.

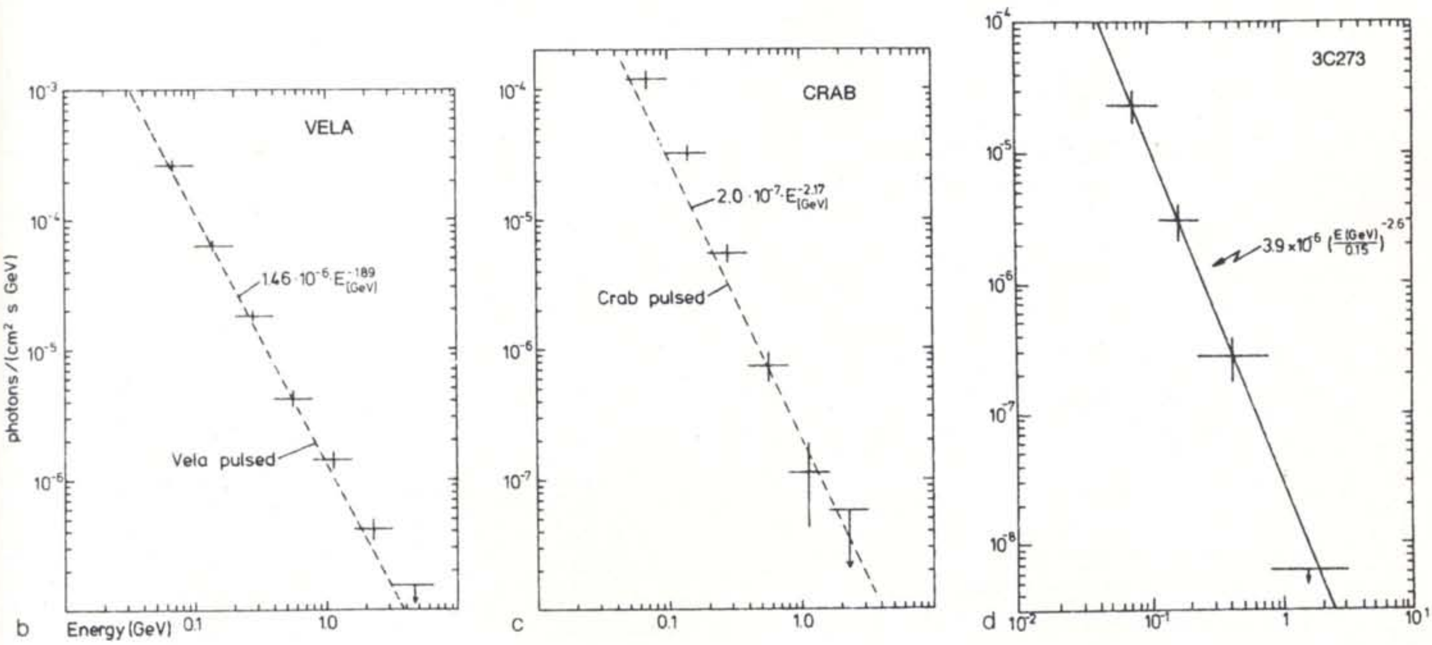
Table 1 – The 2CG catalogue of gamma-ray sources

Source name	No. of observations used	Position l (deg)	Position b (deg)	Error radius (deg)	Flux* $E>100$ MeV (10^{-6} ph cm^{-2} s^{-1})
2CG006−00	3	6.7	−0.5	1.0	2.4
2CG010−31	1	10.5	−31.5	1.5	1.2
2CG013+00	4	13.7	0.6	1.0	1.0
2CG036+01	3	36.5	1.5	1.0	1.9
2CG054+01	3	54.2	1.7	1.0	1.3
2CG065+00	4	65.7	0.0	0.8	1.2
2CG075+00	5	75.0	0.0	1.0	1.3
2CG078+01	5	78.0	1.5	1.0	2.5
2CG095+04	3	95.5	4.2	1.5	1.1
2CG121+04	3	121.0	4.0	1.0	1.0
2CG135+01	3	135.0	1.5	1.0	1.0
2CG184−05	4	184.5	−5.8	0.4	3.7
2CG195+04	3	195.1	4.5	0.4	4.8
2CG218−00	3	218.5	−0.5	1.3	1.0
2CG235−01	2	235.5	−1.0	1.5	1.0
2CG263−02	4	263.6	−2.5	0.3	13.2
2CG284−00	1	284.3	−0.5	1.0	2.7
2CG288−00	1	288.3	−0.7	1.3	1.6
2CG289+64	2	289.3	64.6	0.8	0.6
2CG311−01	2	311.5	−1.3	1.0	2.1
2CG333+01	3	333.5	1.0	1.0	3.8
2CG342−02	5	342.9	−2.5	1.0	2.0
2CG353+16	4	353.3	16.0	1.5	1.1
2CG356+00	1	356.5	0.3	1.0	2.6
2CG359−00	3	359.5	−0.7	1.0	1.8

* Assuming E^{-2} spectra



a



b c d

Figure 12 – Gamma-ray (a) and X-ray (b) light curves of PSR0531+21 integrated over periods of one month and 1.5 d, respectively. The pulsar phase is divided into 66 bins. The broken lines indicate the average numbers of counts per bin excluding those bins containing the pulses and the region between the pulses.

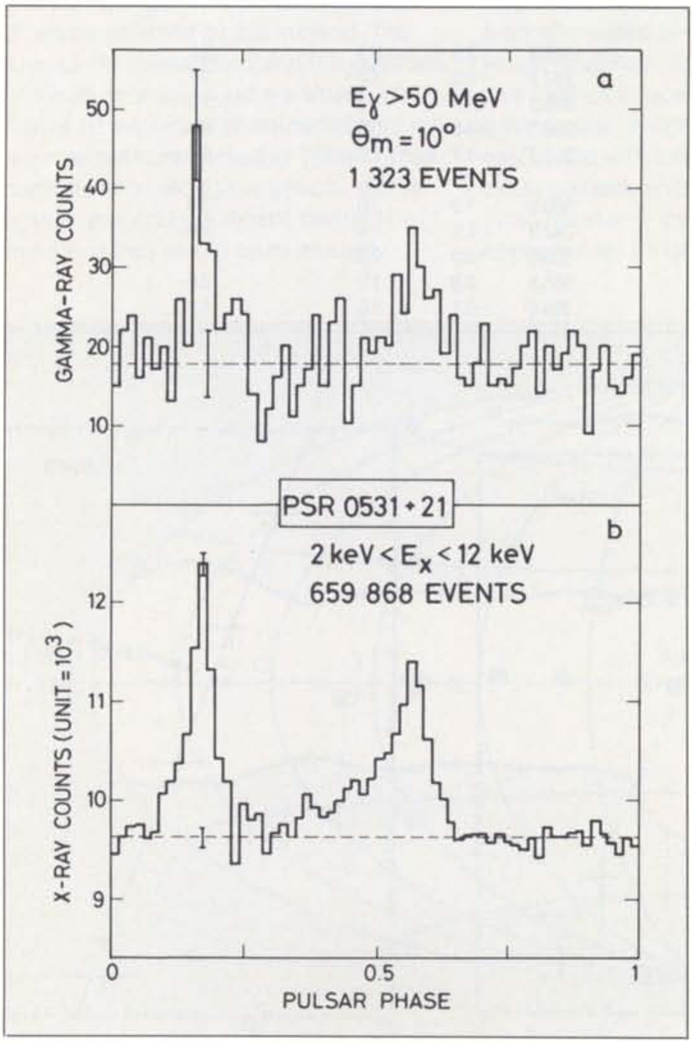
Figure 13 – Comparison of light curves of the Vela pulsar (PSR0833-45) as measured at gamma-ray, optical and radio wavelengths (data from Cos-B, the Anglo-Australian Telescope and CSIRO/NASA Tidbinbilla). The abcissa represents 89 ms full scale.

Gamma-ray pulsars

Amongst the earliest celestial objects to be studied by Cos-B were the radio pulsars PSR0531+21 (Crab) and PSR0833−45 (Vela). The investigations confirmed that these pulsars are among the brightest of gamma-ray sources and worthy of detailed investigation. Using the accurate timing information of the on-board clock, it has been possible to investigate the time structure of the radiation from the two pulsars and their relationships to the known radio-pulsar light curves. To eliminate Doppler effects due to the motions of the satellite around the Earth and of the Earth around the Sun, the individual gamma-ray arrival times in the satellite reference frame were transformed to the solar-system barycentre. The barycentre arrival times were folded with the periods of the pulsars, using values of the period and period derivatives determined from radio observations.

Figure 12 shows the gamma-ray light curve of PSR0531+21 for energies above 50 MeV, derived by selecting photons incident within 10° of the pulsar direction. For comparison the light curve of 2–12 keV X-rays, derived by applying the same procedure to the data from the pulsar synchroniser, is also shown. There is a strong similarity between the curves, both showing two peaks separated by 0.4 of the 33 ms pulsar period.

PSR0833−45 does not emit a measurable flux of X-rays, but is the brightest object in the gamma-ray sky. It has a gamma-ray light curve similar to that of PSR0531+31, with two peaks of widths about 3 ms and 5 ms. This curve is not the same as that measured at optical or radio wavelengths, as can be seen from Figure 13. In that figure the different light curves are shown with their absolute phase relationship which was determined by a careful comparison, made in collaboration with scientists of the Radiophysics Division of the Australian Commonwealth Scientific and Industrial Research Organisation, of the timing measurements made with Cos-B and with the radio telescope of the NASA Deep Space Station at Tidbinbilla,



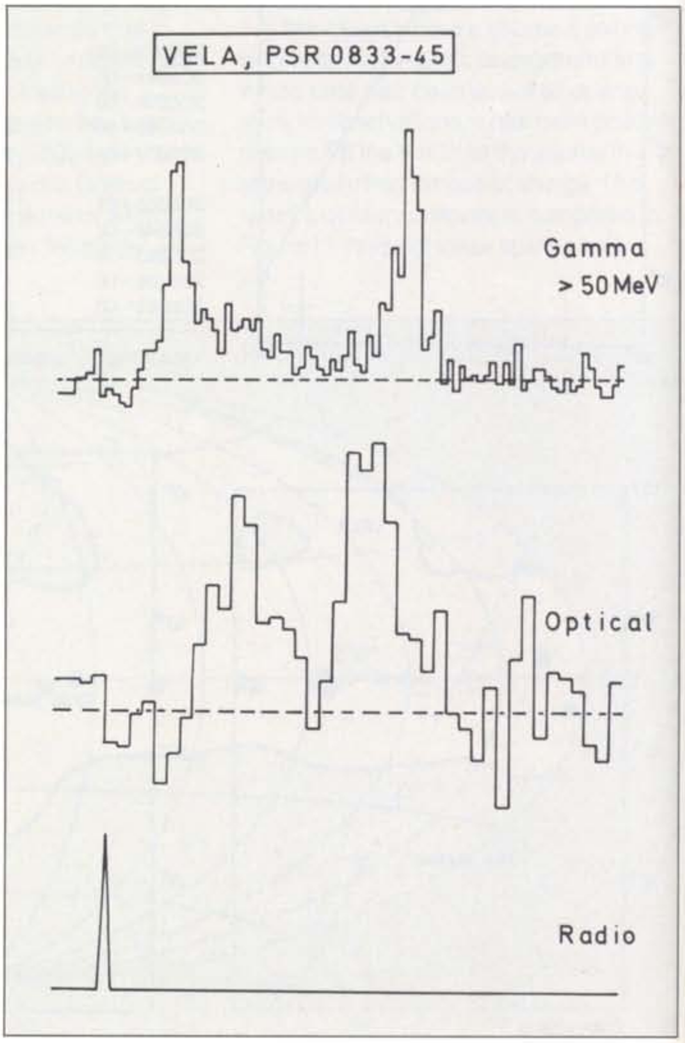
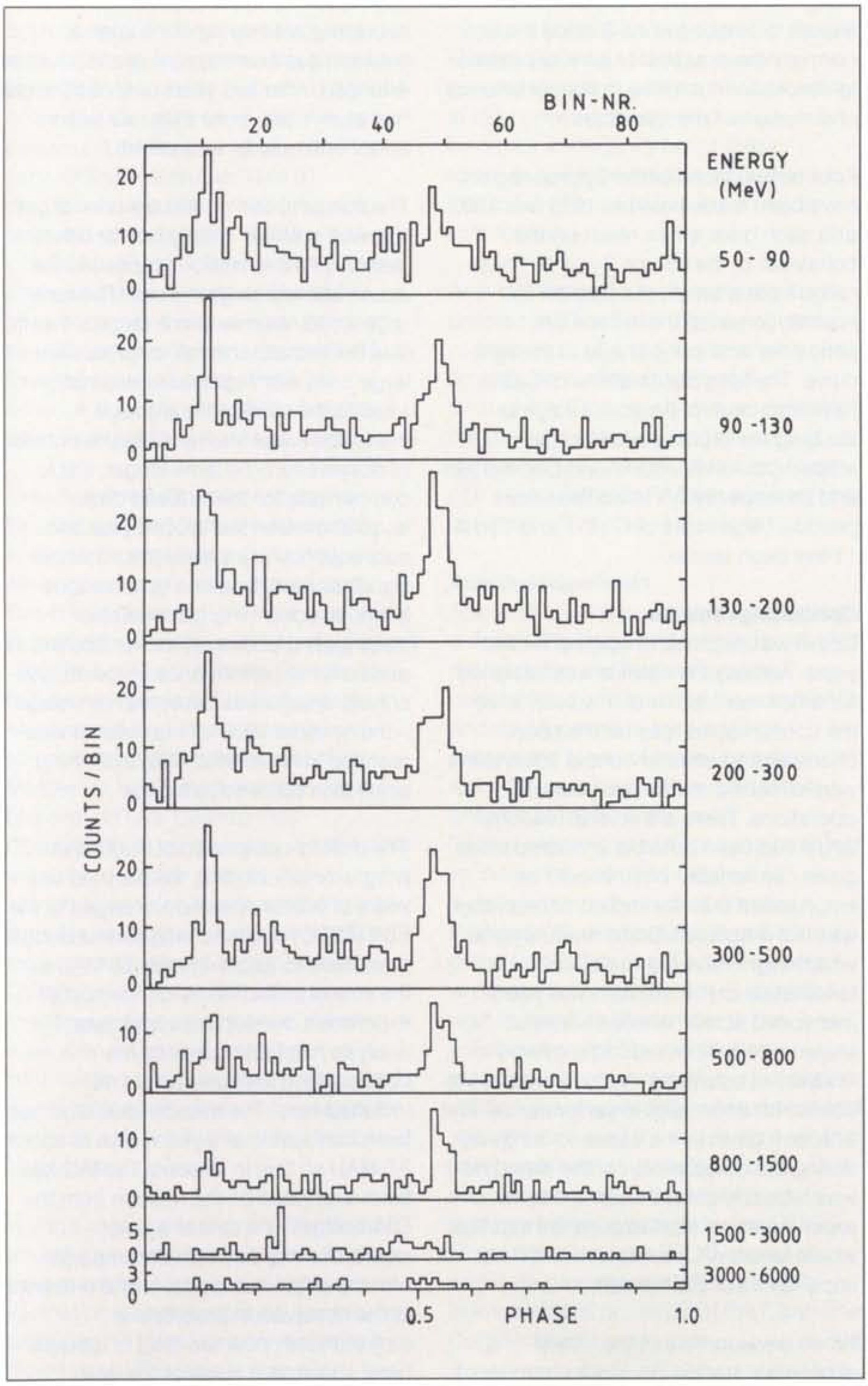


Figure 14 – Gamma-ray light curves of PSR0833-45 in the energy ranges indicated.

Australia. Figure 14 shows separate light curves drawn for each of nine gamma-ray energy ranges. These show a clear trend indicative of differences in the energy spectrum in different parts of the light curve. The complete spectrum of the pulsed gamma radiation is well fitted over the range 50 MeV to 3 GeV by a single power law. This is indicated by a broken line in Figure 11b, which shows that it also fits the spectrum of the point source as measured by the cross-correlation technique. This means that any steady emission from this pulsar must be less than about 10% of the total.



Similar timing analysis of the gamma radiation from the Crab has shown that the energy spectrum can again be fitted by a single power law, but steeper than that of PSR0833−45. This power law extrapolates well to fit measurements of PSR0531+21 at X-ray energies, suggesting that a common physical process may be responsible for the production of X- and gamma-rays. This contrasts with PSR0833−45 for which the pulsed flux around 30 keV is at least a factor of four below the extrapolation of the gamma-ray spectrum. Another difference between these two objects lies in the spectrum of the steady emission. Figure 11c shows that, although the total flux from the Crab above 400 MeV is consistent with its being entirely pulsed, below that energy it is significantly higher than the pulse-spectrum power law. The average contribution of the pulsed flux to the total between 50 and 400 MeV is 55±7%.

A recent comparison of the gamma-ray light curves of the Crab pulsar as measured in five Cos-B observations spanning a period of five years has revealed a change in the relative strengths of the two pulses. This effect is shown in Figure 15. No such effect has been found in the case of Vela, for which a similar history is available, nor has such a variation been reported in any other wavelength range.

Extragalactic gamma rays

A search through the Cos-B data for gamma radiation from a number of extragalactic objects revealed no strong evidence for any positive identification except, as mentioned above, for the quasar 3C273. Upper limits to the photon fluxes were evaluated using a likelihood

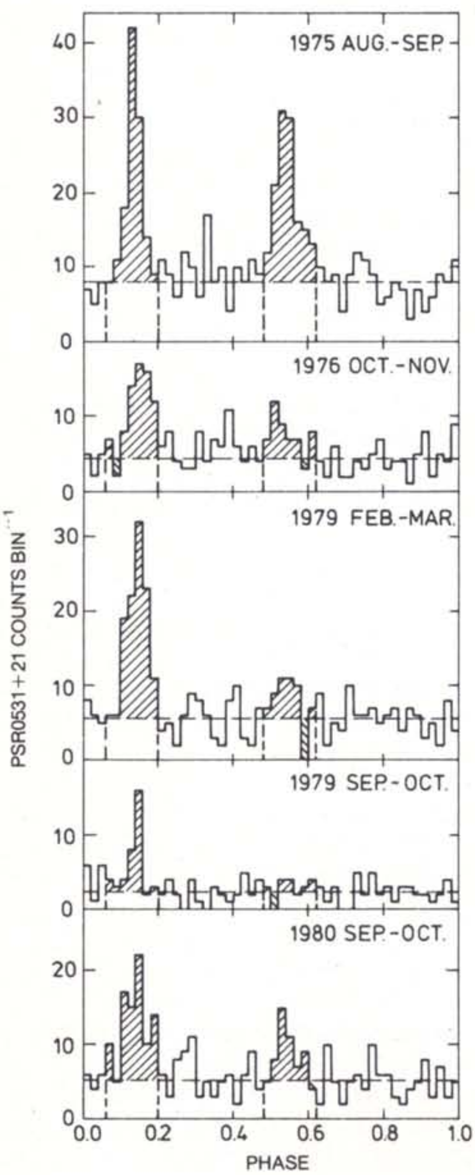


Figure 15 – Gamma-ray light curves of PSR0531+21 at the epochs shown. The shaded areas indicate the phase intervals of the two pulses and the horizontal broken lines shows the levels of the background.

method. They reinforced the conclusion from the SAS-2 results that the fluxes lie substantially below the extrapolations of the X-ray spectra.

X-ray measurements
Although the gamma-ray experiment has a wide field of view, during several observation periods the axis of the experiment has been pointed to a specific object in order to ensure that it is within the more restricted field of view of the pulsar synchroniser. Several other strong X-ray sources have at some time been near enough to the pointing direction to permit a study of the behaviour of their X-ray emission continuously (apart from periods of passage through the radiation belts) over periods of a month. This feature is unique to Cos-B since it is not normally the practice for an X-ray satellite to devote so much time to the continuous observation of a single object.

Four observations of the Cygnus region have been made between 1975 and 1980 and each gave a new result on the behaviour of the source Cyg X-3. These range from a simple modulation of intensity to variations in the 4.8 h periodicity and in the shape of the light curve. The long observations of Cos-B have also been of particular value in studying the orbital periods of the eclipsing binaries Vel X-1 and Cen X-3 (9d and 2d respectively). In addition the periodic behaviours of Cir X-1 and Cyg X-1 have been studied.

Concluding remarks
Cos-B was planned to operate for two years. Actually the satellite was designed for a nominal lifetime of one year, while the consumables (gas for the spark chamber and attitude-control subsystem) were dimensioned for two years of operations. There are several reasons why it has been possible to exceed these goals comfortably, but it should be emphasised that the implied conservation was not misplaced. Some malfunctions which might have led to earlier termination of the mission have been mentioned above, where it was also shown how built-in redundancy and flexibility of operating modes were used to correct for anomalies in performance. The attention given to the aspect of longevity during the development of the experiment was arguably greater than in earlier experiments on multi-experiment satellites, where failure of one instrument did not imply failure of the mission.

When development of the Cos-B experiment started, no spark chamber of the type envisaged had ever been operated in the space environment. Early operations suggested that the estimated requirement in replacement gas had been about right. With time, however, it appeared that the chamber was becoming 'cleaner' and the interval between gas-flushing operations could be extended. After two years only half the gas had been used, while after four years about one quarter was still left.

The consumption of attitude-control gas followed a similar history but for different reasons. As the mission proceeded the observation strategy evolved. The early urgency to observe 'prime targets' meant that the first attitude manoeuvres were large ones with high gas consumption. Later in the mission the average manoeuvre was shorter while the duration of observations became longer, first to compensate for the reduced data acquisition after the second year and subsequently to increase the statistical significance in repeated observations aimed at confirming discoveries or investigating potential time variabilities. In addition, the performance of the attitude-control system was better than envisaged – the nominal 4000° of manoeuvre was reached in November 1979; everything since then has been a bonus.

The cost-to-completion of the Cos-B programme, including the planned two years of orbital operation, charged to the ESA (ESRO) scientific programme budget amounted to approximately 65 MAU at the time of launch in 1975. The cost of experiment development and data analysis has been borne by the collaborating institutes and is not included here. The mission extension has been conducted at a yearly cost of about 2.5 MAU so that in all some 75 MAU has been expended on the mission from the ESA budget. The cost of mission extensions has been small compared with the original investment and reference to the observation programme (unfortunately now too long to tabulate here) shows that many of the new discoveries would not have been made had the mission terminated in 1977.

The map of the Galaxy shown in Figure 8 represents the measured arrival directions of about 100 000 gamma rays. This is an order of magnitude greater than that recorded by all the gamma-ray astronomy satellites that preceded Cos-B. It might be noted that the pioneering gamma-ray experiment on Explorer XI flown in the early 1960s detected perhaps 31 extraterrestrial gamma rays. Only data recorded up to October 1979 have been included in Figure 8, though some later observations have been analysed for other purposes. It is thus clear that many more developments can be expected from the analysis of the data, which will continue for some years after the last telemetry signal has been recorded.

Already the results presented above indicate the need for more advanced missions in gamma-ray astronomy. Although six years have passed since Cos-B was launched, the next experiment in this field will not be in orbit before about 1983. This will be the Soviet-French experiment 'Gamma-1', which will use a new technique to locate gamma-ray sources with much greater precision. Meanwhile NASA is advancing with the preparation of a 'Gamma-Ray Observatory' to be launched in 1987. This will carry four large gamma-ray instruments, which together will study six decades of photon energy. Some of the institutes represented in the Caravane Collaboration are participating as co-investigators in one or more of these experiments. One will represent a continuation of the development in which Cos-B took a part, and will have a spark chamber with a sensitive area about 10 times that of Cos-B.

In addition to publication in the relevant scientific journals, the Cos-B results have been prominent features of numerous international conferences on gamma-ray astronomy in three continents during recent years. There have also been contributions to the biennial International Cosmic-Ray Conferences, culminating in the 1981 Paris conference, at which eight papers on Cos-B results were contributed by the Caravane Collaboration, while numerous papers discussed interpretations of these and earlier results. The introduction of a new session devoted to X- and gamma-ray astronomy at this conference was seen as a landmark in the progress of these sciences, towards the reaching of which the Cos-B mission has made a major contribution.

As a last remark, a feature of the Cos-B programme has been the forging and maintenance of a truly collaborative spirit among the participants spread throughout Europe, which has withstood the passage of time and the trials and tribulations of such an adventure. Everyone associated has had the attitude 'what can I put in?' not 'what can I get out?'

Acknowledgements
About 35 scientists, supported by at least a dozen engineers and technicians within the institutes and four aerospace companies, contributed to the conception and development of the Cos-B experiment. Many of these, joined by some 20 more, have taken part in the analysis of the scientific data. Recognising the important contribution of so many, the authors prefer not to mention names, but would quote Professor H. van de Hulst, then Chairman of the Cos-B Steering Committee, who wrote at the time of the Cos-B launch: 'I wish to thank each member of the collaboration for his contribution, members whose unrelenting input and caution in safeguarding the technical and scientific quality of the experiment are the best guarantee of ultimate success'. The support provided to the experimenters over more than a decade by the ESTEC project team and the ESOC operation and data-processing staff is gratefully acknowledged on behalf of the Caravane Collaboration.

15th ESLAB Symposium on X-Ray Astronomy

Each year ESA Space Science Department, formerly ESLAB, organises a symposium in a different scientific field associated with space research. The 15th ESLAB Symposium was held at the end of June in Amsterdam, the topic being X-ray astronomy.

The aim was to bring together the international astrophysics community to:

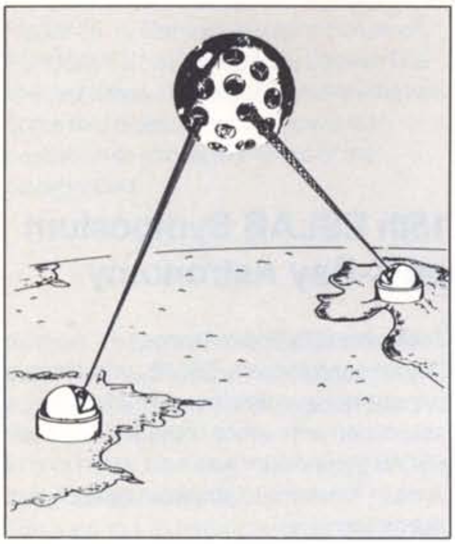
1. review the present state of X-ray astronomy in the light of new observations gathered by recent missions and to review data on interesting objects in correlated wavelength regions
2. discuss theoretical models describing the phenomena observed
3. present ESA's European X-ray Observatory Satellite (Exosat) and to discuss future X-ray missions and their associated instrumentation.

These topics proved so interesting to the scientific community that more than 120 contributions were submitted. Of these, 94 were finally accepted and approximately 200 participants attended the five day meeting.

The discussion topics ranged from nondegenerated stellar X-ray sources and stellar coronae to supernovae, bursters, globular clusters, normal galaxies, and finally to cosmology. The philosophy was to bring together the relevant information in each field obtained from radio, optical and X-ray observations and to follow it up with discussions of the theory.

The presentation of the capabilities of ESA's Exosat observatory, intended to stimulate the interest of the scientific community, was one of the highlights of the Symposium.

The Proceedings of the Symposium (approximately 700 pages) will appear in Space Science Reviews. In addition, it is intended to summarise all manuscripts in a book, to appear in November 1981.



Space Techniques to Monitor Movements in the Earth's Crust

S. Hieber, Directorate of Application Programmes, ESA, Paris

The time has come when space techniques can be expected to complement the classical geological, geochemical and geodetic tools employed in studying the Earth's crust as the birthplace of earthquakes and volcanic activities. These space techniques, when applied to global and regional investigations, are expected to answer important questions concerning the relative motions of tectonic plates. The preparatory studies currently being performed by ESA in this field reflect the Agency's recognition of the role of such techniques as part of its Earth-Observation Programme.

Goals and requirements

The precise determination of distances on the Earth's surface is no longer used exclusively for the classical geodetic tasks of tracing the boundaries of estates, establishing geometric bases for the construction of roads, bridges, dams, pipelines or tunnels, or producing data for cartography. Such determinations can also allow us to measure and monitor geodynamic phenomena, such as the very slow drift of tectonic plates or regional fault motions.

From improved knowledge of these crustal variations, geophysicists expect to acquire a better understanding of the processes in the Earth's mantle that initiate and maintain the motions of the crustal plates, and that are at the origin of seismic and volcanic activities. Given this better understanding, geologists may be able to establish correlations with mineral and fossil-fuel deposits.

Moreover, the results of crustal-movement measurements are extremely important for the assessment of the risks associated with the hazardous behaviour of the Earth's crust and, hopefully, for the prediction of earthquakes.

Today's major research objectives in geodynamics are:

1. Improved understanding of the dynamic processes in the Earth's crust:
   - relative plate-tectonic motions (continuous or episodic)
   - regional fault motions and strain accumulation
   - internal deformation of lithospheric plates
2. Study of Earth kinematics and possible correlations with:
   - plate motions
   - earthquakes
   - other geophysical phenomena.

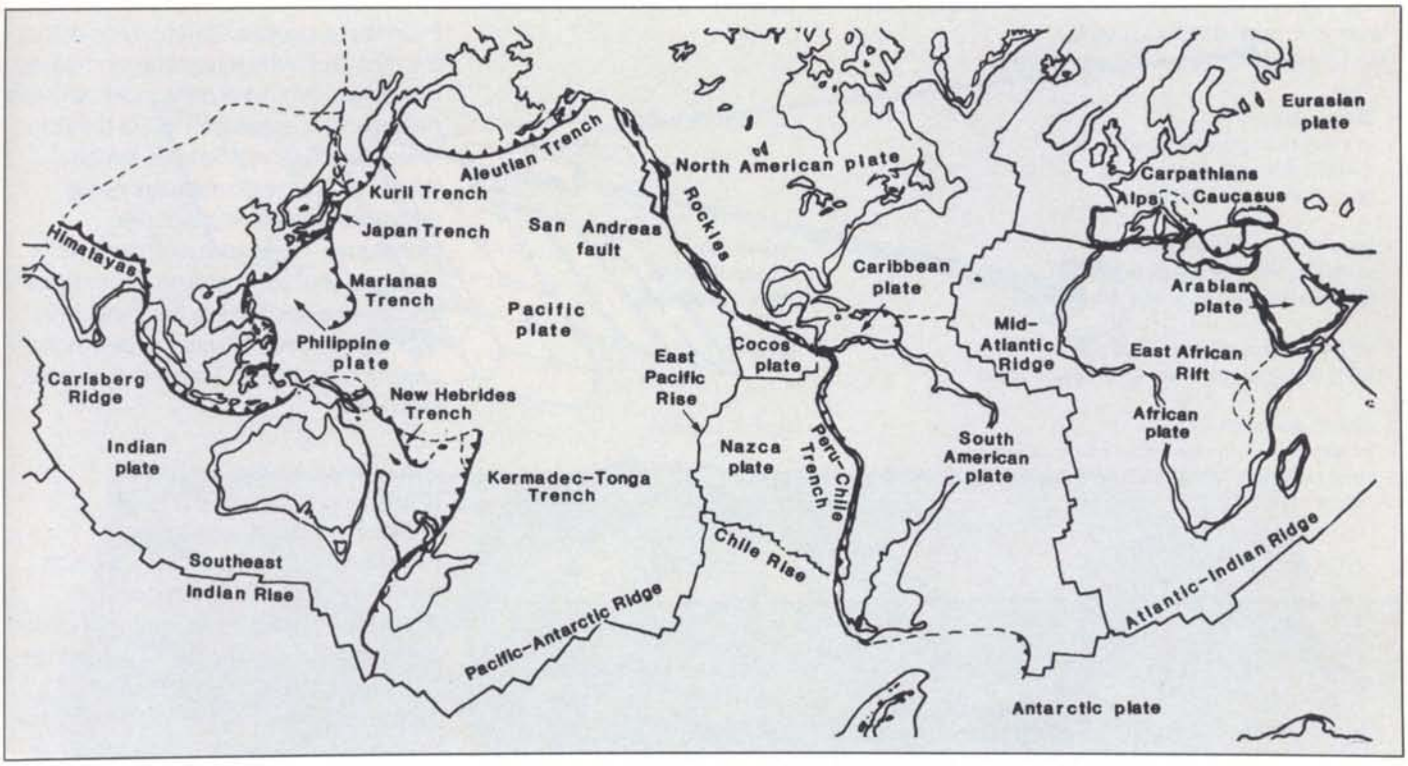
The investigation of relative plate motions is global in nature and involves measurements over intercontinental distances and over extended time periods. It remains to be established whether these motions are continuous or episodic. Study of the internal deformations of lithospheric plates may also contribute to providing an answer.

Equally, the dynamic behaviour of our planet as a whole is assumed to contribute to the various crustal phenomena. How do the irregularities in the kinematic behaviour of the Earth affect the velocities and directions of plate motions? How does the Earth's axis and the globe's rotation around it respond to earthquakes? We may know the answer when we can measure the motions of the poles to centimetre, and the length of day to microsecond accuracies.

Our continual mapping of the geoid and its anomalies, such as those to be found in the subduction zones, has now reached a resolution such that it can provide further evidence regarding the existence of mineral and energy resources and the tectonic backgrounds to their formation.

With each of these research objectives are associated particular measuring requirements (Table 1).

Figure 1 – Tectonic map of Earth showing boundaries of major lithospheric plates (Mercator projection). Plate boundaries are indicated by solid lines where certain and by dashed lines where uncertain. Trenches are shown by hachured lines, with hachures on the overriding plate. Illustration courtesy of Profs. J. Head & S. Solomon and Science Magazine (Vol. 213, 3 July 1981)



Space techniques

The goals and requirements that have been laid out above may not change for some time, but the means by which they are being pursued are certainly evolving. They have already increased in both number and precision with the progress in space techniques for Earth-oriented research. The fact that today we know the diameter of the Earth to an accuracy of about 1 m and the distances between continents with centimetre accuracies is attributable in large part to satellite geodesy using both static (triangulation with satellites as fixed points) and dynamic (analysis of orbital perturbations) methods.

Table 1 – Current measurement requirements for geodynamics and earthquake research

Phenomena to be observed	Magnitude of motion	Measurement accuracy required
Relative global plate motions	2–15 cm/yr	10^{-8}–10^{-9}
Regional fault motions	<10 cm/yr	1–2 cm/yr 0.7 cm/3 yr 0.4 cm/5 yr
Internal plate distortions	<3 cm/yr	10^{-8}–10^{-9}

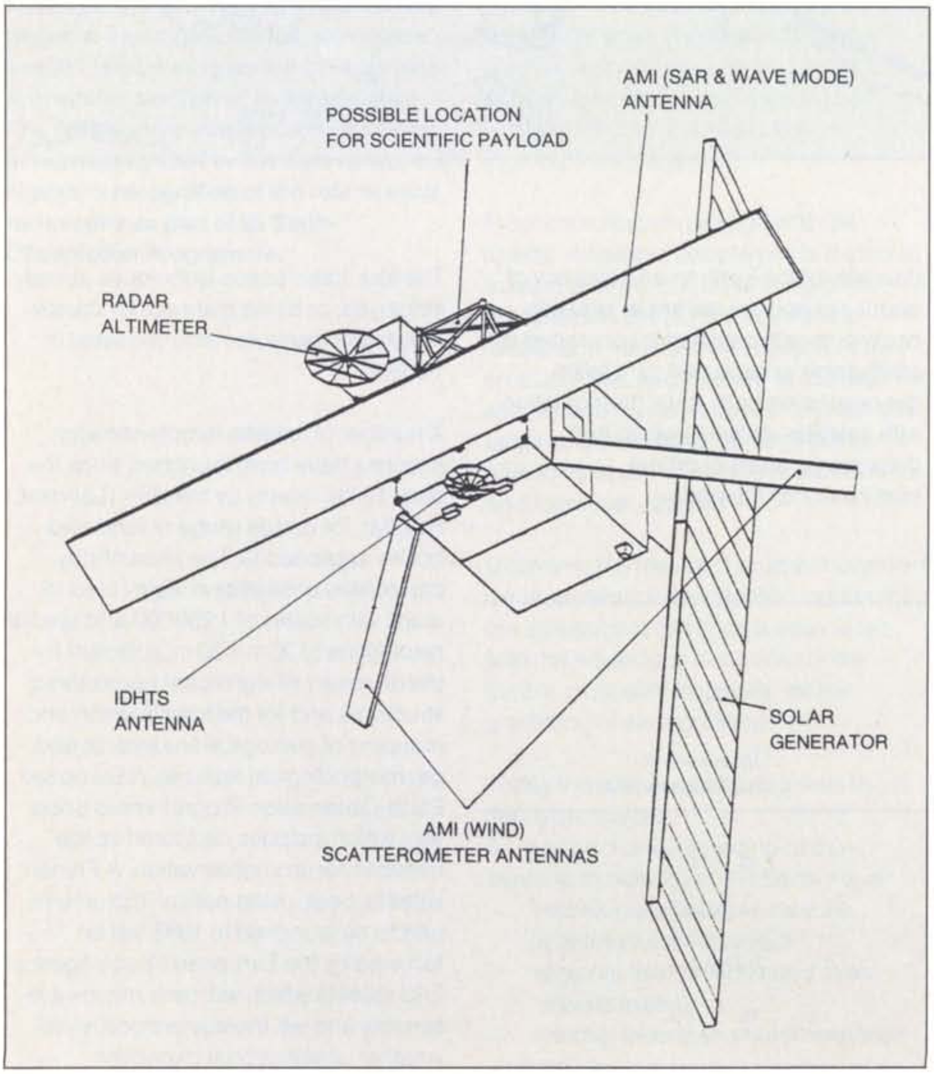
The four basic space techniques already employed, or being planned, for crustal-movement measurements are listed in Table 2.

A number of satellite remote-sensing missions have been launched since the early 1970s, mainly by the USA (Landsat, HCMM), for a wide range of land and ocean applications. The present-day capabilities of satellite imagery lead to maps with scales of 1:250 000 and spatial resolutions of 30 m × 30 m, sufficient for the discovery of significant neotectonic structures and for the identification and mapping of geological lineaments and geomorphological features. A European Earth-Observation Programme is under way which includes dedicated space missions for land observation. A French satellite, Spot, using optical instruments and to be launched in 1983, will be followed by the European Space Agency's ERS satellite which will carry microwave sensors and will thereby provide an all-weather observational capability.

Figure 2 – Possible in-flight configuration for the Agency's earth-resources satellite (ERS-1)

Table 2 – Space techniques for geodynamics and earthquake research

1 Satellite imagery – to reveal neotectonic structures – to find and map lineaments and geomorphological features	Landsat, Spot, ERS
2 Ranging to and from satellites – using microwave and laser techniques – requiring high-accuracy orbit determination	SGRS/Spalt, Lageos/Starlette, NNSS/GPS/Popsat
3 Very-long baseline interferometry (VLBI) – using natural and artificial radio signal sources	GPS
4 Satellite gravimetry – to map the fine structure of the Earth's gravity field – using satellite-to-satellite tracking and gradiometry	Slalom, Gravsat



In principle, geodesy can be considered the most accurate form of ground-based navigation. A natural consequence of this has been the use since 1967 of the US Navy's Navigational Satellite System (NNSS or Transit) to measure range differences, employing Doppler techniques. These measurements allow absolute geocentric station coordinates and relative positions to be computed with accuracies of 20 cm for fixed-station positions, and better than 1 m for mobile stations.

A successor system, the Global Positioning System (GPS) to be completed in 1984, also applies microwave ranging principles. If made available for geodetic purposes this navigation system could improve position determination by an order of magnitude compared to NNSS. A substantial problem that limits the ranging accuracy to and from fast-moving targets like satellites is the difficulty or even impossibility of determining their orbits with an accuracy comparable to that of the range-measuring instruments.

Future space missions with objectives in the fields of Earth observation and solid-Earth physics, and particularly geodetic satellites with applications in precise point-positioning and Earth kinematics, therefore require increasingly more precise determinations of their orbits, compatible with the performances of the improved range and range-rate measurement systems.

Depending on the geophysical parameter to be recovered, on the satellite altitude, and on the measurement technique applied, orbit-determination accuracies of better than 1 m radially and along-track are required – in many cases better than 10 cm. Today's orbit-determination uncertainties are much larger than this (Table 3), thereby preventing the efficient use of high-precision sensing systems, such as altimeters, for physical oceanography and gravity-field measurements.

Figure 3 – Schematic of gravity-field determination by satellite-to-satellite tracking (satellite geodesy)

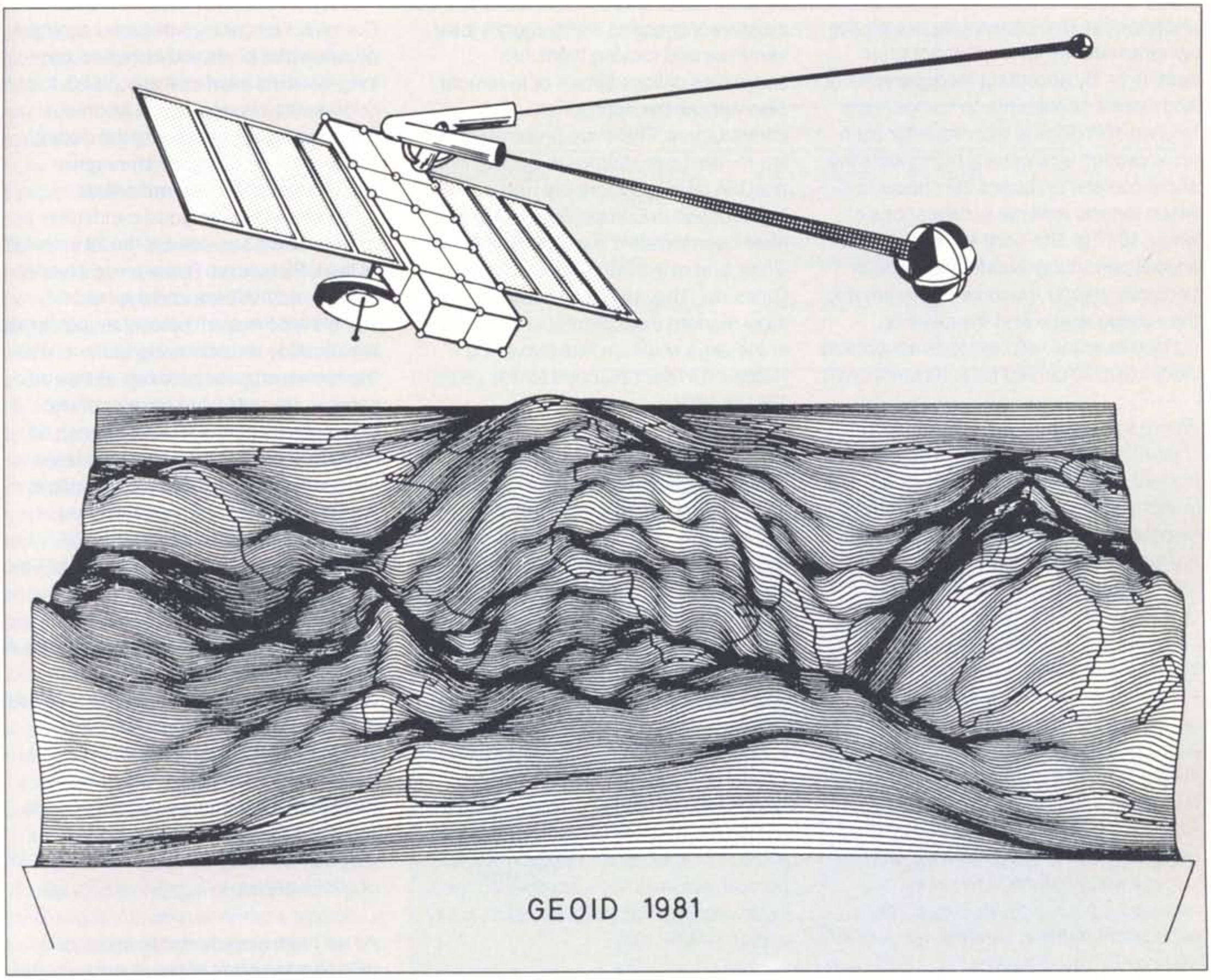


Table 3 – Orbit-determination accuracies available for geodetic satellites (altitude ~1000 km)

Component	Arc length (days)	RMS residuals (m)
Along track	1–2	15–20
	0.2–0.5	3–6
Radial track	1–2	3–6
	0.2–0.5	1–2
Across track	1–2	5–10
	0.2–0.5	2–4

The fundamental elements that affect precise orbit determination, apart from the instrument errors associated with the different measurement techniques, are the various perturbing forces. These include atmospheric drag at lower altitudes, solar radiation pressure at high altitudes, and the inhomogeneity of the Earth's gravity field, in particular its variations due to the solid Earth and oceanic tides. The difficulties lie in the correct measurement or modelling of these forces.

One means of reducing these

uncertainties is to observe separately the nongravitational forces that act on a satellite or, by accepting more complexity and lifetime constraints, to compensate for them. An original technique for such an approach is to carry a highly sensitive accelerometer on board the spacecraft which detects minimal accelerations of about 10^{-11}g. The need to carry such a special perturbing-acceleration sensor becomes greater the more nonsymmetric the satellite shape and the more its surface-to-mass ratio exceeds acceptable values (e.g. 10 cm^2/kg for a 1000 km orbit).

Where these design constraints do not impair the mission requirements, the most elegant and least critical technique is to launch relatively small and heavy satellites (compact spherical 'cannon balls'), which are less affected by atmospheric and solar-radiation pressures. Such high density and symmetry requirements, however, are hardly compatible with several design principles for active satellites: namely their need for solar generators, for antenna structures, and for active control systems that involve mass losses. Nevertheless this technique, which is the favoured solution for passive satellites equipped with retro-reflectors for geodetic laser-ranging observations (e.g. Lageos and Starlette), cannot be excluded a priori from studies of future-generation geodetic satellites with active on-board instrumentation.

It is for this reason that the Popsat (Precise Orbit Positioning Satellite) concept studies being conducted by ESA are considering alternative configurations, with and without an accelerometer, in the early phases of system definition. The principal payload would be an extremely precise microwave range and range-rate measuring system, in addition to optical reflectors for laser tracking.

Laser tracking of satellites for crustal-movement measurements calls for the installation of laser stations at the sites where significant features can be expected to be measured. In practice, this means constructing highly mobile laser terminals and moving them into sometimes difficult terrain or to remote sites without the appropriate infrastructure. There are presently about ten mobile laser stations in operation in the USA, and two more are under construction in Europe. Since 1972, some have been installed every other year on either side of the San Andreas Fault in California. They will also constitute the most modern instrumentation to be used in the large-scale Crustal Dynamics Research Project planned for the years 1981 to 1986.

As part of this project, a group of European geodetic and geophysical institutes will concentrate their joint measurement efforts, using mobile laser stations, on the Eastern Mediterranean area where the Earth's crust is known to be broken into numerous smaller plates.

A possibly more elegant and more economic approach to the use of laser techniques for regional crustal-dynamics investigations would be to install the active laser equipment on board an orbiting space platform and to limit the investment and operations on the ground to the setting up of a passive reflector network, for instance across rift zones or in the vicinity of large structures in areas of high seismic risk.

Similar concepts for such an 'inverted laser tracking system' are being studied in the USA in the form of a Spaceborne Geodynamics Ranging Satellite (SGRS), and in Europe through the Spaceborne Altimetry (Spalt) project. Both concepts assume that during each satellite pass over a reflector array the laser beam could scan approximately 60 targets several times and thus determine their relative distances with centimetre accuracy. The technical solution, which may not be implemented before the end of this decade, is conditioned by the feasibility of developing reliable long-life space lasers and low-cost ground targets.

Currently competing with laser ranging is a radio-electric method based on very-long-baseline interferometry (VLBI). It is considered a space-based technique although for the time being the distant signal sources are not man-made spacecraft but natural radio stars (quasars). However, good candidates as artificial radio sources are the 18 satellites of the GPS system. These are to be at an altitude of 20 000 km and their radio signals will therefore present a quasi-plane wavefront to the observing stations. With the known angular positions of the radio sources, by employing time- or phase-difference techniques baselines can be measured with an accuracy of a few centimetres. The large radio telescopes in Europe and the USA have already demonstrated such a capability for intercontinental baselines, but again – as in the case of laser ranging – transportable units are needed for crustal-dynamics research applications. A few such stations have been built to observe Astronomical Emissions for Radio Interferometric Earth Surveying (Aries) and to receive Satellite Emissions for Radio Interferometric Earth Surveying (Series). Their antennas range from 1 to 4 m in diameter. A 5 cm accuracy is reported as being achieved with only 1.5 h of observations.

As we have already mentioned, the refined knowledge of the structure of the Earth's gravity field is the key to precise orbit determination for geodetic satellites and, therefore, a prime parameter for high-accuracy station positioning. The acquisition of this information, necessarily on a global scale, is an objective that cannot be separated from the goals of geodetic and geodynamical research.

Again, satellite techniques are an efficient means of solving the problem, the most interesting possibilities at this moment being satellite-to-satellite tracking and satellite gradiometry. Both methods rely on the fact that a satellite in its orbital trajectory reacts to variations in the gravity field: the lower the satellite's altitude, the greater its sensitivity to these forces. Nongravitational forces tend, of course, to introduce errors which have to be eliminated, either by measuring them separately (with a micro-accelerometer) or by using such measurements to compensate for their effects.

The principle of satellite-to-satellite tracking is to measure the relative velocity between two spacecraft and, from the accelerations derived, to compute the intensity of the gravity field, in particular its short-wavelength structure. The concepts studied include HI-LO (high-low) techniques, where the lower satellite is the sensitive element and the higher satellite in its almost unperturbed orbit represents a reference position; and LO-LO (low-low) techniques with two low-flying spacecraft in virtually the same orbit, but properly phased in that orbit. To recover gravity parameters with the requisite resolution, the relative velocity must be measured with an accuracy of a few millionths of a metre per second! Feasibility studies have shown that laser and millimetre-wave methods can provide this performance. Two systems under study in the USA and Europe for future projects have the names Gravsat and Slalom, respectively.

The second technique of interest is satellite gradiometry, whereby a single satellite carries an instrument that measures the gradient tensor of the gravity potential directly. Though simpler in its system configuration, this solution is still proving a technological challenge.

The present-day capabilities of the various space techniques are collected in Table 4. Figure 4 compares them in terms of measurement distances and hence their potential uses in local, regional, or global applications for crustal-movement research.

Table 4 – Capabilities of space techniques for geodynamics and earthquake research

	Mobile		Fixed	
	Number	Accuracy	Number	Accuracy
Microwave Doppler	10 000–12 000 including ships	<50 cm (Transit) 2–6 cm (GPS)	20 (Tranet)	20 cm
VLBI	7 (Aries, Series, Mites)	5–10 cm (Aries) 3 cm (Series, GPS)	15 (Radio telescopes)	2–10 cm
Laser ranging	~10 (Moblas, TLRS)	5–10 cm relative	~10	5–10 cm point positive <5 cm relative

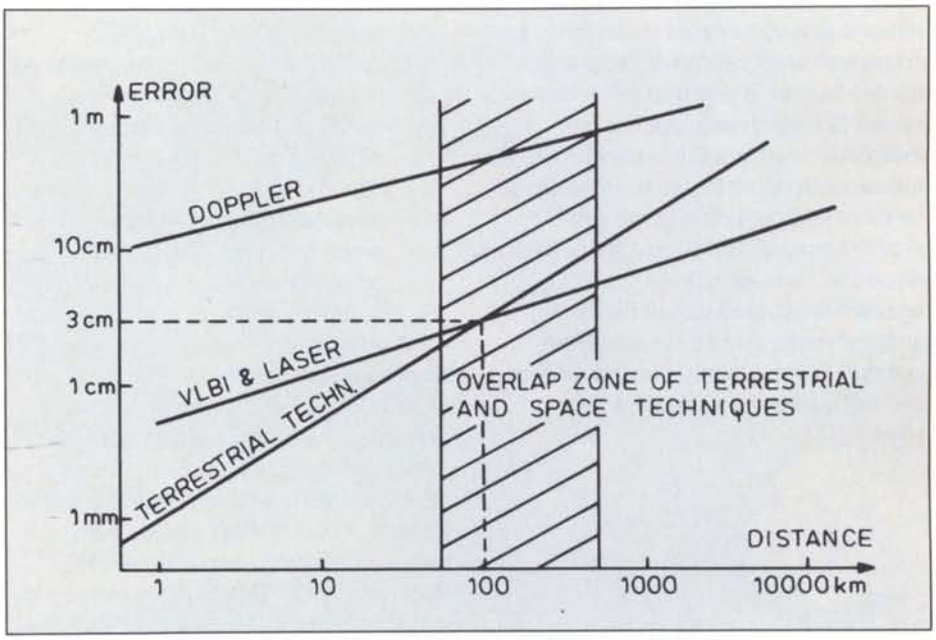


Figure 4 – Typical accuracies for high-precision measurement techniques for geodynamics studies and earthquake research (logarithmic scale) (After Campbell, 1978)

Conclusions

The time has come when space techniques can be considered complementary tools for geoid crustal-movement measurements, their usefulness being enhanced by their immediate availability for both regional and global applications. Satellite imagery can be used in many more ways to the benefit of interdisciplinary research in geophysics and geology, while the ultimate capabilities of microwave ranging techniques (Doppler) have yet to be fully exploited.

Very-long-baseline-interferometry and laser-tracking methods are direct competitors as regards performance, cost and operational flexibility.

The new techniques that are coming along, such as active space sensors combined with passive ground targets, will further increase the cost-effectiveness of field operations, but they will not be available before the end of the decade.

Le deuxième Ensemble de Lancement Ariane (ELA-2)

C. Dana, Direction des Systèmes de Transport spatial, ESA, Paris

Le programme de réalisation d'un deuxième Ensemble de Lancement (ELA-2) constitue une extension majeure des moyens de lancement d'Ariane, en vue d'une meilleure satisfaction des besoins des utilisateurs du lanceur. La construction d'ELA-2 répondait à un double besoin: d'une part, se prémunir contre tout incident grave sur les installations de lancement actuelles, qui entraînerait un arrêt des lancements et de ce fait un préjudice grave aux programmes utilisateurs; d'autre part, disposer d'une souplesse opérationnelle accrue qui facilite la programmation des lancements en fonction de l'évolution des calendriers de réalisation et des besoins des satellites.

Les objectifs généraux du programme ELA-2 sont les suivants:

- assurer la redondance de l'Ensemble de Lancement actuel;
- accroître la souplesse opérationnelle et la compétitivité par réduction sensible de l'intervalle minimum entre deux lancements et par optimisation des coûts d'exploitation;
- développer les moyens de préparation des charges utiles correspondant à ces objectifs opérationnels.

Conception générale
Les études de conception et d'avant-projet sommaire, qui ont conduit à la définition de la configuration technique du deuxieme Ensemble de Lancement Ariane, ont été menées par le CNES depuis la mi-1979 jusqu'à la fin 1980. Parmi les différentes solutions techniques examinées dans la réalisation d'ELA-2, l'optimisation des coûts d'investissement et d'exploitation a notamment été recherchée. Les études d'avant-projet ont fait l'objet d'une revue de conception à la mi-1979 selon la méthode 'Analyse de la valeur' et d'une revue de définition préliminaire en octobre 1980.

ELA-2 sera réalisé à Kourou à proximité de l'Ensemble de Lancement actuel (ELA-1). Conçu pour le lancement des versions du lanceur Ariane 1, 2, 3, il pourra être adapté moyennant quelques investissements spécifiques, pour assurer les lancements des versions améliorées du lanceur au-delà d'Ariane 3.

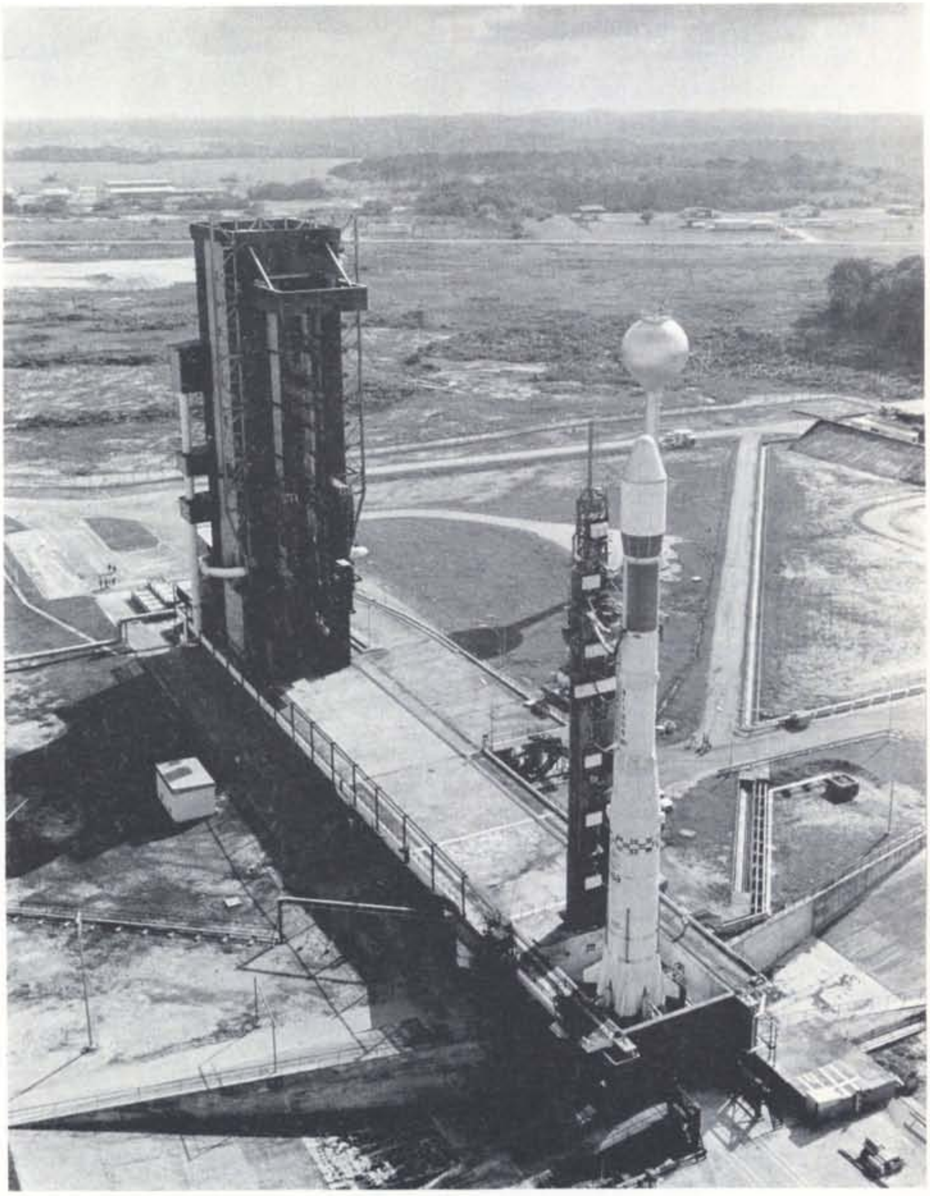
ELA-2 est constitué essentiellement de deux zones distinctes: la *zone de préparation des lanceurs* et *la zone de lancement.*

La zone de préparation des lanceurs est indépendante et située à une distance de sécurité (950 m) de la zone de lancement, laquelle est également à distance de sécurité de l'actuelle zone de lancement d'ELA-1. Les deux zones d'ELA-2 sont reliées entre elles par un chemin de roulement sur lequel se déplacent les tables de lancement mobiles.

La séparation géographique de la zone de préparation des lanceurs et de la zone de lancement est la caractéristique principale de l'ELA-2. Cette configuration permet en fait de bénéficier d'une grande souplesse d'utilisation des moyens de lancement puisqu'un lanceur peut être érigé, assemblé et contrôlé en zone de préparation, alors que lanceur précédent, érigé sur sa table de lancement mobile amené en zone de lancement, y subit les dernières opérations de préparation en vue de son lancement imminent.

Il convient de rappeler que la conception classique d'ELA-1 ne permet que l'érection, l'assemblage et le contrôle d'un lanceur à la fois. L'exécution de toutes ces opérations en série sur ELA-1 ne permet pas d'effectuer de lancement à des intervalles inférieures à deux mois. La possibilité d'utiliser en parallèle les deux zones de préparation et de lancement d'ELA-2 permet l'exécution simultanée de deux campagnes de lancement et par conséquent de réduire notablement le délai entre deux lancements.

Figure 1 – Table de Lancement ELA-1



La conception d'ELA-2 permet donc, en disposant de deux tables de lancement mobiles, d'effectuer des lancements à un intervalle d'un mois.

Le programme de réalisation d'ELA-2 comprend également l'extension de l'Ensemble de Préparation des Charges Utiles (EPCU) actuel en assurant notamment l'adjonction et l'agrandissement des locaux techniques existants, à savoir les Bâtiments de Préparation des Satellites (S1) et les Bâtiments de Remplissage et d'Assemblage des Satellites (S3).

Description des installations

Zone de préparation des lanceurs

Située à proximité immédiate de l'actuelle zone support d'ELA-1, elle comprend en complément aux moyens existants:

- un hall d'érection des étages;
- un dock d'assemblage lanceur (la conception est telle qu'un deuxième dock peut être facilement ajouté);
- un centre de contrôle et de lancement avec les équipements de vérification;
- une zone technique logistique regroupant les principales servitudes des complexes de lancement (production et stockage des fluides, climatisation centrale, magasin, bureaux, etc.).

Dans la zone de préparation des lanceurs sont effectuées les principales opérations suivantes:

- érection du lanceur jusqu'au niveau de la case d'équipements;
- contrôles d'étanchéité;
- contrôles électriques;
- contrôles du lanceur à distance durant la chronologie de lancement.

Le temps de présence du lanceur dans cette zone est d'environ un mois.

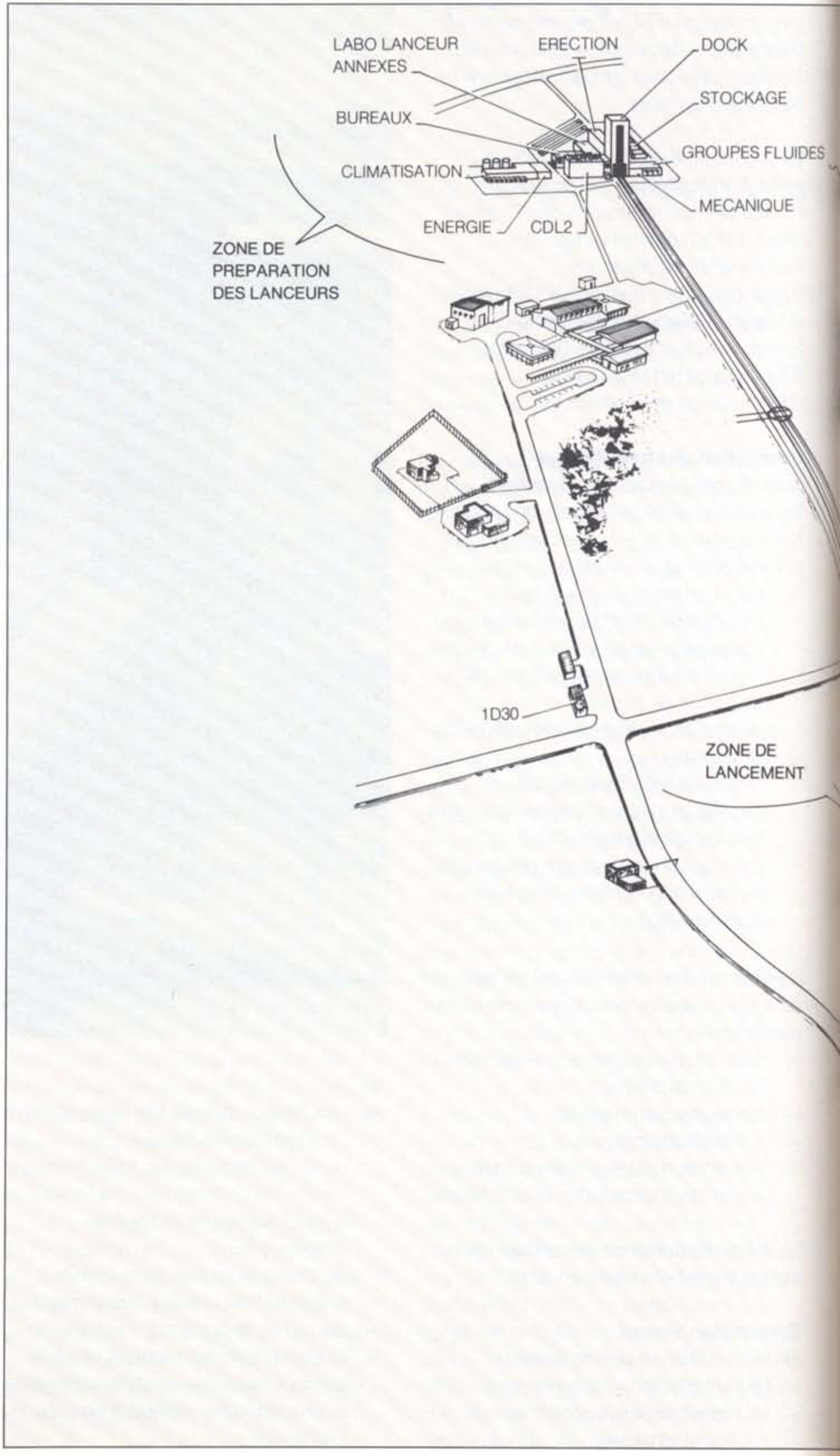
Zone de lancement

Située à 500 m au sud de l'aire de lancement d'ELA-1, elle comprend:

- le massif de lancement et les déflecteurs de jets;
- une tour ombilicale fixe regroupant tous les moyens de liaisons, contrôles, régulations, avitaillement et servitudes diverses liées au lanceur et à l'exploitation de la zone de lancement;
- un portique de servitude mobile protégeant le lanceur, notamment la partie haute du lanceur (en vue de l'assemblage des charges utiles au lanceur dans une enceinte climatisée et propre) et permettant les accès principaux au lanceur;
- des zones de stockage et de transfert des ergols pour les avitaillements opérationnels N_2O_4, UDMH, LO_2, LH_2. Elles sont pour la plupart communes aux deux Ensembles de Lancement ELA-1 et ELA-2.

Pour son transfert entre la zone de préparation et la zone de lancement, le lanceur, assemblé jusqu'au niveau de la case d'équipements est posé à la verticale sur sa table de lancement, elle-même solidaire d'une structure support fortement dimensionnée, se

Figure 2 – Ensemble de Lancement ELA-2



déplaçant sur une double voie ferrée à l'aide de bogies.
Une plate-forme tournante permet d'assurer le croisement et l'aiguillage des deux tables de lancement sur le chemin de roulement.
Dans la zone de lancement sont effectuées les principales opérations suivantes:

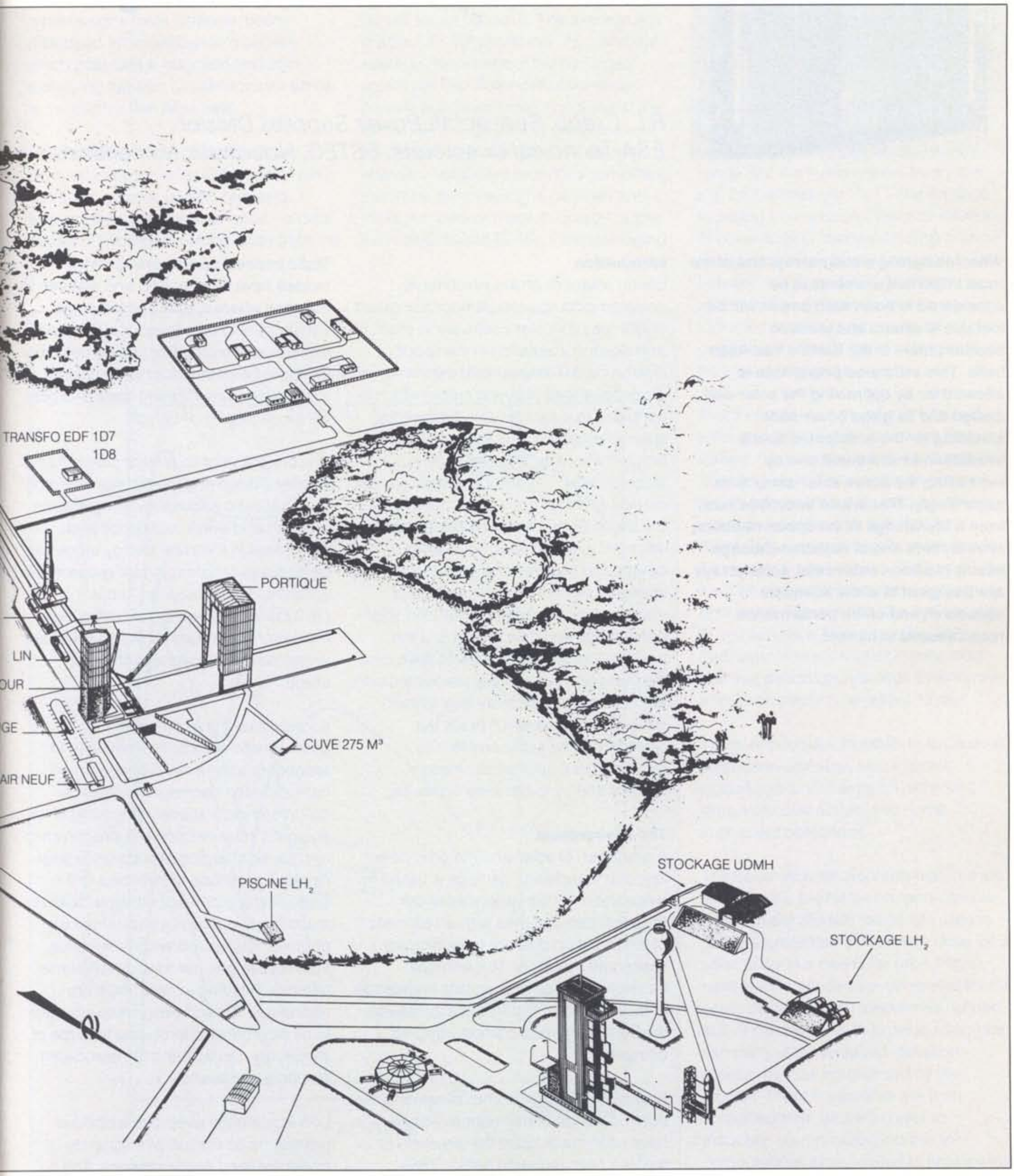
- phase finale de raccordement et de contrôle du lanceur;
- mise en place, assemblage et contrôle de la charge utile, assemblage de la coiffe;
- préparation au lancement;
- chronologie et lancement.

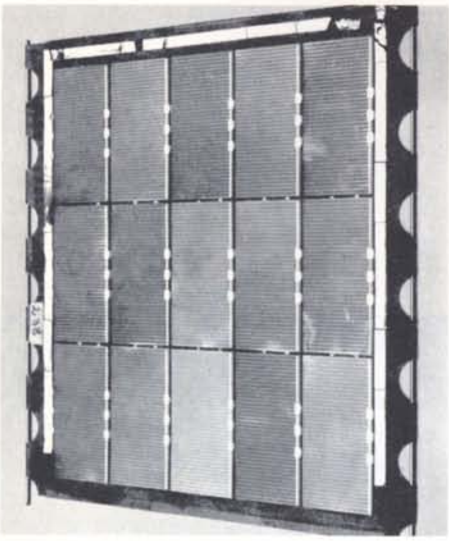
Le temps de présence du lanceur dans cette zone est inférieur à un mois.

Calendrier prévisionnel
En vue d'une disponibilité opérationnelle à la fin 1984 conduisant à un premier lancement au premier trimestre 1985, le chantier de réalisation devra être achevé à la mi-1983, afin de laisser environ 14 mois pour toutes les opérations de recette, les mises au point et les validations.

Les principales étapes de réalisation sont les suivantes:

mi-1981:	début du chantier d'infrastructure en Guyane
mi-1981:	lancement des approvisionnements en Europe
mi-1982:	fin du chantier de gros oeuvre d'infrastructure permettant le début du chantier d'équipements
fin-1982:	fin du second oeuvre d'infrastructure
mi-1983:	fin du chantier d'équipements
mi-1983:	début des opérations de recette
fin-1984:	fin de la mise en service et validation.


TRANSFO EDF 1D7
1D8
PORTIQUE
LIN
OUR
GE
CUVE 275 M³
AIR NEUF
PISCINE LH₂
STOCKAGE UDMH
STOCKAGE LH₂



Solar-Array Radiation Damage

R.L. Crabb, Spacecraft Power Supplies Division, ESA Technical Directorate, ESTEC, Noordwijk, Netherlands

When designing a solar array, one of the most important elements to be considered is how much power will be lost due to proton and electron bombardment in the Earth's Van Allen belts. This estimated power loss is allowed for by optimising the solar-cell design and its glass cover-slide shielding for the anticipated space irradiation environment and by increasing the active solar-array area accordingly. This article describes how, from a knowledge of the space-radiation environment and of radiation-damage effects in silicon solar cells, solar arrays are designed to allow adequate spacecraft end-of-life performance requirements to be met.

Introduction

Silicon solar-cell arrays which have powered most spacecraft since Vanguard (1958) are particularly sensitive to proton and electron irradiation in the space environment. The solar cells exhibit a progressive loss of power output which is attributed to a steady fall in base-region spectral response. This fall in response is brought about by the premature recombination of photogenerated current carriers at defect complexes created in the silicon crystal lattice by proton and electron bombardment. Solar-array design and performance predictions have improved along with the collection of more and more environmental and solar-cell material and device data, but the basic problem remains: how to overcome the mass and size penalty associated with this important solar-array degradation factor. Current research holds the promise of solving the problem by reducing the culprit silicon impurity content and by in-situ laser annealing.

The environment

A prediction of solar-array in-orbit power loss due to radiation damage is based on a correlation of laboratory solar-cell radiation damage data with an estimate of the radiation dose for the anticipated spacecraft trajectory. This estimate therefore requires an accurate knowledge of the spacecraft flight-path exposure to the Earth's charged-particle trapping domains.

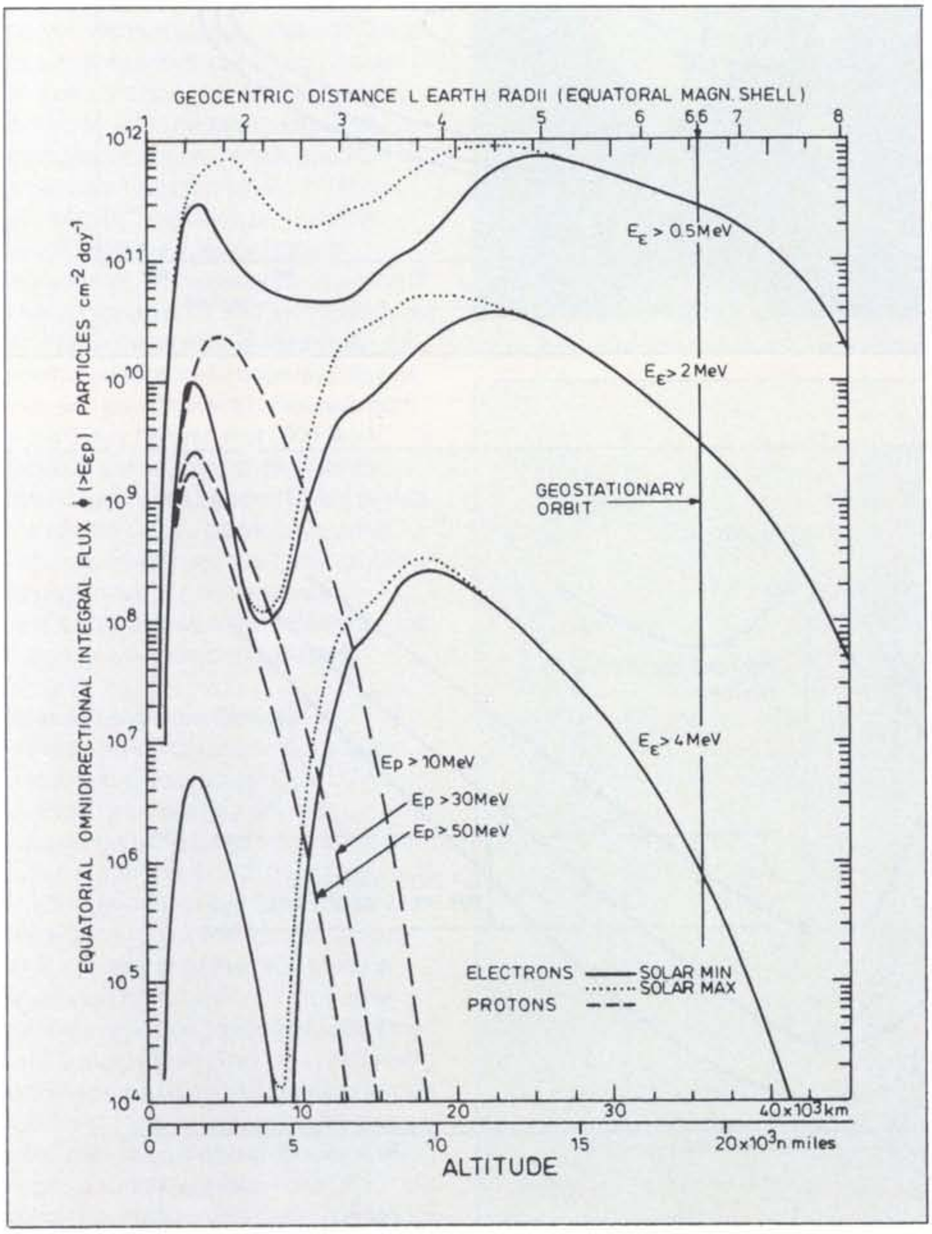
Steady improvements and refinements to our knowledge of the magnetosphere have been made since the discovery of the Van Allen radiation belts in 1959. Static trapped-particle-environment models have thus evolved and matured to the point where spatial and temporal variations may be allowed for. The radial electron and proton flux profiles depicted in Figure 1 demonstrate the complexity of the task and why different types of orbits will be damaging or benign.

The prediction of solar-flare proton fluxes is more difficult and models are based on a probabilistic analysis involving mission duration and event confidence levels. The high doses in the lower energy range can be particularly damaging for spacecraft in eccentric or geostationary orbits (36 000 km) whereas spacecraft in low-inclination, near-Earth orbits (600 km) are protected by geomagnetic shielding effects.

An associated phenomenon – geomagnetic substorms – can lead to secondary solar-array damage. In this case localised geomagnetic-field distortions allow spacecraft irradiation by energetic solar-electron streams, which in turn cause charging of surfaces to large negative potentials with respect to the surrounding plasma or different dielectric materials. Surfaces not discharged by photo-emissions following emergence from eclipse give rise to large differential potentials leading to destructive arc discharges. Special design features have to be incorporated to obviate this type of secondary damage and the associated electrical interference.

Low illumination levels place obvious restrictions on the use of solar-array power for deep-space missions. Solar-

Figure 1 – Earth's trapped electron and proton radial-flux profiles



array designs have, however, been developed for spaceflights to Jupiter, which posesses a magnetic field and damaging trapped radiation zones similar to the Earth's Van Allen belts.

The radiation in interplanetary space is dominated by the solar wind, solar-flare radiation, galactic cosmic rays and micrometeoroids. The solar wind consists mainly of hydrogen moving away from the Sun at about 500 km/s. The average flux is about 2×10^8 atoms $cm^{-2} s^{-1}$ and the average density about five hydrogen atoms per cm^3. Solar-cell cover-slides provide adequate protection against the rather low energy (keV s) protons and electrons. Much more serious are the energetic solar-flare eruptions comprising electrons, protons, alpha particles and small numbers of medium-energy nuclei such as C, N and O. The most damaging components for solar arrays are the protons and alpha particles. Galactic cosmic rays – usually neglected in solar-array damage predictions – consist of approximately 90% protons, 8% alpha particles and 2% nuclei of heavier elements. The energies are in the GeV range, but the fluxes are extremely low, e.g. 2.5 particles $cm^{-2} s^{-1}$. The damage expected from micrometeoroids is related to cover-slide or thermal-coating erosion, the particle mass of most concern being between 10^{-9} and 10^{-6} kg. In-flight spacecraft performance has so far indicated that solar-array power output degradation due to micrometeroids must be almost negligible.

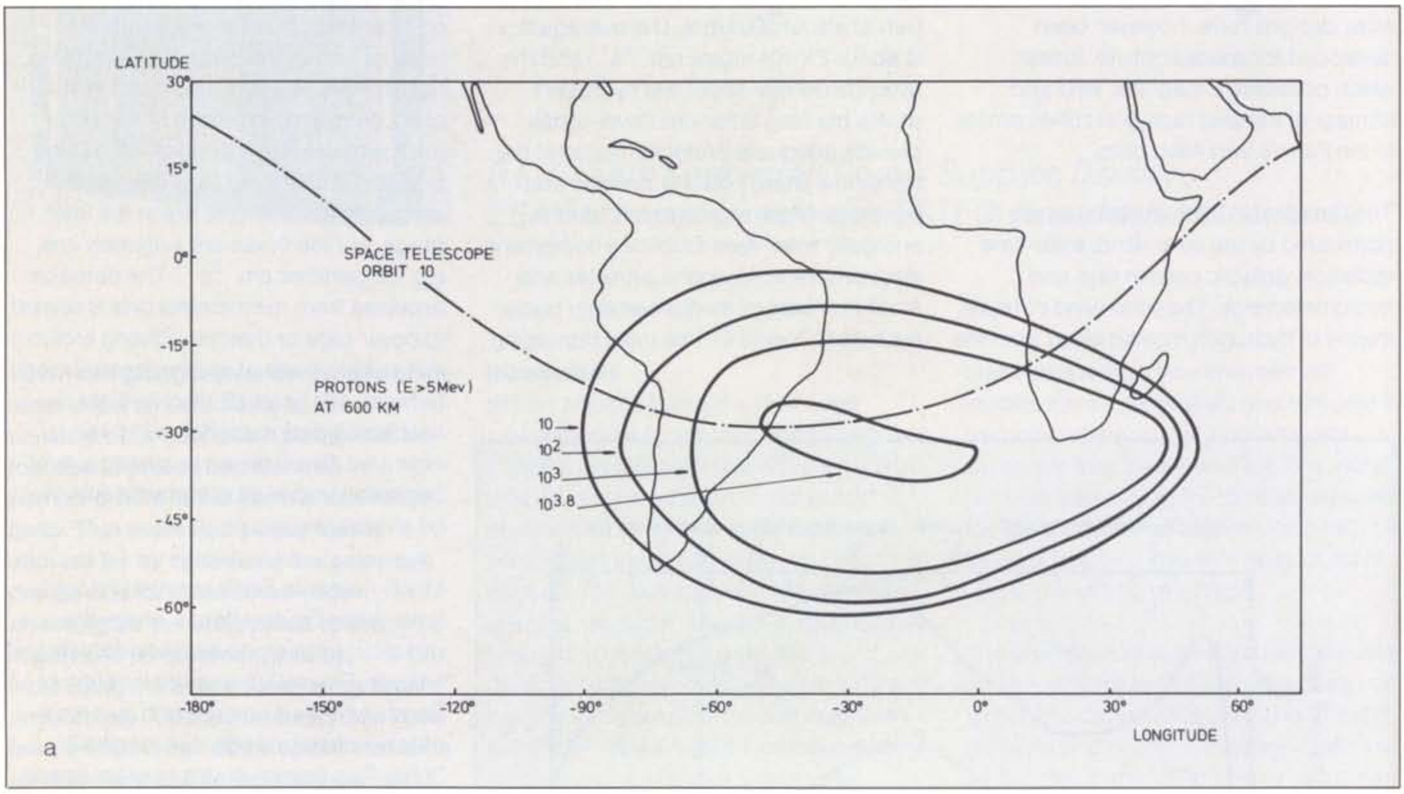
Much nearer to Earth, another hazard lurks in the South Atlantic where the radiation belts dip to an anomalously low altitude. Figure 2 shows the location of South-Atlantic Anomaly, and a vertical cross-section through it at longitude 35°W. This demonstrates how for Space Telescope orbits between 398 and 593 km it will be impossible to avoid an Anomaly encounter. This also applies to Spacelab. A typical Space Telescope (Fig. 3) or Spacelab orbit will thus comprise long flux-free periods punctuated by Anomaly encounters lasting for about 15 min.

These encounters, in addition to causing solar-array damage, also impose operational constraints on astronaut extra-vehicular activity and some instrument operations.

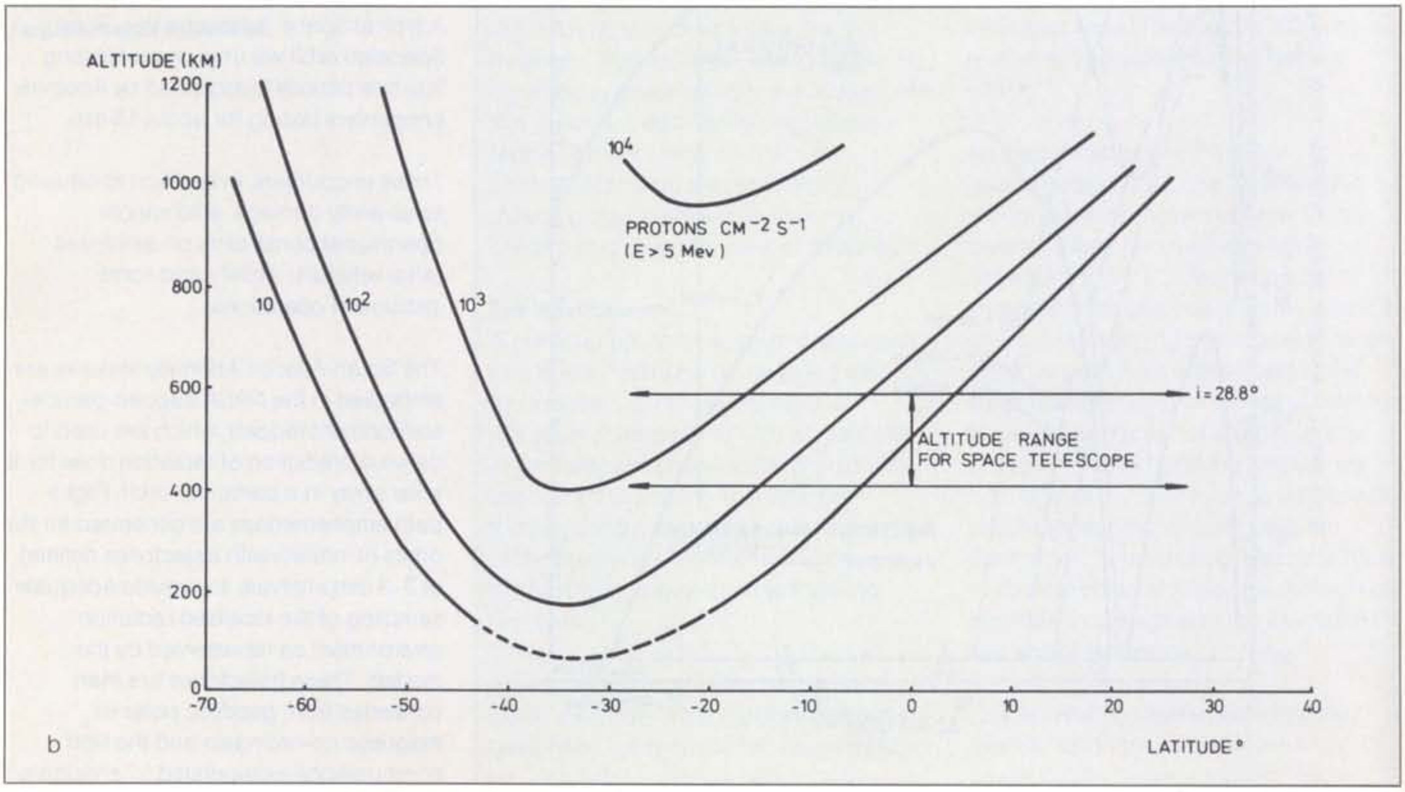
The South-Atlantic Anomaly features are embodied in the NASA trapped-particle-environment models, which are used to derive a prediction of radiation dose for a solar array in a particular orbit. Flight-path emphemerides are generated for the orbits of interest with trajectories defined at 2–3 min intervals, to provide adequate sampling of the localised radiation environment as represented by the models. These trajectories are then converted from geodetic polar to magnetic co-ordinates and the field computations extrapolated to anticipated

Figure 2a – Location of the South-Atlantic Anomaly

Figure 2b – Cross-section through the South-Atlantic Anomaly (35°W)



a



b

Figure 3 – The Space Telescope, with its roll-out solar-array blankets deployed

Figure 4 – Proton-damage ratio used to determine 1MeV equivalent electron doses

mission epochs, for which flight-path exposures to proton or electron trapping domains are computed.

For silicon solar-cell arrays it has been found desirable and possible to convert integral proton and electron-spectra outputs from the above computations into a monoenergetic 1 MeV equivalent electron flux which, when time-integrated, yields a 1 MeV equivalent electron dose ϕ(1 MeV electrons/cm^2).

These ϕ values are readily and inexpensively simulated by Van de Graaf accelerators, thereby enabling a solar cell's degradation characteristics to be characterised in the laboratory. The 'equivalence' concept holds good for penetrating radiation for which proton and electron irradiation produce the same qualitative solar-cell device degradation. The conversion of proton fluxes to equivalent 1 MeV electrons fluxes is made by means of experimentally determined proton-damage ratio curves such as those depicted in Figure 4, from which it may be seen that 3000 1MeV electrons are required to produce the same degradation as one 10 MeV proton in a 10 ohm cm n-p silicon solar cell. It should be mentioned that these proton-damage ratios are not universal constants, but have to be determined for each new type of silicon solar cell.

Solar-cell radiation damage

The modern silicon solar cell is a large-area photo-diode (typically 2 × 4, 2 × 6 or 5 × 5 cm²) produced by diffusing phosphorus into a boron-doped, single-crystal silicon wafer ($\sim$200 μm) to form a very shallow n on p junction (0.15 μm). The shallow junction enhances the blue photon response of the cells, which is required to make best use of the solar spectral irradiance conditions above the Earth's atmosphere. This blue response is further enhanced by an anti-reflection coating of titanium dioxide on the active cell surface, which also embodies a fine negative-current collection grid of titanium, palladium and silver. The rear

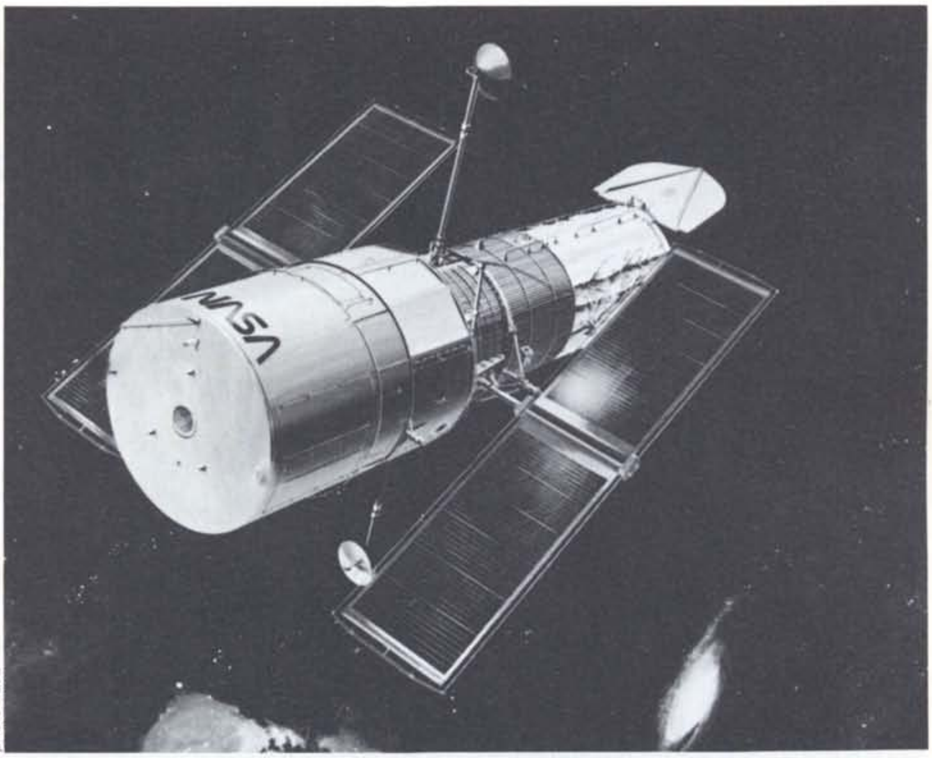


photo nasa

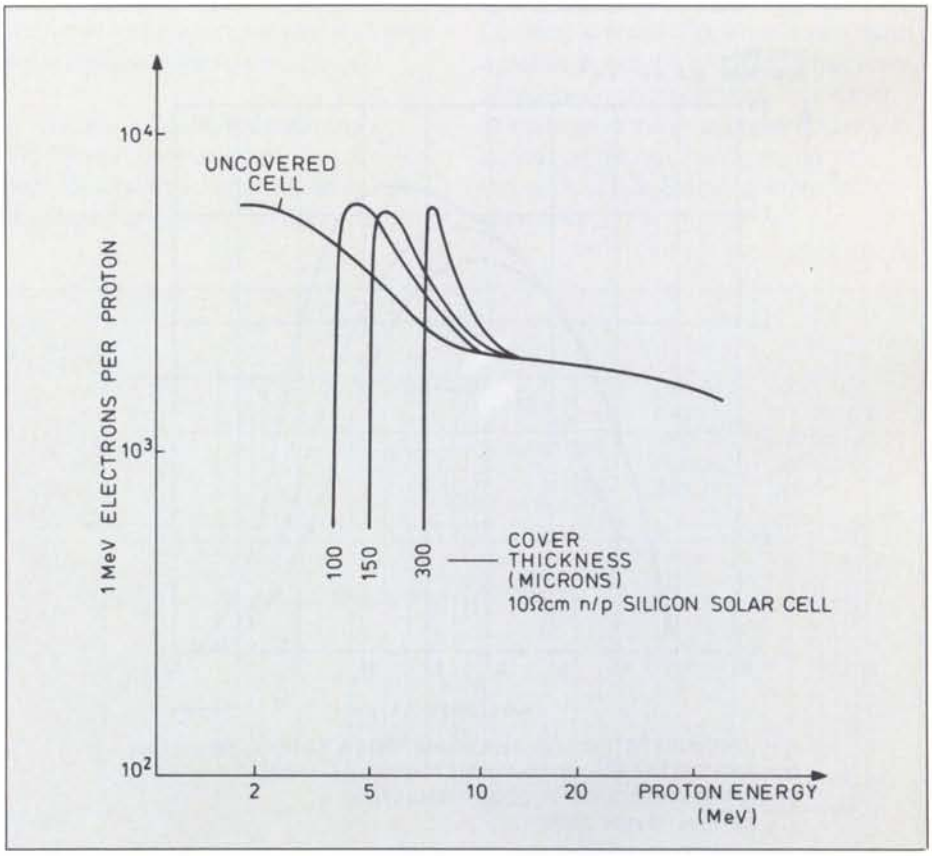
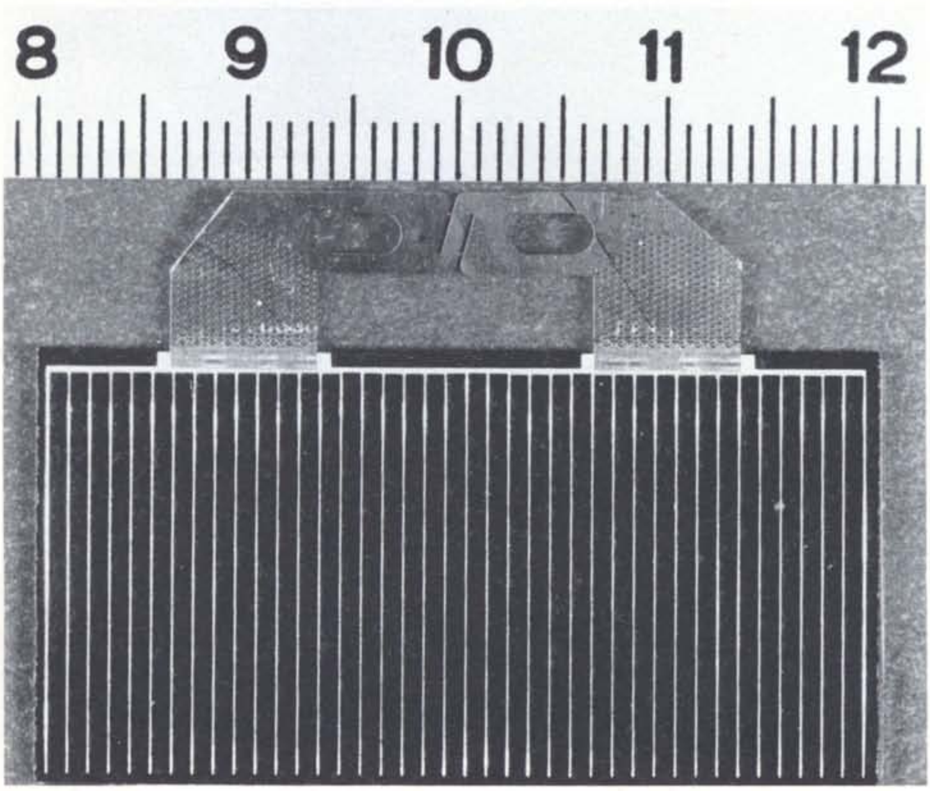
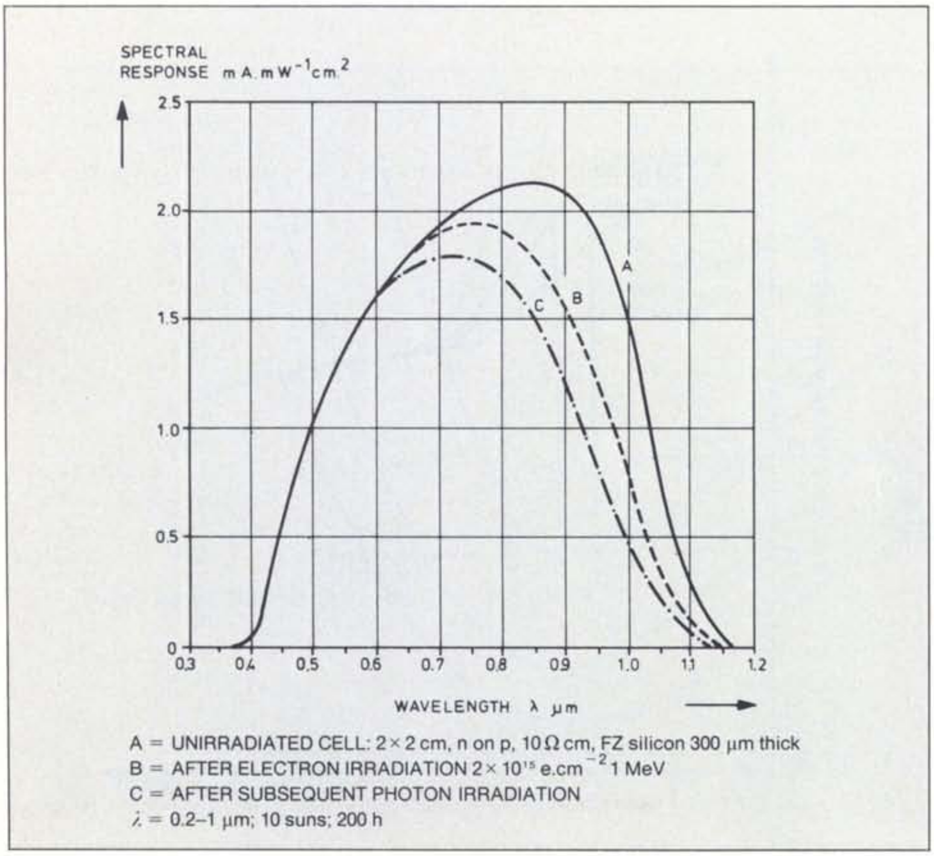


Figure 5 – An AEG Space-Telescope silicon solar cell; efficiency 12.7%

Figure 6 – Solar-cell response degradation after sequential electron-photon irradiation





cell curface is completely coated with the same metallisation to form the positive contact (Fig. 5). Current state of the art efficiency is about 14%.

The absorption characteristics of silicon are such that blue photons are absorbed close to the cell surface while red and infrared photons are absorbed at appreciable depths (>100 μm). The total spectral response range extends from 0.35 to 1.2 μm, the lower limit being set by the 'cut-on' characteristics of a cerium-stabilised glass cover-slide, which is fixed to the active cell surface with silicone adhesive. The cover-slide (100–300 μm thick) affords radiation-damage protection and provides an emissive thermal-control surface.

The silicon solar-cell spectral response curve takes the form depicted in Figure 6, which also illustrates why electron bombardment has such a deleterious effect on a cell's electrical performance. Penetrating electron or proton irradiation creates vacancies in the silicon lattice. These defects act intrinsically or combine with other impurities to form recombination centres, which cause photogenerated current carriers to be annihilated before being collected at the solar-cell p-n junction. Since the solar cell has a shallow junction and is mainly base-region responsive, the performance degradation manifests itself by a drop in red and infrared spectral response (curve A degrades to curve B in Fig. 6). For certain types of silicon it has also been found that subsequent photon irradiation (illumination) can render the irradiation-induced defect centres even more damaging and cause a further drop in red and infrared response (curve C in Fig. 6).

Before considering what research has been and is being undertaken to overcome the radiation-damage problem, it is propitious to examine our 'flight' experience to date for a few ESA spacecraft.

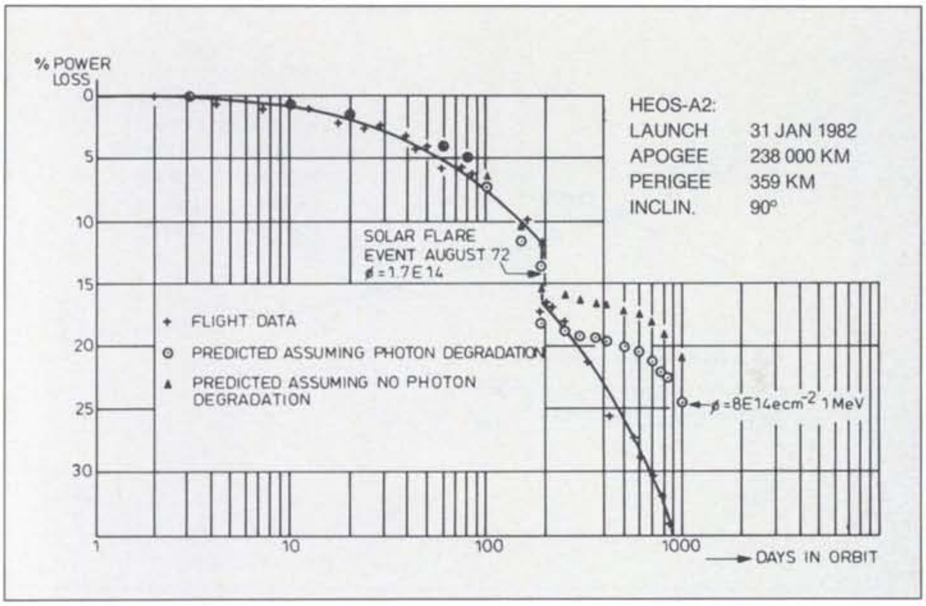


Figure 7 – Heos-2 solar-array performance degradation (Cells: SAT n on p, 10 Ω cm; Float-zone silicon, 300 µm thick; Cover-slides 150 µm microsheet)

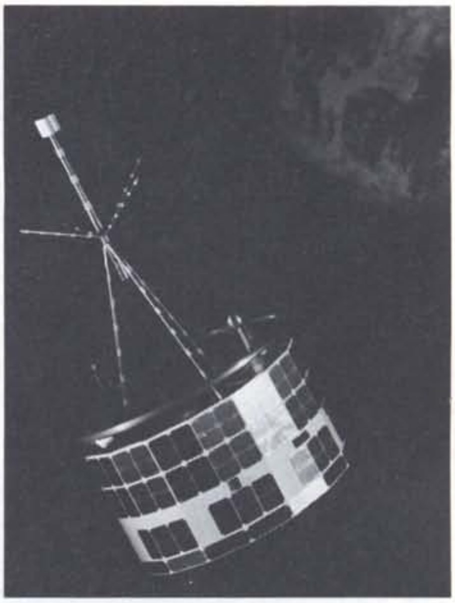


Figure 8 – The Heos-2 spacecraft

Flight data

From Figure 7 it can be seen that the predicted degradation in the Heos-2 solar array (Fig. 8) agreed well with the flight data (± 1% accuracy) until day 182, when heavy damage was sustained due to the severe solar-flare event of August 1972. Thereafter the predicted degradation was in poor agreement with the in-flight power-output degradation, which was much more severe than expected. The solar cells were particularly sensitive to the aforementioned photon degradation effect, which was only discovered in the laboratory after the Heos-2 launch. The excessive degradation cannot, however, be accounted for on this basis. It is much more likely that areas of exposed silicon and contacts suffered anomalously high proton damage, which caused a change in cell voltage/current characteristic.

In the case of Cos-B, the solar array (Fig. 9) was constructed cognizant of the need for total shielding of the solar-cell active area and of photon-degradation hazards. For these elliptic orbits, a spacecraft can spend 30 min per orbit traversing the Van Allen belts, followed by several days of flux-free flight, possibly punctuated by a solar-flare event as in the case of Heos-2. The flight data from the Cos-B spacecraft (Fig. 10) is in very good agreement with the predicted solar-array degradation characteristics. The rather sharp knee in the degradation curve was caused by the rapid and progressive incursion of Cos-B's perigee into the Van Allen belts.

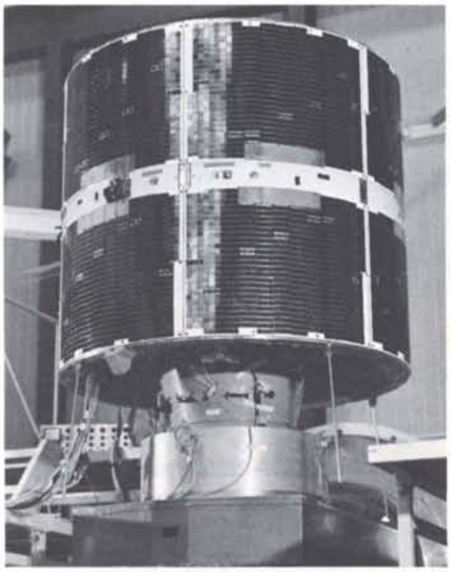


Figure 9 – The Cos-B spacecraft (9480 solar cells in 12 panels)

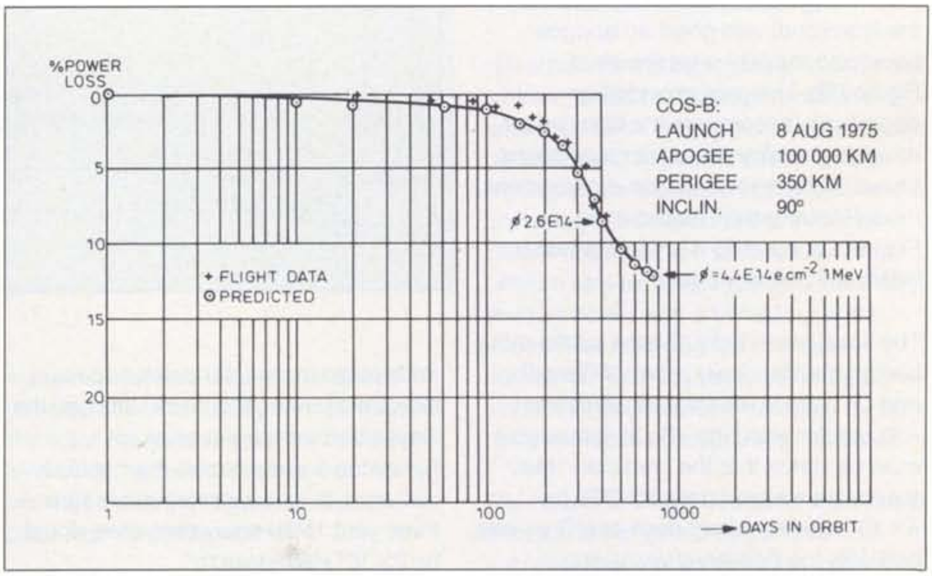


Figure 10 – Cos-B solar-array performance degradation (Cells: Ferranti n on p, 10 Ωcm; Crucible-grown silicon, 300 µm thick; Cover-slides 300 µm cerium-stabilised microsheet)

Figure 11 – The Geos spacecraft (7200 solar cells in four panels)

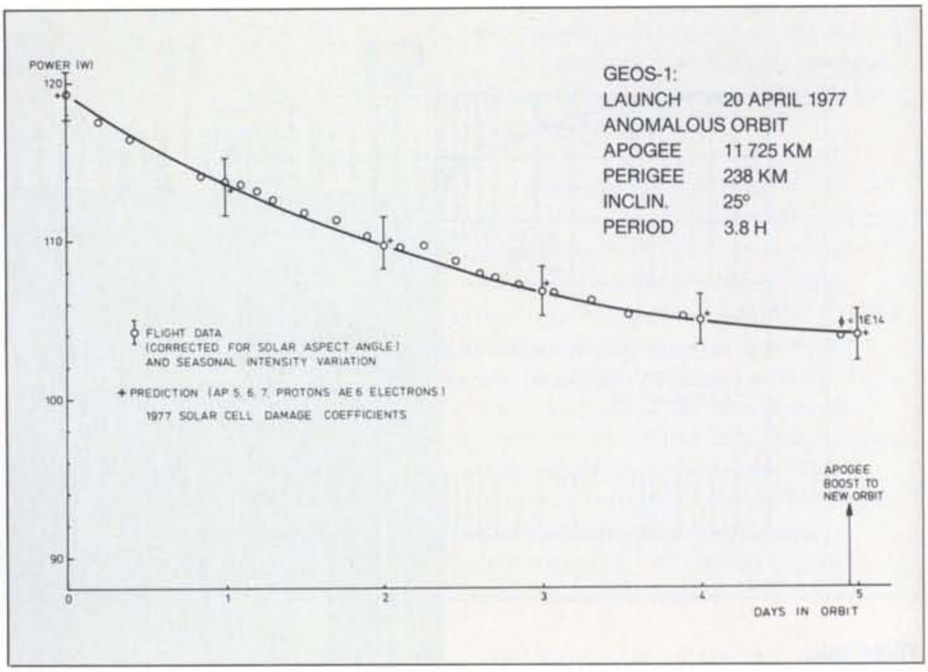


Figure 12a – Geos-1 solar-array performance degradation during the first five days in a damaging eccentric transfer orbit (Cells: n on p, 2 cm × 2 cm, 1 Ω cm; Cover-slides 300 μm fused silica, coated with In_2O_3)

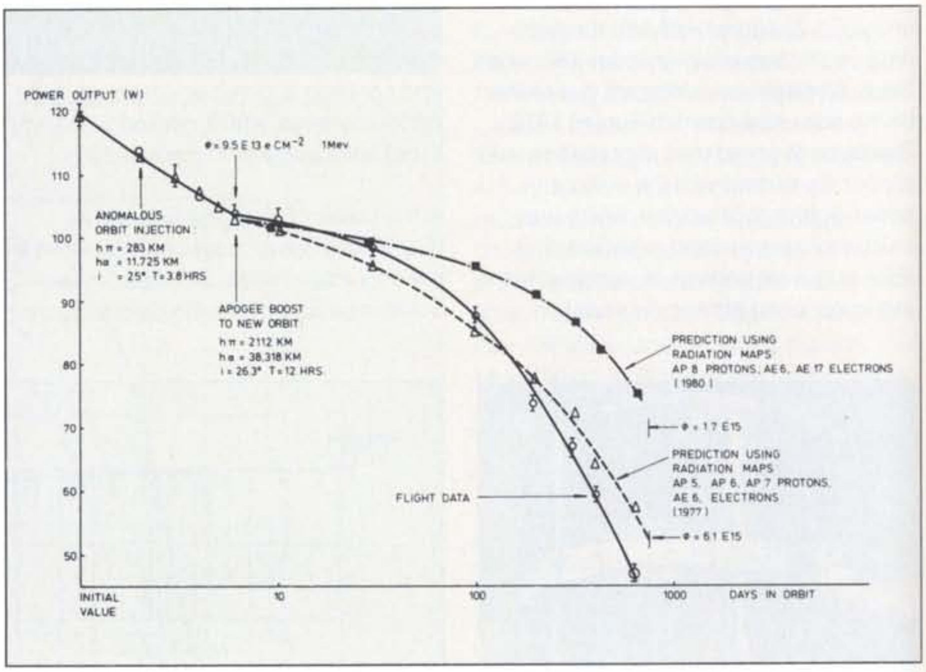


Figure 12b – Geos-1 solar-array performance degradation in a damaging eccentric orbit

A partial failure of the Delta vehicle that launched Geos-1 in April 1977 left the satellite (Fig. 11) in an unforeseen parking orbit, traversing the most damaging regions of the Van Allen belts.

The orbital characteristics and solar-array degradation are shown in Figure 12a for the first five days, during which the solar array suffered as much damage as originally anticipated for the whole two-year lifetime. After this damaging period the spacecraft was given an apogee boost into the new orbit shown in Figure 12b. This orbit provided an opportunity to compare the flight solar-array degradation data with predictions based on different radiation-environment model inputs which, as shown in Figure 12b, agree to a greater or lesser extent with the flight data.

The solar array degradations for the more benign geostationary orbits of Geos-2 and OTS are in reasonable agreement with predictions (Figs. 13a,b), although it must be stated that the predicted 1 MeV equivalent electron dose for OTS (a 4×10^{14} electrons/cm² dose after 3 yr) was probably too conservative, having anticipated more solar flares and rear-side irradiations (30% extra) through the woven carbon-fibre/aluminium honeycomb array panels than actually occurred. In retrospect a more realistic three-year 1 MeV equivalent dose would be 2×10^4 electrons/cm².

The inclusion on spacecraft, whenever possible, of inexpensive radiation detectors, together with adequate solar-array diagnostics, would considerably enhance our ability to refine degradation predictions.

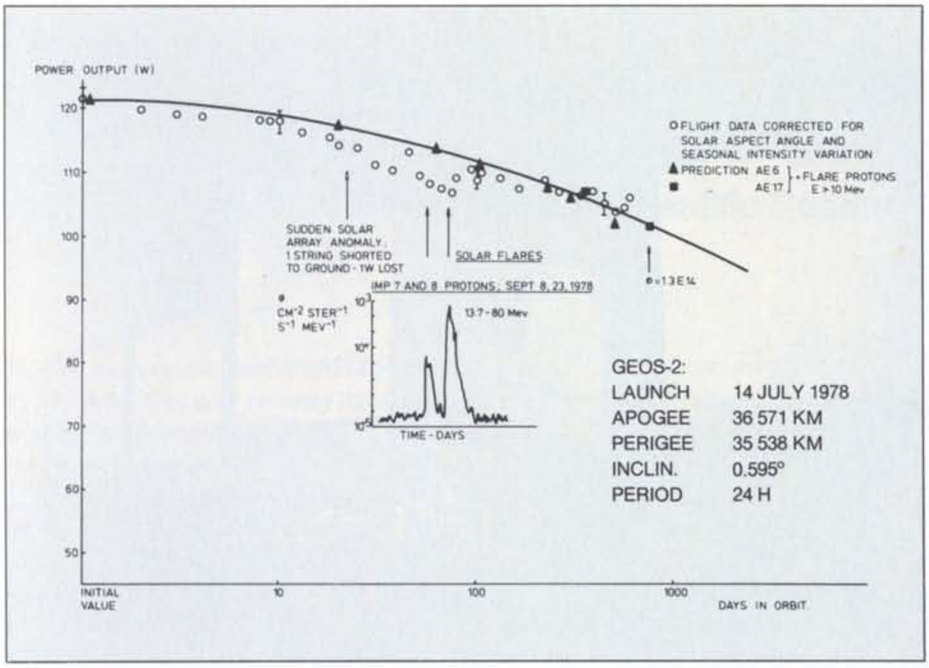


Figure 13a – Geos-2 solar-array performance degradation in a benign geosynchronous orbit (Cells: n on p, 2 cm × 2 cm, 1 Ω cm, float-zone silicon 350 μm thick; Cover-slides 300 μm fused silica, coated with In_2O_3)

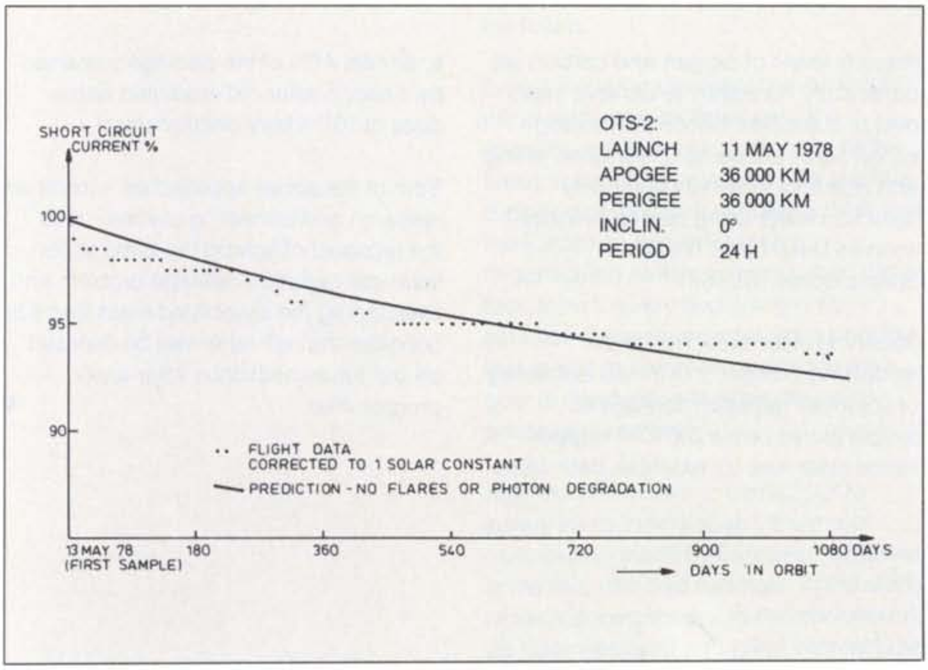


Figure 13b – OTS solar-array performance degradation in geostationary orbit (Cells: AEG, 2 cm × 2 cm, n on p, 1 Ω cm, Waso-S silicon 200 μm thick, TiO anti-reflection coatings; Cover-slides 300 μm cerium-doped PPE microsheet)

Improving solar-cell radiation resistance
The earliest improvements in radiation resistance came in the summer of 1960 when RCA researches established a significant breakthrough by changing the p-n junction configuration of the solar cell from p on n to n on p. The reasons for this improvement were related to mobility considerations for the current carriers in the solar-cell base region. For the same level of degradation, this new cell withstood a 30 times greater electron dose than its predecessor.

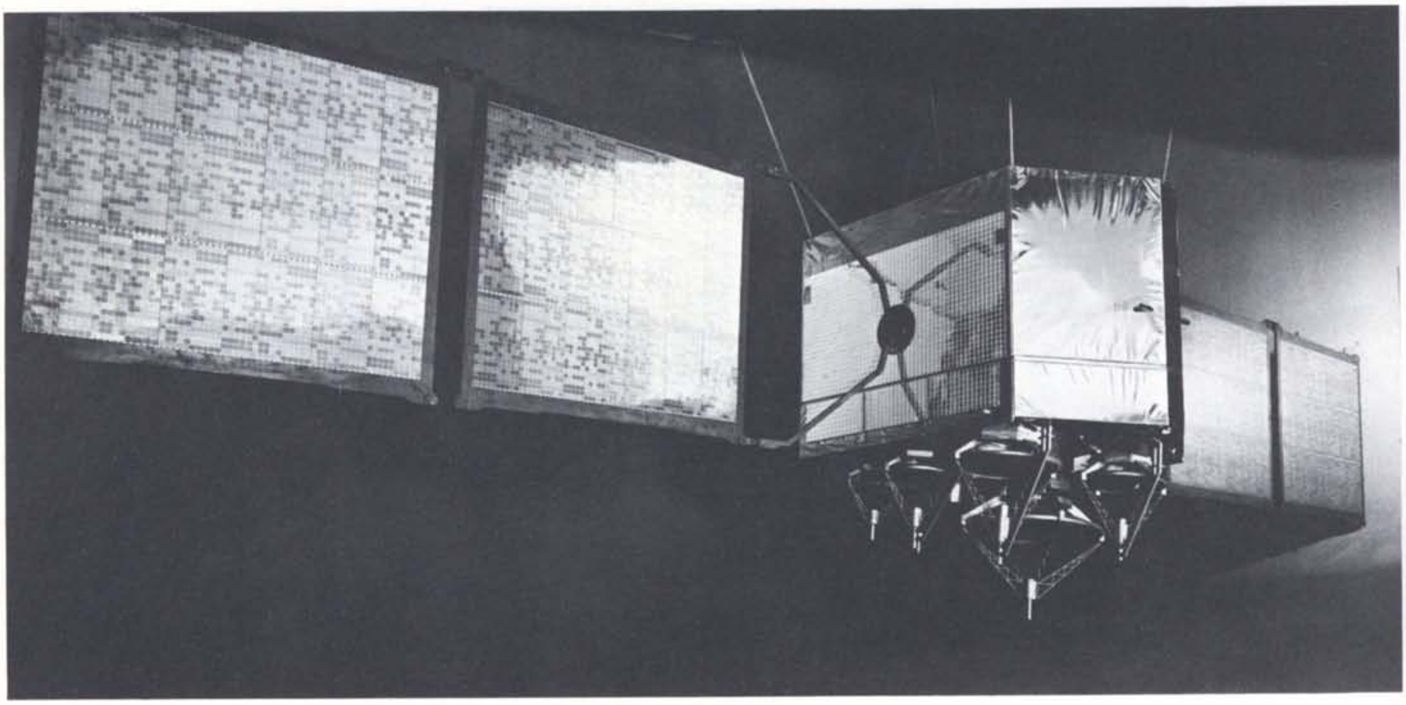
With the demonstration of the artificial Starfish electron belts in 1962, military interest grew and extensive annealing studies were initiated. By 1968 researchers at the Naval Research Laboratories in Washington DC had established the feasibility of almost totally annealing proton damage in n on p silicon solar cells at temperatures of 500°C, with various degrees of annealing for lower temperatures. At this point the engineering problems associated with in-situ annealing in space seemed to thwart further investigation.

By 1965 it had become appreciated in Europe that oxygen-lean Float-Zone (FZ) silicon provided greater radiation tolerance than Czochralski (CZ) silicon (FZ cells withstood twice the fluence of CZ cells before exhibiting the same degradation). In the ensuing years a number of 'device' design changes were considered which effectively circumvented the basic radiation defect problem and at the same time provided improved end-of-life power-to-weight ratios for solar arrays. These methods were quite successful; thin cells which sacrificed mass and the associated superfluous 'red response' already destined to be lost during irradiation; improved blue response (largely unaffected by penetrating radiation) from shallower junctions; and improved antireflection coatings.

Nevertheless, the basic desire to solve the intrinsic radiation-damage problems associated with the solar-cell base silicon persisted and this same period (1966) witnessed considerable efforts following a Soviet lead to develop self-annealing, lithium-doped p on n silicon solar cells. Lithium acts as a highly mobile, interstitial, shallow donor with a behaviour in the silicon host reflecting the chemical equilibrium of the system, rather than the kinetics-limited situation exhibited by the more immobile substitutional impurities.

The results of the US research were rather mixed and not generally considered a success. This was unfortunate, since the

Figure 14 – The OTS spacecraft (16 080 solar cells on four rigid panels)



most promising results to be achieved emerged from Europe in 1972 (ESA/ESTEC-sponsored research at Siemens), but arrived too late to make a significant impact on the course of events.

Present research in the USA and Europe is mainly centred on 'improved silicon material' studies to enhance efficiency and radiation resistance. It has been found that the use of gallium rather than boron as a base silicon dopant can lead to the elimination of the photon degradation effect and that reduced impurity levels of oxygen and carbon are particularly necessary to achieve these overall objectives. Silicon processing experiments are being undertaken, along with attempts to enhance impurity detection levels using new techniques such as Deep Level Transient Spectroscopy (DLTS).

Scanning laser experiments are revitalising prospects of in-situ annealing of solar-cell radiation damage at temperatures below 200°C. A copper-halide laser has, for example, been used to anneal 41% of the damage sustained by a silicon solar cell irradiated with a dose of 10^{15} 1 MeV electrons/cm^2.

Both of the above approaches – materials research and annealing studies – hold the prospect of solving the basic silicon solar-cell radiation-damage problem and overcoming the associated mass and size penalties that will otherwise be imposed on our future ambitious solar-array programmes.

Addresses to the Science Programme Committee

Address by the Italian Minister for Scientific Research

This address by the Honourable Mr. Pierluigi Romita, until recently Italian Minister for Scientific Research, is extracted from a presentation that he made to members of the Agency's Science Programme Committee (SPC) during their meeting on 25 and 26 June in Rome, on the occasion of the retirement of Professor Edoardo Amaldi after two years as President of the SPC.

'The importance of the work carried out by your Committee is in compliance with the basic importance that scientific activities have always had within the European Space Agency. I think that the priority given to such activities should be maintained not least because of the institutional agreements of the Agency. Yet we must also take into account the role that some applications activities have acquired over the last few years, applications that will surely continue in the future.

Even if the latter represent the inevitable result of the new technologies, the scientific activity must continue to be the basis, the starting point even, for a further evolution of all space activities. I think that the European Space Research Organisation always accomplished this task, from the very beginning of its activities. It has thus respected a principle that is also in compliance with society's goal of conducting space science for peaceful purposes.

After the first missions, carried out to survey surrounding space, the major contribution made by European initiatives in the scientific field has been in the study of the magnetosphere. In this connection, we have observed with great interest how the ESRO satellite launches, conducted at an average of one per year between 1968 and 1974, have been followed by more important satellite launches during the 1975–1979 period, as the 100 kg median weight of the early satellite payloads has grown to closer to 300 kg.

This growth has been due to the new approach pursued in the survey of the magnetosphere, progressing from the earlier low, and extremely eccentric orbits (Heos-1 and 2) to today's synchronous ones. As we all know very well, the Earth's whole environment depends on the magnetosphere, and I therefore think that ESA has done very well to increase this research by asking its Member States for adequate financial contributions.

I think that these sorts of studies should always be carried out on a wide organisational basis, because the collection of comparative data on a wide scale can be extremely useful. They can only result from large projects which can only be carried out thanks to international cooperation, not only within ESA but also between ESA and the other nations that make important contributions to space science.

I therefore think that your Committee should act within this framework, to provide appropriate programming for the Agency. These projects will pave the way to a further development of the experiments for the measurement of particles and radiation.

They not only represent the basis for the analyses that will be carried out beyond the magnetosphere, as the ISEE satellites are already doing, but also for those that will be implemented on the primary energy source of our solar system.

In this context, the ISPM project represents an evolution in these surveys, and its relevance cannot be neglected. By leaving the ecliptic, our measuring instruments will

The Honourable Mr. Pierluigi Romita (right) during a visit to ESTEC, Noordwijk in March 1981

be able to monitor as yet unexplored space and to detect phenomena that will allow us to deepen our knowledge of the environment in which we live.

I would like to express my deepest appreciation for the efforts that the Executive is making to ensure that this mission is not made impossible by NASA's sudden cancellation of the second spacecraft.

Eventually, the Giotto project, which will take us to Halley's Comet in 1986, will provide a further contribution to these studies thanks to the space encounter taking place at what, from an astronomical point of view, is a relatively small distance from Earth.

Perhaps the giving of the name of the Florentine painter to the project has been the Committee's way of justifying the intrusion on the Comet's romantic image with the scientific survey?

Yet the Universe is also a form of architecture! How can we think about space science without considering the interrelated positions of the heavenly bodies, and how they move with respect to one another? I think it goes almost without saying that astronomy must be given an adequate role in space activities. I therefore welcome such projects as Hipparcos, which Italy has supported from the outset. Bearing in mind also the results that will be obtained from the Space Telescope project, undertaken in cooperation with NASA, Europe is playing an important role in the development of astronomy.

The Cos-B and Exosat satellites also represent important contributions to astronomical research from space, with the former's exploration of the gamma-ray sources in the Galaxy, and the accurate detection of the positions of X-ray sources that will be provided by the latter.'

At this point the Minister went on to discuss geographical and industrial returns in ESA (this aspect is reported in full in ESA Document SPC(81)MIN27), before returning to the more general aspects of European cooperation

'Italy is convinced that all our countries have a common interest in following up the European cooperation in the space field, not least because of the gap between the current European efforts and those that are carried out by other powers. Yet we cannot ignore the different views that the individual Member States have on such subjects as:
- the degree to which national initiatives can be coordinated within the framework of the Agency's programmes;
- the priorities to be assigned to the various problems;
- the basis on which an equilibrium between European autonomy and cooperation with other countries must be established.

The stalemate resulting from this divergence of opinion seems all the more worrying after the success of the first Shuttle flight, and when one takes into account the magnitude of the Agency's activities in:
- the compulsory programme which includes the scientific programme, through which Europe has acquired an extremely important position at an international level, the technological programme and the studies for future programmes;
- the field of applications satellites;
- the space transportation systems.

Within this framework, so as not to waste any time, I have recently met with some of my colleagues and I have corresponded with all the Ministers who represent the Agency's Member States. Their reactions have been positive and this would seem to indicate that it will be possible to reaffirm the political will for our countries to cooperate in compliance with the spirit of ESA, at the same time ensuring that all Member States derive equal satisfaction in terms of both scientific and industrial returns. A package deal for ESA's future activities should be established on this basis.

This will avoid unacceptable continuation of a situation characterised by a need to take successive fragmentary decisions in the absence of a general reference structure, and it will give ESA the political force that it needs to avoid an erosion of the importance of its activities and thereby a gradual deterioration.

It is with this viewpoint, namely believing in ESA's usefulness and confirming our will to support it, while emphasising the need for more rigorous respect of its Convention, that I wish you a successful meeting of the SPC in terms of both decisions and results.

I would like to close by expressing, on behalf of the Italian government and myself, our appreciation and our gratefulness to Professor Edoardo Amaldi, whose term of office as President of the Science Programme Committee comes to an end at this meeting. Italy, which has been very proud to be able to offer a President of Prof. Amaldi's capabilities, has followed his activities with confidence during these two years. His efficiency and his unbiased nature have been equal to his scientific standing. I thank him with all my heart, and I very much hope that he will continue his very valuable contribution to the Agency.'

Professor E. Amaldi (right) during a visit to ESTEC, Noordwijk in March 1979

Response by Professor Edoardo Amaldi

'I should like to thank both Minister Romita and Mr. Quistgaard, Director General of ESA, for their kind words. In relinquishing the Chairmanship of the SPC, I would like also to add a few thoughts of my own, of a general nature, to those of the Italian Minister.

Firstly, I believe that the Agency's Council should be more conscious of the vital role played by the Science Programme within the Agency. Though this programme may no longer by the sole raison d'être of ESA, it is and will remain the driving force behind technological innovation and demand. An increase in the budget of the Science Programme is mandatory if we are to produce projects of quality and in a quantity sufficient to maintain a competitive presence for the European community in all fields of space research. The five small to medium sized projects that we have for our whole community over a ten-year period at present is not the right reply to that challenge.

Clearly, the European Space Agency cannot be based on the Science Programme alone, as its forerunner the European Space Research Organisation (ESRO) was. Conditions have evolved since then and space is now open to commercial users and Europe must maintain a presence here too if it is to be faithful to its heritage. A well thought out and solid programme of applied research, particularly in the still exploratory areas of climatology and remote sensing, is a vital necessity.

The Agency should maintain its research and development characteristics and its scientific origins. New programmes and projects should be introduced only if they are research oriented and their aims and developments based on scientific methods.

The third essential component of the European Space Agency, without which the excellence of the other programmes cannot be guaranteed, is a solid programme of technological research. The engineers of the European Space Research and Technology Centre (ESTEC) must be given the means for carrying out their research, just as Space Science Department functions for scientific matters.

The Agency must not only be a centre for redistributing the funds of Member States to industry; it must also remain a development centre itself, if it is to coordinate and lead European industry in the advanced technology required for the sophsiticated space projects of the future.

ESA stands at a critical junction; centrifugal forces, in the form of obstinate defences of national interests, could be a sudden disruptive influence if a spirit of compromise does not prevail in the interests of European unity. Let the Science Programme Committee be one of the motivators for getting ESA on the move again, because if we don't succeed, a little bit of Europe will have disappeared.'

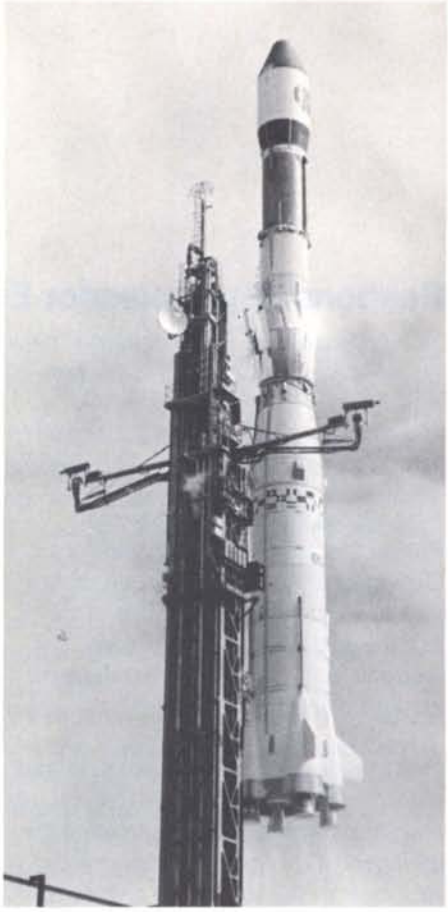
In Brief

Marecs-A to be Launched on Final Ariane Test Flight (L04)

The detailed analysis of the L03 flight data has confirmed the results announced immediately after launch and the total success of the L03 mission (see ESA Bulletin No. 27, pp 75–79).

The fourth and final Ariane test flight is scheduled to take place on 18 December 1981 from the Guiana Space Centre in Kourou.

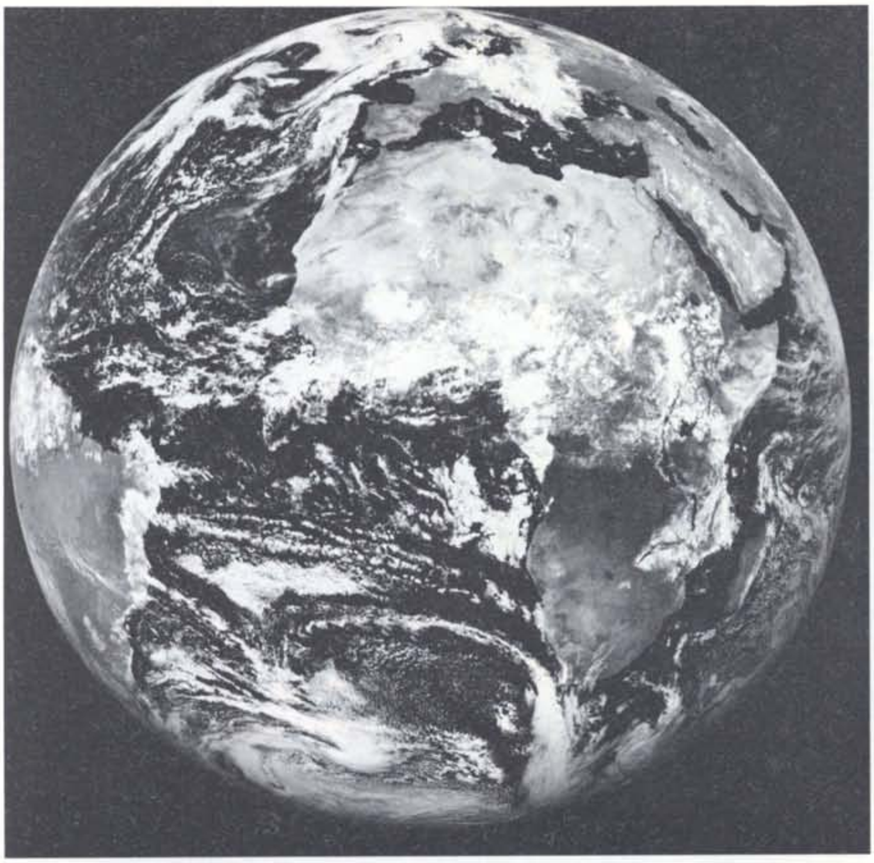
On this fourth flight, the European launcher will carry the first (Marecs-A) of two maritime communications satellites which are to be leased to Inmarsat (see elsewhere in this issue), as well as the technological capsule (CAT) designed to provide information on the launcher's performance and which has been carried on all the Ariane test flights. On this fourth flight the CAT will also carry a scientific experiment – Thésée – conceived and built by a team of young people from the GAREF Aerospace Club in Paris.



Europeans Complete Astronaut Training

Claude Nicollier and Wubbo Ockels have successfully completed their basic astronaut training for mission specialists, which they began in July 1980 at NASA's Johnson Space Center (Houston). They have, therefore, acquired their basic qualifications as European Mission Specialists.

In October Wubbo Ockels rejoined the First Spacelab Mission (SL-1) crew to complete his training as FSLP Payload



METEOSAT 1981 MONTH 7 DAY 28 TIME 1225 GMT (NORTH) CH. VIS 1
NOMINAL SCAN/RAW DATA SLOT 25 CATALOGUE 1033810007

Meteosat-2 – First Images Received

The very first images, in the visible channel, from Meteosat-2, the second European meteorological satellite, were recorded at the European Space Operations Centre (ESOC) in Darmstadt, Germany on 28 July 1981, and the first image in the infrared channel was recorded on 30 July. The images received are all of excellent quality.

Following a series of performance tests on the satellite, the radiometer was brought into service on 28 July and the first images in the visible were duly recorded at ESOC. After a short decontamination period, designed to remove any possible surface impurities from the optical and cooling systems, the infrared channels, including the water-vapour absorption channel, were activated on the evening of 29 July and the morning of 30 July.

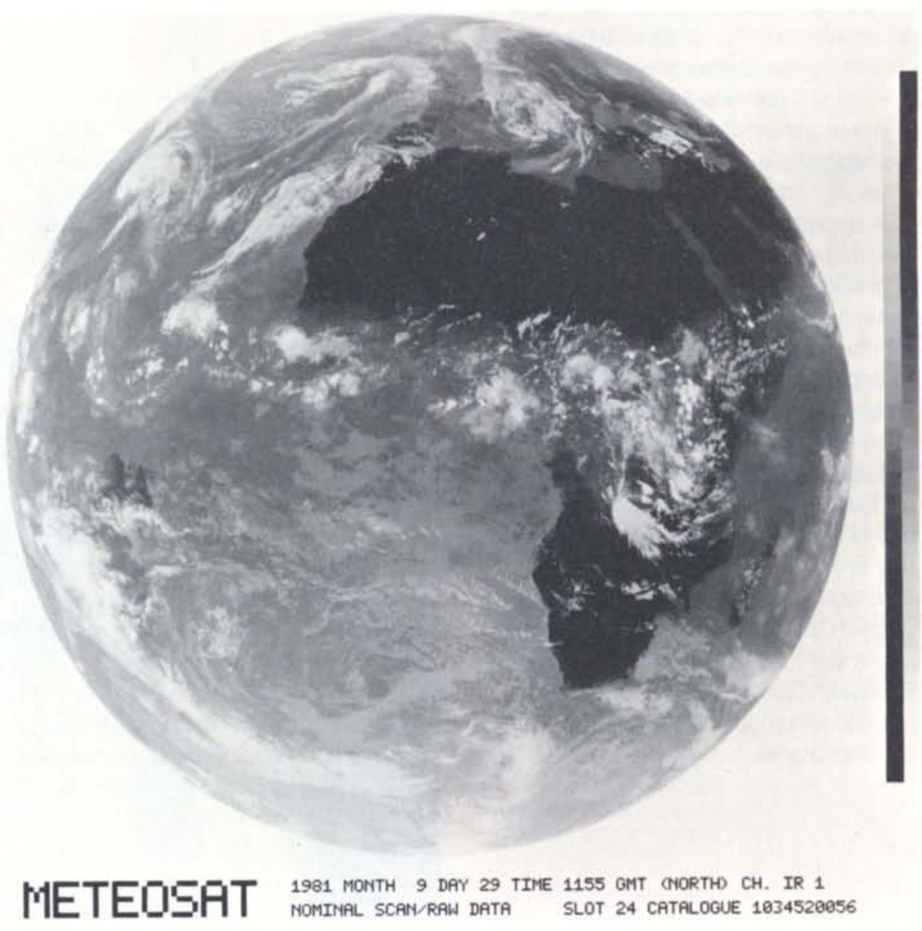
Regular dissemination of images from ESOC, via Meteosat-2, to the data user stations situated within the coverage area of the satellite (Europe, Africa, the Middle East and parts of South America) began in the middle of August.

Specialist. During this training, which will take place in Europe as well as in the USA, he will join forces with Ulf Merbold (the third European Payload Specialist), the two US Payload Specialists, and the two US Mission Specialists.

Claude Nicollier will stay at Johnson Space Center to continue his dedicated Mission Specialist training with a view to obtaining full familiarity with this field for future Shuttle missions carrying European Payloads.

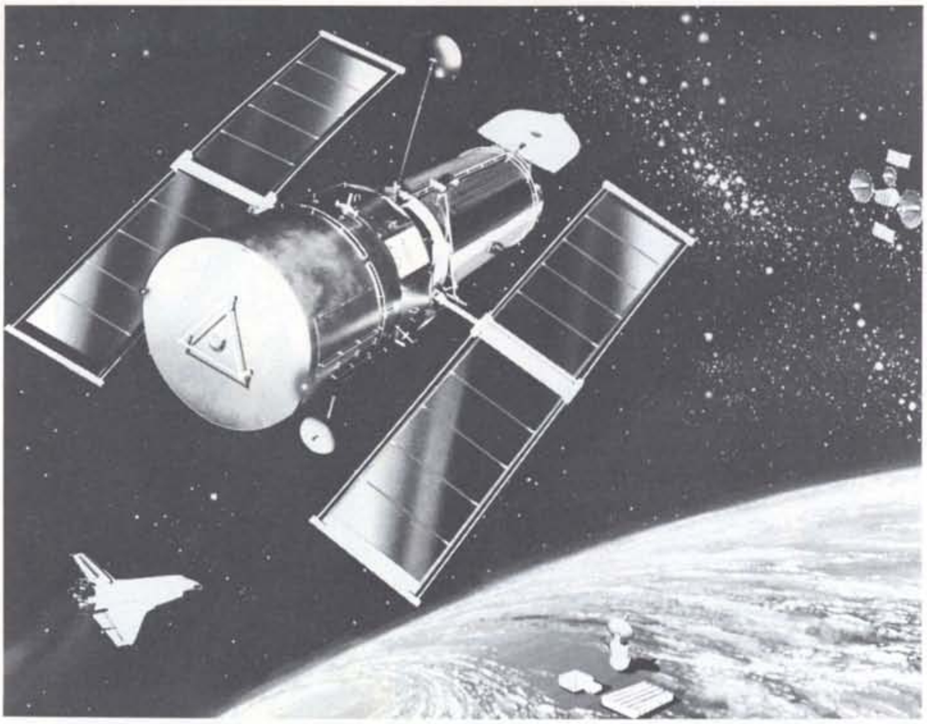
The final selection of the Payload Specialists for the First Spacelab Mission (one European and one American) will take place about six months prior to the flight, which is currently planned for September 1983.

NASA agreed to include the Europeans in their astronaut training programme in recognition of the substantial contribution ESA is making to the Space Transportation System ('Space Shuttle') by developing Spacelab.



METEOSAT 1981 MONTH 9 DAY 29 TIME 1155 GMT (NORTH) CH. IR 1
NOMINAL SCAN/RAW DATA SLOT 24 CATALOGUE 1034520056

European Coordinating Facility for Space Telescope Selected



The Agency's Science Programme Committee recently selected the European Southern Observatory (ESO), whose headquarters are in Garching, Germany, as the Institute that will serve as the European Coordinating Facility (ECF) for the Space Telescope (ST). ESO is an intergovernmental organisation for astronomical research which currently has six member states – Belgium, Denmark, France, Germany, Netherlands and Sweden. Italy and Switzerland are in the process of formally joining the Organisation.

The ECF will work closely with NASA's Space Telescope Science Institute, which is to be run by the Association of Universities for Research in Astronomy (AURA) and sited on the campus of the Johns Hopkins University in Baltimore (Maryland).

The Space Telescope is a high-resolution 2.4 m diameter optical telescope to be placed in orbit in 1984 by the Space Shuttle. It will provide an astronomical capability unattainable by any ground-based telescope, enabling scientists to detect objects six to eight times more distant than presently observable. It will thereby provide new insights into the origin, structure and evolution of the Universe.

ESA decided to participate in the Space Telescope project with NASA in 1976 in return for a minimum of 15% of the overall observing time. The main tasks foreseen for the ECF will be to coordinate work throughout Europe on ST data analysis software, to concentrate and distribute information on the ST itself, and to make available advanced computer facilities to the European astronomers. The creation of this centre in Europe will play a major role in ensuring that European astronomers will be in the best possible position to obtain the maximum scientific return from the high-quality ST data. The European Coordinating Facility will be open to astronomers from all ESA Member States.

ESA 'Man and Space' Art Competition Winners Visit KSC

The twelve prize winners of the art competition organised by ESA last year for young Europeans on the subject of 'Man and Space' (see pp 74–79 of ESA Bulletin No. 25, February 1981) recently spent a week in the USA as guests of the Agency. The highlight of the trip was a visit to Kennedy Space Center and a tour of the Space Shuttle/Spacelab facilities, where the group were able to watch Space-Shuttle integration in progress and to look over the engineering model of Europe's Spacelab.

The art competition formed part of the 'Young Europeans and Spacelab' (YES) programme developed by the Agency to promote the Spacelab programme and its evolution, to promote interest in scientific/technical space-oriented hobbies among young people, and to promote future European cooperation in space ventures. The next step in this programme will offer young Europeans the possibility of proposing experiments for future Spacelab flights.

Progress in ESA/CEC Remote-Sensing Campaign

During June and July the European Space Agency and the Commission of the European Communities conducted the flight campaign for their joint experimental radar remote-sensing project. Known as the SAR-580 Campaign, it relied on a Canadian Convair 580 aircraft equipped with an experimental fine-resolution multifrequency synthetic-aperture radar system.

The project is directed at a broad range of objectives associated with the future ESA Remote sensing Satellite (ERS) programme and the European Commission's interest in agricultural and environmental monitoring. The experiments include work in the fields of oceanography, agriculture, geology, and cartography, as well as topics related to the engineering design of future radar remote-sensing satellites.

The Convair aircraft has been based at the Royal Aircraft Establishment, Farnborough (UK) and at DFVLR in Germany for the duration of the campaign. More than 40 flights have been made over a total of 39 test areas in ten European countries. The cloud-penetration ability of the radar imaging system has allowed data to be collected in almost all weathers, and consequently imaging has been possible on approximately 200 separate data-collection 'passes' (flights over targetted areas) compared with the 150 originally foreseen for the project.

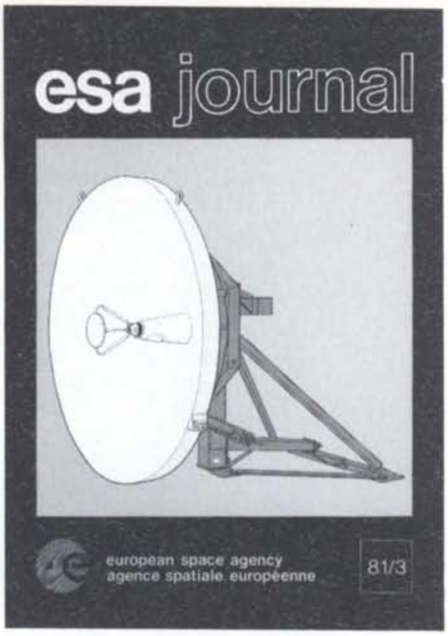
The next phase in the project will be the generation of high-quality imagery from the basic data collected during the Campaign. This will then be distributed to the scientists responsible for the individual experiments, for detailed analysis in conjunction with other data collected on the ground, from ships, and from other aircraft.

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 94 and using the Order-Form on page 95.

ESA Journal

The following papers were published in ESA Journal Vol. 5, No. 3:



SATELLITE SERVICING IN ORBIT
VANDENKERCKHOVE J A

PERFORMANCES OF FIXED-MOUNT EARTH-STATION ANTENNAS
DINWIDDY S E

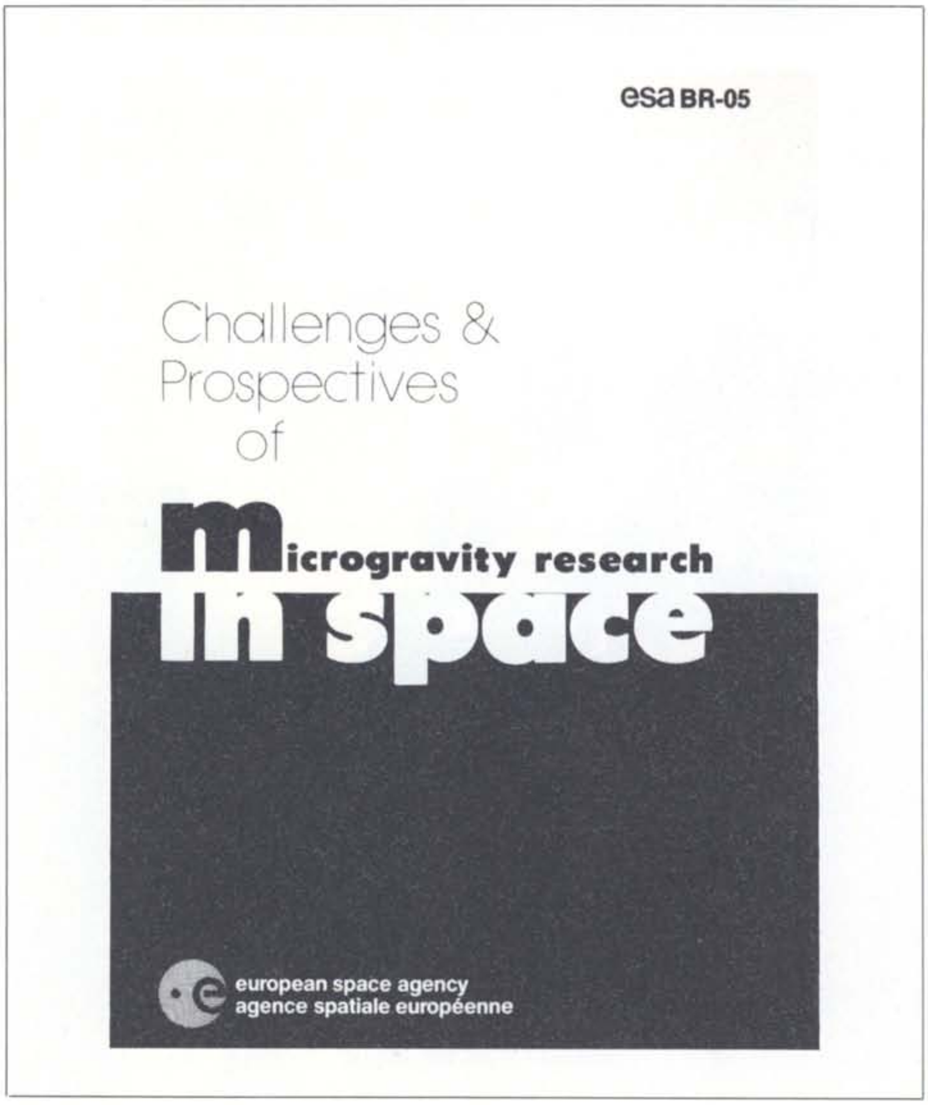
THE ELECTRONIC SOLID-STATE SWITCH (ELS³) – AN AUTOMATIC PROTECTION FOR SPACECRAFT HIGH-POWER LINES
CAPEL A ET AL

SIMULATION OF THE CONDUCTED EMC IN SPACECRAFT PERFORMANCE PREDICTION: THE ESA EMC COMPUTER PROGRAM
CAPEL A & FERRANTE J G

DIGITAL ATTITUDE-CONTROL DESIGN FOR SPACE APPLICATIONS
CHRETIEN J-P

MATERIAL AND CIRCUIT EVALUATION FOR MILLIMETRE-WAVE APPLICATIONS: A 3 dB FIN-LINE PRINTED PROBE COUPLER FOR 31 GHz
ARNDT F ET AL

GAIN-BEAMWIDTH PRODUCT AND OTHER REFLECTOR-ANTENNA RELATIONSHIPS
SAITTO A



Special Publications

ESA SP-1039 INTRODUCTION TO THE SIRIO-2 PROGRAMME (AUGUST 1981)
BERLIN P/BATTRICK B
ESA PRICE CODE E1

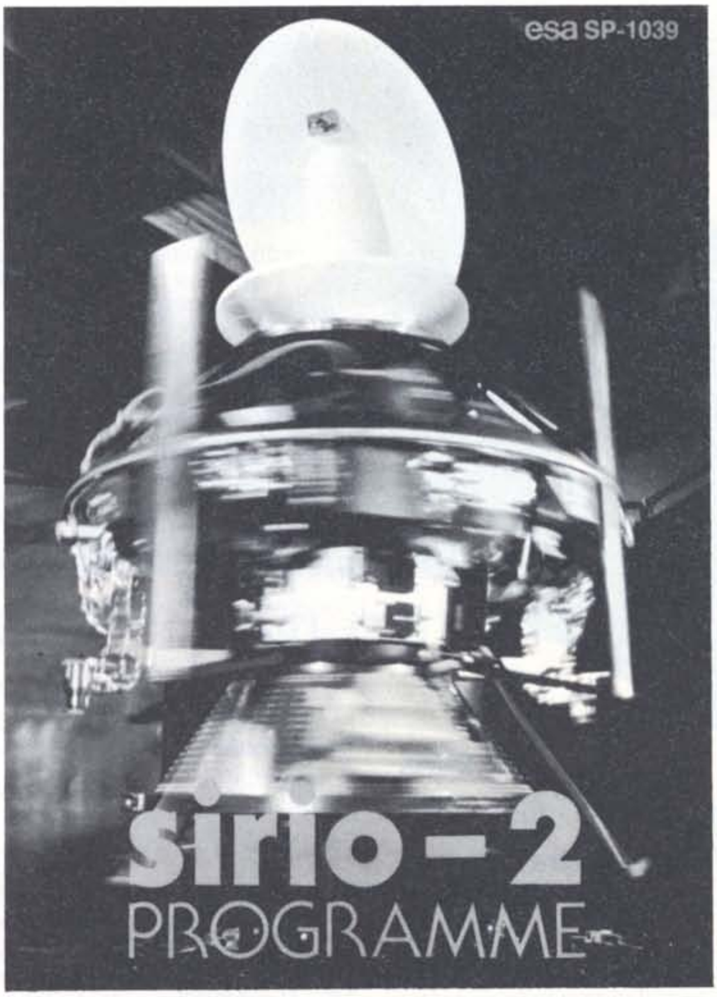
ESA SP-160 SPACECRAFT FLIGHT DYNAMICS. PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM, 18-22 MAY 1981, DARMSTADT, GERMANY (AUGUST 1981)
GUYENNE TD & LEVY G
ESA PRICE CODE C4

Brochure

ESA BR-05 CHALLENGES AND PROSPECTIVES OF MICROGRAVITY RESEARCH IN SPACE (OCTOBER 1981)
MALMEJAC Y & AL
ESA PRICE CODE E1

Contractor Reports

ESA CR(P)-1398 STUDY OF A SAFETY SYSTEM FOR A HYDRAULIC MULTIDEGREE-OF-FREEDOM VIBRATION FACILITY. (MAR 1980)
IABG, FRG
ESA PRICE CODE E1



ESA CR(P)-1399 INFLUENCE OF MODELLING ERRORS ASSOCIATED WITH THE ATTITUDE RECONSTITUTION FOR SPIN-STABILISED SATELLITES IN ORDER TO PROVIDE OPTIMAL ESTIMATION TECHNIQUES – FINAL REPORT. (JUN 1980)
BADG, UK
ESA PRICE CODE C2

ESA CR(P)-1401 DEVELOPMENT OF A CCD IMAGE SENSOR – PHASE 3 – FINAL REPORT. (MAY 1980)
GENERAL ELECTRIC CO., UK
MICROFICHE ONLY

ESA CR(P)-1403 THERMOGRAPHIC SYSTEMS FOR MATERIAL SCIENCE EXPERIMENTS – FINAL REPORT. (OCT 1980)
TECHNO SYSTEM DEVELOPMENTS, ITALY
ESA PRICE CODE C1

ESA CR(P)-1404 SOFTWARE QUALITY ASSURANCE STUDY – FINAL REPORT. (OCT 1980)
LOGICA, UK
ESA PRICE CODE C1

ESA CR(P)-1406 PRELIMINARY STUDY OF DIGITAL ATTITUDE CONTROL DESIGN TECHNIQUES FOR SATELLITE. (APR/JUN 1980)
ONERA, FRANCE
ESA PRICE CODE C3

ESA CR(P)-1408 SUSCEPTANCE MEASUREMENTS. (NOV 1980)
MARCONI, UK
ESA PRICE CODE C2

ESA CR(P)-1409 OPTIMISATION OF THE TECHNOLOGY RELATED TO GERMANIUM/BERYLLIUM INFRARED DETECTORS – FINAL REPORT. (OCT 1980)
BATELLE, FRG
ESA PRICE CODE C1

ESA CR(P)-1410 HARDWARE EVALUATION OF A SPACECRAFT AC POWER DISTRIBUTION SYSTEM – FINAL REPORT. (JUL 1980)
DORNIER SYSTEM, FRG
MICROFICHE ONLY

ESA CR(P)-1411 STUDY ON INFRASTRUCTURE CONSIDERATIONS FOR MICROWAVE ENERGY GROUND RECEIVING STATIONS (SPS – OFFSHORE RECTENNA SITING STUDY IN W. EUROPE) VOLUME 1: EXECUTIVE SUMMARY. (NOV 1980)
HYDRONAMIC B.V., NETHERLANDS
ESA PRICE CODE C1

ESA CR(P)-1412 DEVELOPMENT OF A DETECTOR/MIXER FOR OPERATION FROM 0.55 TO 0.75 MILLIMETRES – FINAL REPORT. (JUL 1980)
FARRAN RESEARCH ASSOCIATES, IRELAND
MICROFICHE ONLY

ESA CR(P)-1413 DEVELOPMENT OF AN ACOUSTO-OPTIC (BRAGG CELL) SPECTRUM ANALYSER – FINAL REPORT. (NOV 1980)
PLESSEY RESEARCH (CASWELL) LTD, UK
ESA PRICE CODE C1

ESA CR(P)-1414 DESIGN FEASIBILITY REPORT ON INVESTIGATION OF MAGNETIC BEARINGS FOR THE OCEAN COLOUR MONITOR RADIOMETER SCANNER. (FEB 1981)
BADG, UK
ESA PRICE CODE C1

ESA CR(P)-1415 STUDY OF A MICROWAVE SCANNING MECHANISM ASSEMBLY (MISMA) – FINAL REPORT. (JUN 1980)
DORNIER SYSTEM, FRG
ESA PRICE CODE C1

ESA CR(X)-1400 ASTP, RF CIRCUIT TECHNOLOGY STUDY – FINAL REPORT. (JUL 1980)
SELENIA, ITALY

ESA CR(X)-1402 ADM – ANTENNA DEPLOYMENT MECHANISM – FINAL REPORT. (NOV 1980)
CONTRAVES, SWITZERLAND

ESA CR(X)-1405 OSCILLATEUR A QUARTZ HF DE HAUTES PERFORMANCES – RAPPORT DE FIN DE PHASE II. (MAY 1980)
OSCILLOQUARTZ S.A., SUISSE

ESA CR(X)-1407 APSMO – ADVANCED POWER SUBSYSTEM MONITORING UNIT – FINAL REPORT (OCT 1980)
THERMA ELEKTRONIK AS, DENMARK

Technical Translations

ESA TT-566 COMPATIBILITY TEST OF OXYGEN EXPOSURE IN THE RANGE 2.2 TO 2.8 BAR ABS (MARCH 1981)
KREKELER, H, CABAROU, P & FUST, H-D, DFVLR, GERMANY

ESA TT-633 STUDY OF AN EXPERIMENTAL PROBE FOR THE MEASUREMENT OF THE ACOUSTIC PRESSURE INSIDE AN AIRFLOW (MARCH 1981)
HUGUENIN, H, ONERA, FRANCE

ESA TT-646 DRAG MEASUREMENTS OF CONICAL AFTERBODIES AT SUBSONIC AND TRANSONIC SPEEDS (APRIL 1981)
ESCH, H, DFVLR, GERMANY

ESA TT-648 OPTIMIZATION OF BARRIERS (MARCH 1981)
LOHMANN, D, DFVLR, GERMANY

ESA TT-658 RADIATION BUDGET OF THE TROPICAL ATMOSPHERE: RESULTS FROM MEASUREMENTS OF THE HEMISPHERICAL RADIANT FLUX DENSITIES IN THE VISIBLE SPECTRAL RANGE DURING THE '1969 ATLANTIC EXPEDITION' (MARCH 1981)
QUECK H, DFVLR, GERMANY

ESA TT-660 FLIGHT TEST RESULTS OF THE MODEL SIMULATION CONTROLLER FOR THE HFB 320 FOR IN-FLIGHT SIMULATION OF THE A310 AIRBUS (APRIL 1981)
LANGE H-H, DFVLR, GERMANY

ESA TT-661 STUDY OF THE FIBER-MATRIX INTERFACIAL STRUCTURE AND OF THE INTERFACIAL DIFFUSION PHENOMENA IN COTAC-TYPE SOLIDIFICATION COMPOSITES; EFFECT ON THE THERMAL STABILITY OF FIBERS (APRIL 1981)
MARONI, E, ONERA, FRANCE

ESA TT-665 DESCRIPTION AND UTILIZATION OF A COMPUTATION PROGRAM OF THE OPTICAL RADIATION TRANSMITTED, EMITTED OR DIFFUSED BY THE ATMOSPHERE FOR SATELLITE OBSERVATION (MARCH 1981)
BOUCHARDY, A-M & FONTANELLA J-C, ONERA, FRANCE

ESA TT-666 SYSTEM IDENTIFICATION OF THE LONGITUDINAL MOTION OF THE DFVLR HFB 320 RESEARCH AIRCRAFT WITH PARTICULAR CONSIDERATION OF CONTROL SURFACE EFFECTIVENESS (APRIL 1981)
RIX O, DFVLR, GERMANY

ESA TT-669 PERFORMANCE EVALUATION OF UNCONSTRAINED OPTIMIZATION TECHNIQUES (APRIL 1981)
KRAFT D & KREISSELMEIER G, DFVLR, GERMANY

ESA TT-670 EXPERIMENTS WITH THIN-WALLED, ISOTROPIC CONES SUBJECTED TO AXIAL LOAD, AXIAL LOAD COMBINED WITH CONSTANT INTERNAL PRESSURE AND EXTERNAL HYDROSTATIC PRESSURE (APRIL 1981)
HEIDEMANN U, DFVLR, GERMANY

ESA TT-672 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1980-4 (MARCH 1981)
ONERA, FRANCE

ESA TT-673 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1980-5 (MARCH 1981)
ONERA, FRANCE

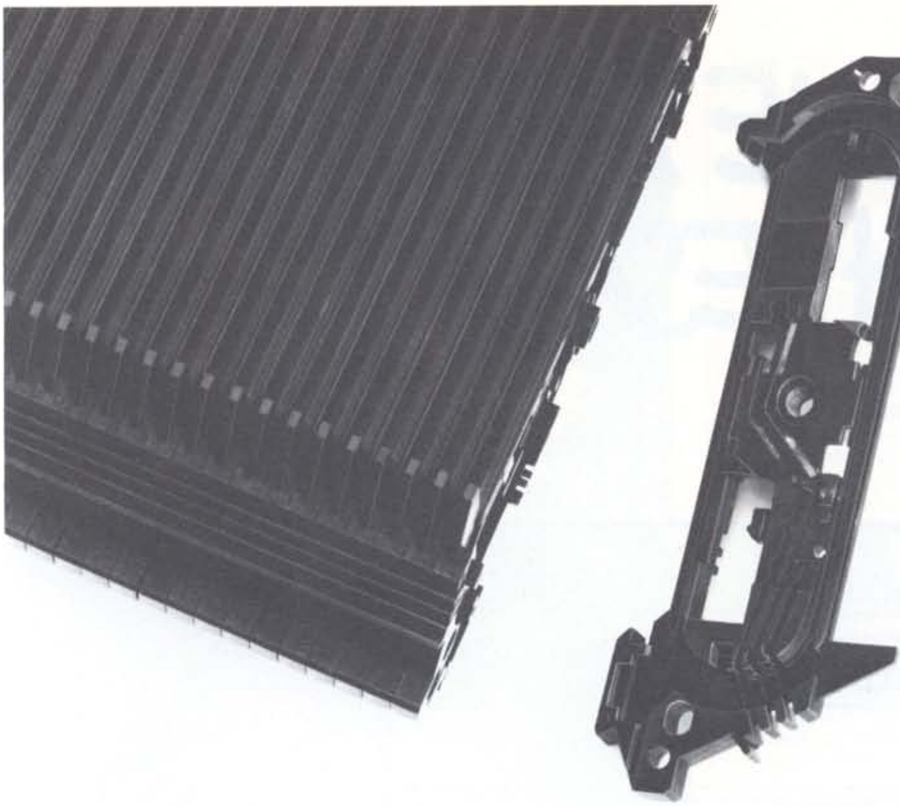
ESA TT-678 REVIEW OF THEORETICAL AND EXPERIMENTAL RESULTS ON THREE-DIMENSIONAL TURBULENT WAKES AND BOUNDARY LAYERS (APRIL 1981)
COUSTEIX, J., AUPOIX B & PAILHAS G, ONERA, FRANCE

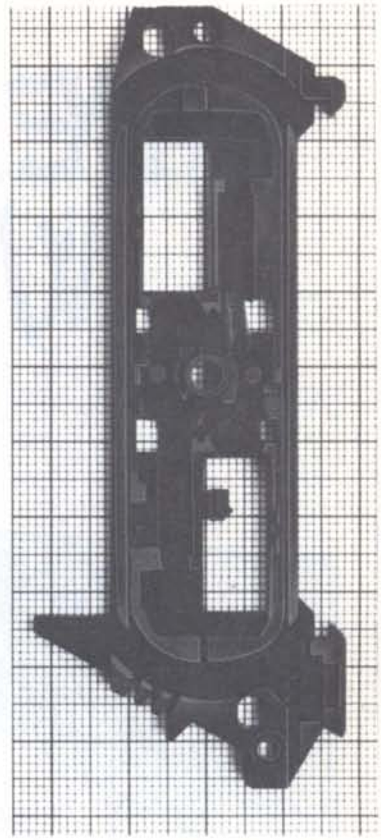
ESA TT-687 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1980-6 (APRIL 1981)
ONERA, FRANCE

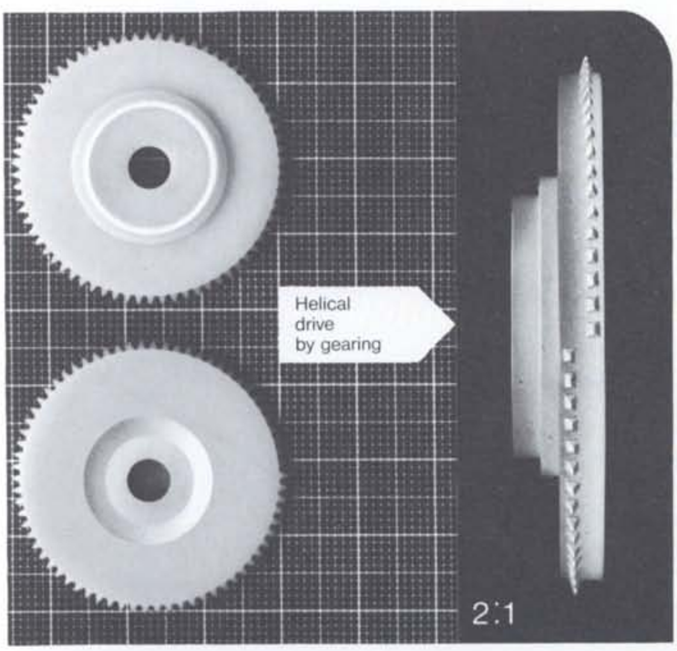
ESA TT-688 REENTRY OF SKYLAB. ORBITAL COMPUTATION ASPECT (MARCH 1981)
CARROU J, ROBERT J, VIENNE D, BARLIER F & FUTUALLY R, CNES, FRANCE

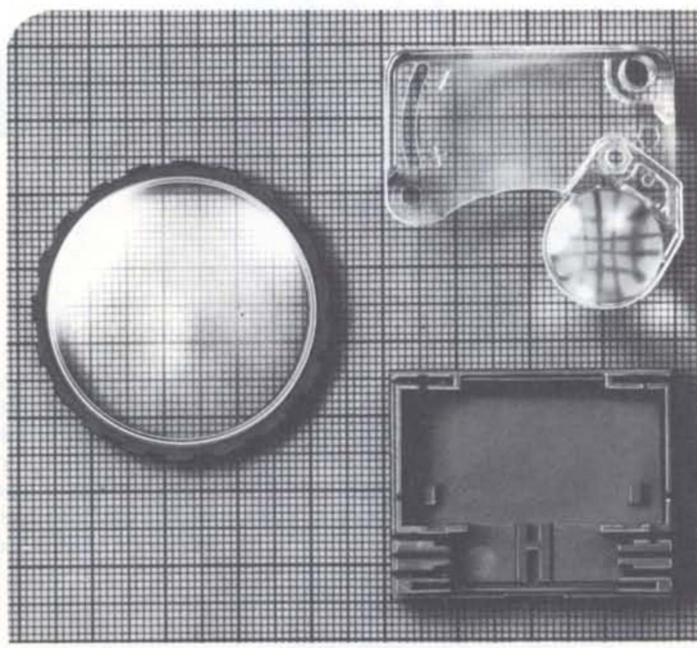
ESA TT-692 REENTRY OF SKYLAB. OPERATIONAL ASPECTS (APRIL 1981)
CAROFF J, TREBAOL J, LEGOFF I & SCULFORT J, CNES, FRANCE

ESA TT-693 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1981-1 (MAY 1981)
ONERA, FRANCE






Helical
drive
by gearing
2:1



Availability of ESA and NASA Publications

Publications	Series	Available as	From
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	
Periodicals			
ESA Bulletin		Available without charge as a regular issue	
ESA Journal		or back numbers (as long as stocks last)	
Public relations material		General literature, posters, photographs, films, etc.	ESA Public Relations Service 8-10 rue Mario-Nikis, 75738 Paris 15, France

Printed documents Number of pages	Code	Price
001—100	E1	FF 55
101—200	E2	FF 80
201—350	E3	FF 125
over 350	E4	FF 160
001—100	C1	FF 55
101—200	C2	FF 80
201—350	C3	FF 125
over 350	C4	FF 160

Photocopy and Microfiche

Photocopy	FF 110 per title plus FF 25 per 25 pages
Microfiche	FF 115 per title

All prices exclude postage and value-added tax

1 Photocopies will be supplied if the orginal document is out of print, unless microfiche is specified.

2 These charges apply to Member States, Austria, Canada and Norway. A 20 per cent surcharge will be levied on orders from 'other states'.

3 These prices are subject to change without prior notice.

N.B. FOR HARD-COPY CHARGES, SEE FACING PAGE

ESA and NASA Scientific/Technical Publications **ORDER FORM** Before using this Order Form read the important information on the reverse.	To: DISTRIBUTION OFFICE ESA SCIENTIFIC & TECHNICAL PUBLICATIONS BRANCH ESTEC, POSTBUS 299, 2200 AG NOORDWIJK THE NETHERLANDS From: ______________________ ______________________ ______________________

PLEASE SUPPLY:

Customer's Ref ______________________

Date ______________________ Signature ______________________

No. of copies: Printed	Microfiche	Photocopy	ESA or NASA Reference	Title	For ESA use	

→ IF OUT OF PRINT SUPPLY / DO NOT SUPPLY IN MICROFICHE

- -

MAILING LABEL (Print or type carefully)

Customer's Ref ______________________

ESA Order No.

To Name or Function ______________________

Organisation ______________________

Street Address ______________________

Town, Province, Postal Code ______________________

Country ______________________

ESA/NASA PUBLICATIONS ORDER FORM

INFORMATION

1. Use this form for your order.

2. (a) Except as mentioned below, publications are available in printed form (as long as stocks last), in microfiche and as photocopies.

   (b) If a publication ordered in printed form is out of print, a microfiche copy will be supplied (unless NOTE 1 on the form has been completed to indicate otherwise) and the Order Form will be amended accordingly.

   (c) Publications in the following series are not available in printed form:

   – the ESA CR(P) series;
   – the ESA TT series;
   – all NASA series.

   (d) Publications in the ESA CR(P)* and CR(X) series are not available from ESA. (They are given a very restricted distribution in printed form to the States participating in the relevant programme. The addressees in that distribution can be supplied on request).

EXECUTION OF ORDER

3. After the handling of your order has been completed, the form will be returned to you, marked with the following symbols:–

A circle	–	the items encircled have been despatched
X	–	out of print or unavailable in printed form
Z	–	not available from ESA in any form
R	–	publication is restricted and cannot be supplied on this order
N	–	publication is in hand, stock not yet received.
C	–	unable to identify the publication from the information provided.
Y	–	publication requested from NASA, delay of at least 2 months expected.

4. In any subsequent correspondence, please QUOTE THE ESA ORDER NUMBER.

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	etats membres
belgium	allemagne
denmark	belgique
france	danemark
germany	espagne
ireland	france
italy	irlande
netherlands	italie
spain	pays bas
sweden	royaume-uni
switzerland	suède
united kingdom	suisse