esa bulletin

number 34

may 1983

european space agency

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

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of Space Transportation Systems, the Technical Director, the Director of ESOC, and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Prof. H. Curien (France).

Director General: Mr. E. Quistgaard.

agence spatiale européenne

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

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

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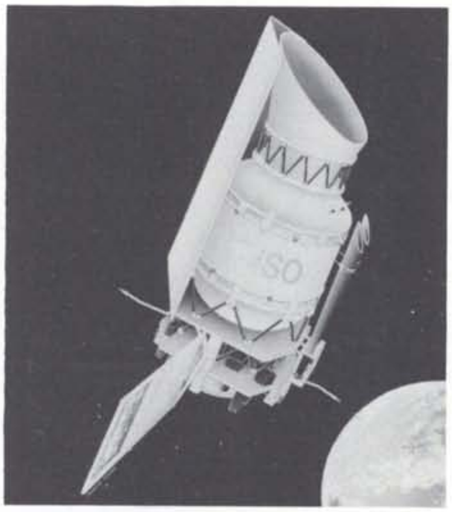

Front cover: The Infrared Space Observatory (ISO) satellite, ESA's new scientific project (see page 67).

Back cover: Spacelab-1 being readied for its Shuttle flight at Kennedy Space Center.

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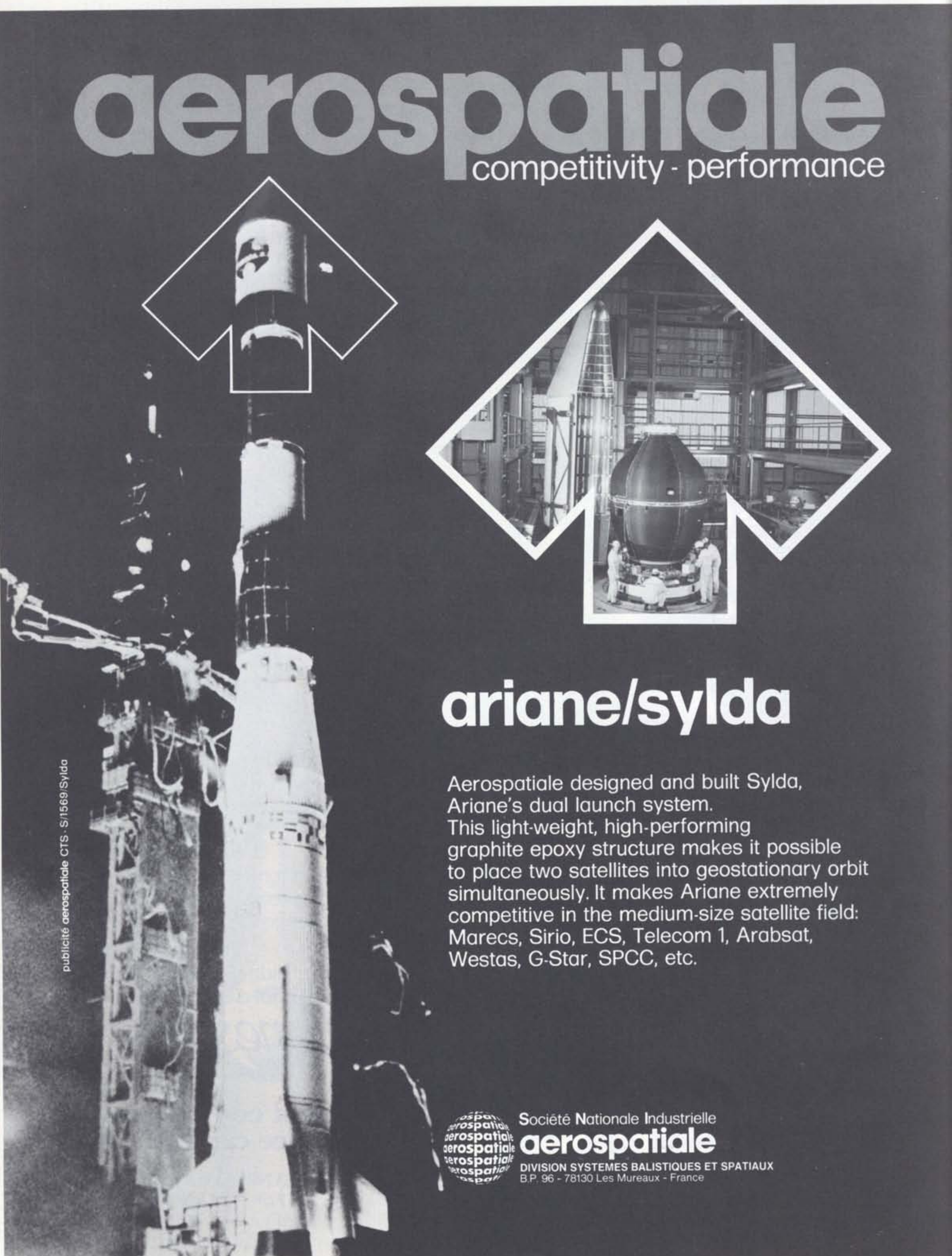
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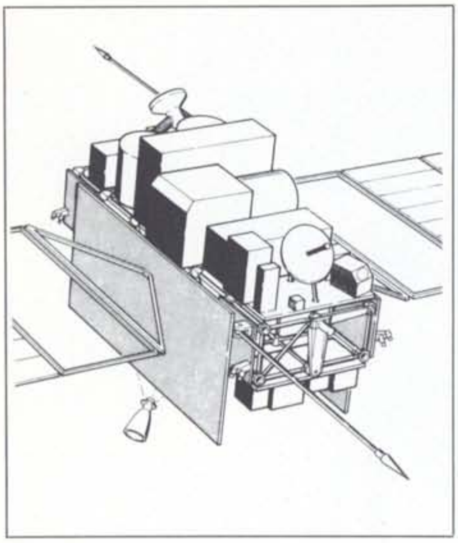

The Microgravity Payload for The First Eureca Mission

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K. Fuhrmann, Eureca Project, ESA Directorate of Space Transportation Systems, ESTEC, Noordwijk, The Netherlands

From a user viewpoint, a gap exists between the short-duration research opportunities offered by Spacelab and the permanent space stations planned for the 1990s. By exploiting the deployment and retrieval capability of the Space Shuttle, Eureca, a retrievable autonomous platform, fills this gap for investigations that do not require man's presence.

Introduction
ESA's Member States recently approved the development of a retrievable space platform and a group of experimental facilities dedicated to scientific experimentation in a very-low-acceleration ('microgravity') environment. Called the European Retrievable Carrier, or Eureca for short, the spacecraft will be launched on its maiden-flight in 1987 by the Space Shuttle. It will be retrieved and returned to Earth after some six months in orbit. This flight will be the first of a series of medium- to long-duration space missions, planned to occur at approximately two-yearly intervals.

The experimental hardware proposed for the first Eureca mission consists mainly of a so-called 'Core Payload' to be provided by ESA. Up to six multi-user facilities will allow the processing of metallurgical samples, crystal growth from the melt and from high- and low-temperature solutions, as well as biological and biochemical investigations (plant growth in a low-gravity environment, protein crystallisation, etc.). In addition, there will be two categories of experimenter-supplied 'add-on' hardware, one from the fields of materials science and life sciences to exploit the microgravity environment provided by the carrier, and a second from other – non-microgravity-related – disciplines, mainly space science and technology related.

It is intended that the core payload will constitute 70–80% of the total 1000–1200 kg payload for the first mission. The experimenter-provided materials-science/life-sciences instruments will be limited to about 200 kg. The instrumentation from non-microgravity-related disciplines will take up about 100 kg of the available capacity.

The spacecraft and its mission
Approximately 2.2 m long and weighing about 3.5 tons, Eureca will be a fairly heavy space vehicle (Table 1). Fully equipped, it will almost fill the cross section of the Shuttle's cargo bay (Fig. 1). It has been conceived with a high degree of flexibility and growth-potential in mind, and its design incorporates the ability to accommodate and support a wide range of payloads beyond those dedicated to microgravity research.

Eureca will have the same kind of subsystems as a comparable nonretrievable Earth satellite, for:

- structural integrity
- thermal control
- power generation and distribution
- data management and telecommunication
- attitude control.

In addition, however, Eureca will be equipped with a novel Orbit-Control Subsystem (OCS). A 400 N thruster and tanks containing sufficient propellant for a total velocity change of 400 m/s will allow the carrier to lift itself from its shuttle deployment orbit (about 300 km) to altitudes compatible with the atmospheric drag and orbit-decay requirements of the microgravity mission (about 500 km). The OCS will be used again at the end of orbital operations to reach retrieval orbit and rendezvous with the Shuttle.

Figure 1 – Possible concept for the first Eureca mission payload

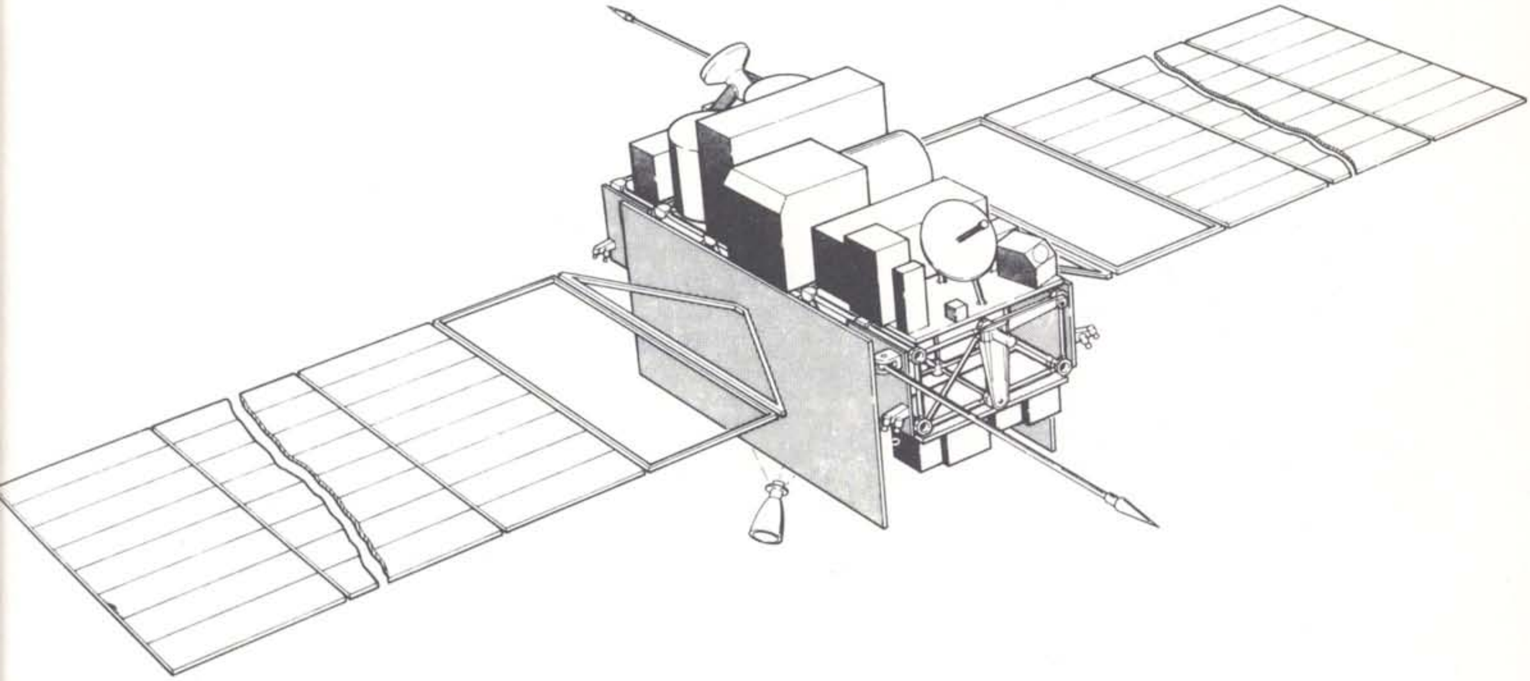


Table 1 – Some key data for Eureca

Total spacecraft mass	about 3500 kg
Payload mass	about 1100 kg
Payload power (continuous)	1700 W
Payload data rate (continuous)	2500 bit/s
Pointing accuracy with relation to Sun	$\pm 0.5°$
Pointing accuracy third axis	$\pm 1°$
Operating temperature in orbit	$+5°C$ to $+45°C$ *
Operating altitude	500 km (circular)
Residual acceleration in orbit	10^{-4} m/s² **

* Actual temperature will vary as a function of orbital location (sunlight or shadow), season (solstice or equinox), and power consumed (operating mode).
** Increasing to 10^{-3} m/s² at 10 Hz and 10^{-2} m/s² at 100 Hz and above.

Planning for a typical Eureca mission calls for the carrier's launch by the Shuttle, removal from its cargo-bay by means of the Remote Manipulator System, and subsequent release. Once the Orbiter has moved to a safe distance, Eureca will be activated and checked. If all is well an Orbit Transfer Manoeuvre (OTM) from deployment- to operating-altitude will be initiated.

An in-orbit stay of approximately six months is scheduled for the experiment operations. The return to Earth will take place as soon as possible after completion of the experiments, but waiting ('dormant') periods of several weeks or even months may occur, depending on the Shuttle's flight schedule.

Retrieval will commence with a descent OTM. Rendezvous and docking operations will be performed by the Shuttle with Eureca as a cooperative, passive target. Following deactivation, Eureca will then be re-stowed in the Orbiter cargo-bay for return to Earth (Fig. 2).

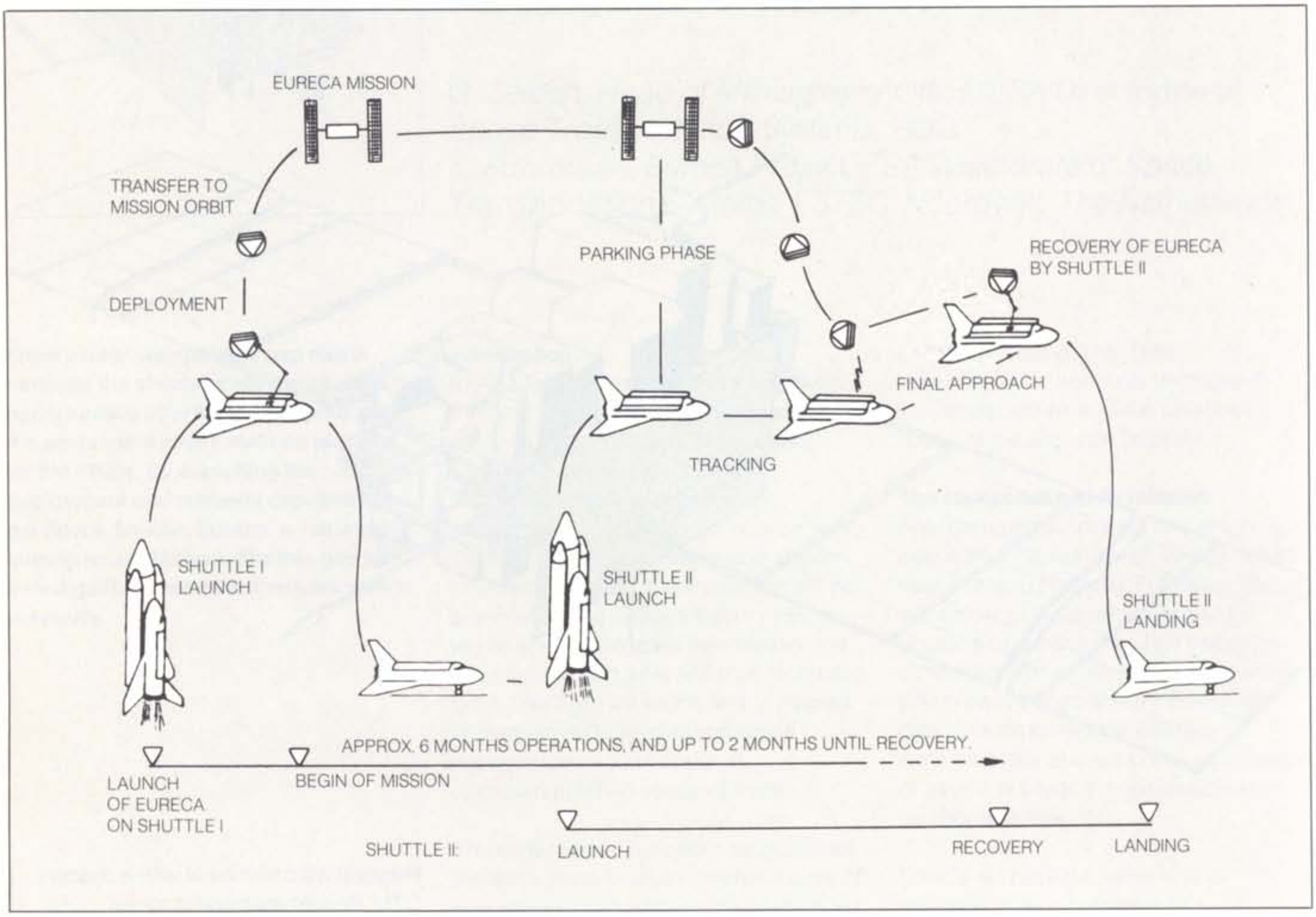
Scientific objectives

Materials sciences

A major feature of the space environment for investigations involving fluids is the greatly reduced gravitational force. This has a number of specific advantages, including:

- greatly reduced gravity-driven convection
- negligible sedimentation and buoyancy
- negligible hydrostatic pressure
- possibility of containerless positioning, handling, and shaping of liquids.

Figure 2 – Eureca mission schedule



Most attractive for basic studies on solidification and materials processing is the fact that even with systems involving large thermal and concentration gradients, stable conditions can be obtained in the fluids. This facilitates the study of solidification and processing under largely diffusion-controlled heat- and mass-transfer conditions.

At present, crystal-growth processes on Earth have to be optimised empirically, as theories mainly cover situations that cannot be achieved experimentally. Transients due to convection, which affect solute transport and heat transfer and result in variations in growth-rate, chemical composition, interface shape, interface stability, fault and dislocation generation etc., cannot be treated quantitatively, since convective flow cannot be modelled for realistic crystal-growth situations. This gap between theory and experiment not only hampers process optimisation, but also retards progress in theoretical understanding. Microgravity experiments with model systems could contribute greatly to the bridging of this gap. Model experiments to study segregation phenomena, morphological stability of interfaces, generation of defects, interdependence of growth-rate and supercooling during solidification etc., are urgently needed. Moreover, the processing of specific substances that cannot be produced in a controlled fashion on Earth is a prime candidate for Eureca.

Fundamental investigations of thermodynamic properties at liquid/vapour or liquid/liquid critical points are of interest, as well as investigations of the molten state. Physical and physico-chemical parameters, such as diffusion coefficients and segregation coefficients, can be determined more precisely in a microgravity environment. Such processes as homogeneous nucleation and glass fining can be studied with large samples and under better controlled conditions. A large number of furnaces are available, some of which can be tailored to specific experiment requirements. Automated sample exchange and in-flight programming of experiment profiles will facilitate series of experiments and experiment iterations (variation of parameters, etc.).

Protein crystallisation

For our biochemical understanding of enzyme action, exact knowledge of the three-dimensional structure of enzyme protein molecules is very important. Such information can be obtained from X-ray or neutron-diffraction studies of crystals of the protein (0.2–1 mm crystals for X-ray diffraction, and approximately 10 mm crystals for neutron diffraction).

In preparing protein crystals, a distinction must be made between water-soluble proteins and water-insoluble, usually membrane-bound proteins. In the case of water-soluble samples an aqueous solution of the purified protein is made to crystallise by reducing its solubility. This can be done by bringing the pH close to the isoelectric point, or by raising the temperature or the salt-concentration of the solution, or a combination of these. The most suitable conditions have to be found by empirical study for each protein. In the case of membrane-bound enzymes there is an extra complication due to their water-insolubility and the presence of membrane lipids, which interfere with crystallisation. Detergents must therefore be used to solubilise the protein, adding another set of variables (type and concentration of the detergent) to be manipulated in empirical fashion.

It is quite difficult to produce protein single-crystals of the required size and degree of crystalline perfection on Earth. Proteins have very large molecules (molecular weights of $10^4 – 10^6$) and form mechanically weak crystals, which usually stop growing after reaching sizes far below those required for successful diffraction studies. A major cause of this limited crystal growth seems to be convection and a convection-free microgravity environment may therefore offer an answer. Recent pilot experiments on sounding rockets have supplied evidence supporting this assumption. During the 6–8 min period of low gravity, single-crystals some 100 μm long have been produced – a process that takes 60 h or more on Earth – and the salt-diffusion process was strictly laminar and convection-free. The much faster and more perfect crystallisation achieved is thought to be due to enhanced near order of the macro-molecules in saturated solution prior to crystallisation.

Botanical sciences

Botanical interest in the space environment is mainly based on previous experiment results, whereby a gravity relevance in the biological system has been demonstrated either by zero-g simulation or exposure to the microgravity environment. Some topics for investigation are:

- gravity-dependent reactions, such as gravitropism, nastic phenomena and development and morphogenesis, including the development of strengthening tissues
- reactions in which gravity may play a modifying role, e.g. phototropic responses
- the regulation and ultra-structural characterisation of cellular polarities influenced by the gravity-vector direction
- the persistence and characteristics of circadian rhythmicity in the absence of external 24 h periodicities in the g-vector cues
- radiation effects produced by particles on living tissues
- plant genetics.

Exobiology/radiation biophysics

The Eureca mission offers the opportunity for long-duration exposure of materials of terrestrial origin to the space environment or selected aspects of it, e.g.

- the radiation environment, with electromagnetic radiation and high-energy charged particles
- the space vacuum
- extreme temperatures
- microgravity conditions.

Fundamental data have already been obtained on the mechanism of cosmic-ray-particle interaction with biological matter, on the synergism of space vacuum and solar ultraviolet radiation, and on the spectral effectiveness of solar ultraviolet radiation on virus viability.

The extension of the exposure time to six months offered by Eureca will increase research opportunities in several areas of exobiological and radiobiological significance, such as

- chemical and prebiotic evolution unprotected from solar radiation
- formation and stability of organic molecules in cosmic matter
- biological mechanisms of resistance to environmental extremes
- interplanetary transfer of life
- effects of cosmic-ray particles on biological matter
- consequences of combined action of cosmic radiation and microgravity.

Eureca core-payload facilities

Automatic Mono-ellipsoidal Mirror Furnace Facility (AMMFF)

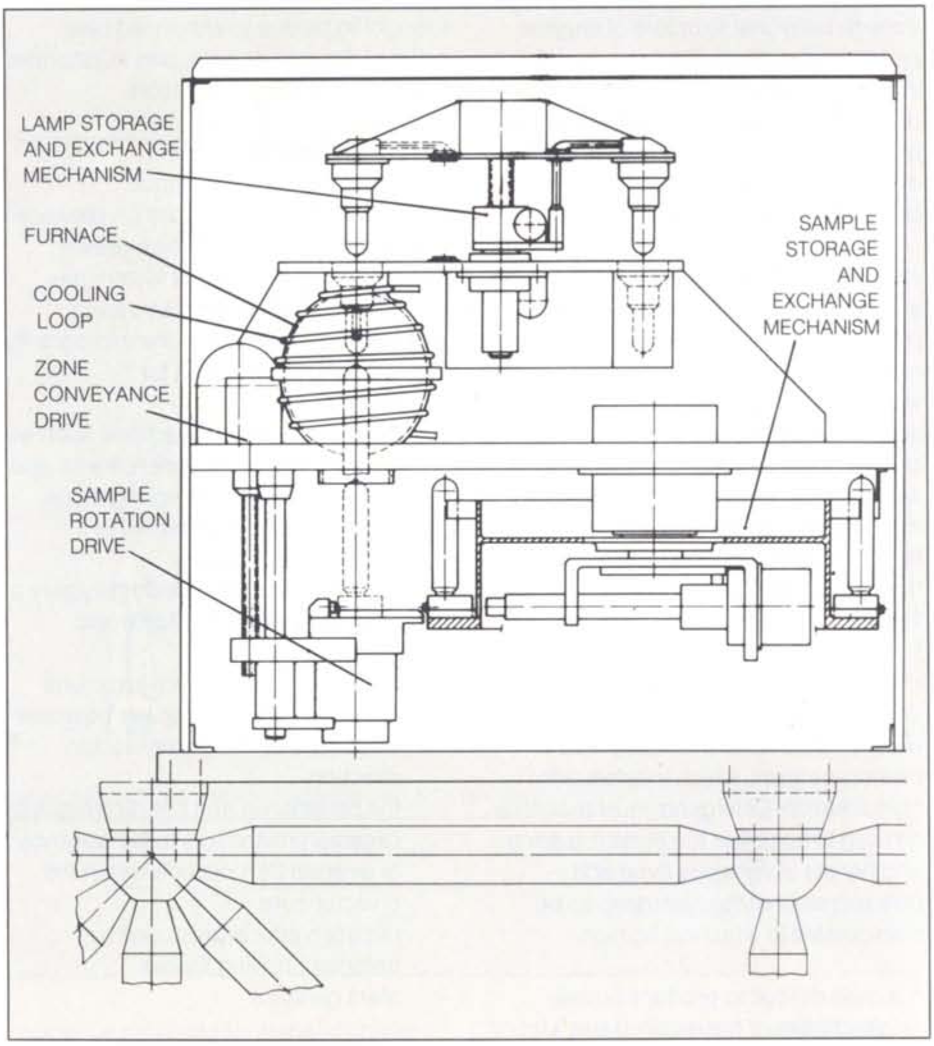
The AMMFF is an optical radiation furnace particularly suited to crystal-growth experiments. Its concept has been derived from similar facilities developed for FSLP (First Spacelab Payload) and D1-Spacelab payloads and from pre-Phase-A studies.

The core of the facility is formed by a shell in the shape of a rotational ellipsoid, the interior of which is polished and reflection-plated. A halogen lamp at one of the foci acts as radiation source which is imaged into the other focus, the location of the sample to be processed. Samples are contained in transparent ampoules. Homogenisation of temperature distribution can be achieved by rotation of the sample about the major axis of the ellipsoid.

The facility design will provide storage room for about 25 samples. A handling and transport mechanism will remove the appropriate sample from its storage location, transport it to the furnace, and expose it to the radiation at selectable values of translational and rotational velocities.

Since the mean lifetime of a halogen lamp is expected to be less than six months, in-orbit lamp replacement will be needed.

Figure 3 – Possible concept for the Automatic Monoellipsoidal Mirror Furnace Facility (AMMFF)



Tentative technical and performance data for the AMMFF (Fig. 3) are as follows:

Furnace	rotational ellipsoid
– Size (half axes)	80 × 90 mm
– Atmosphere	vacuum
– Heater power (lamp)	300 W
– Power stability	1%
Number of samples	about 25
Sample holder	Fused silica cartridge
– Size	100 mm long × 25 mm dia (max)
– Pulling speed	$10^{-3} - 10^{-1}$ cm/min
– Rotational speed	0.5 – 20 rpm
Max. sample temperature	>1000°C

Solution Growth Facility (SGF)
The SGF is essentially a set of 'reactors' for diffusion-controlled crystal growth from solutions. Its concept has been derived from similar facilities developed for FSLP and the NASA Long-Duration Exposure Facility (LDEF), and from pre-Phase-A studies.

Each reactor consists of two reactant reservoirs and a solvent chamber, interconnected via special valves, operation of which must create a minimum of turbulence in the liquids.

The SGF for the first Eureca mission will consist of three 'modules', each accommodating four reactor vessels. They will provide the following thermal conditions for the experiments:

- isothermal, constant temperature
- isothermal, temperature varying as a function of time
- thermal gradient.

Technical data for the SGF are as follows:

Number of reactors	12 in 3 groups of 4
– Dimensions	670 mm long × 76 mm dia
Typical operating temperatures:	
– isothermal, constant T	40 ± 0.1°C
– isothermal, varying T	35 – 45°C
– thermal gradient	35/45°C (ends of reactor)

Protein Crystallisation Facility (PCF)
The PCF will enable investigators to perform protein crystallisation experiments in space. Its concept has been derived from the FSLP Cryostat Experiment 1ES334 (ESA Bulletin No. 31, page 43), and from pre-Phase-A studies.

The design (Fig. 4) employs 12 identical reactor vessels which provide an individually controlled temperature environment for each of the 12 samples. Each vessel will consist of three adjacent chambers, carrying an enzyme-, a salt-, and a buffer-solution, respectively. These chambers can be physically interconnected by remote control. Protein crystallisation is initiated by allowing the enzyme- and salt-chamber solutions to diffuse into the reaction chamber.

Processing times in the order of 60 days are planned. Progress in crystal growth can be observed on the ground by means of a video camera. Performance data for the PCF are as follows:

Reactor vessels	Optical grade glass
– Number	12
– Volume of sample chambers	1 cm^3 each
– Volume of reaction chamber	2 cm^3
– Process temperature	−15 to +45°C
Video	Black/white
– Resolution	3 μm × 3 μm
– Contrast	32 steps

Multi-Furnace Assembly (MFA)

The MFA is intended to provide a modular payload dedicated to materials-science experiments by grouping up to 30 furnaces with common subsystem interfaces. The furnaces will be user-provided, on the basis of design recommendations by ESA. It will be possible to reuse furnaces already developed for other purposes, such as sounding-rocket flights.

The furnaces, with their samples and sensors, will be specific to one research topic and the MFA will provide common equipment and services for the different types of furnace. The normal operating environment will be space vacuum; certain furnaces may, however, be pressurised at the user's request.

The MFA will normally be operated in a fully automatic mode, but a facility for reprogramming from the ground is envisaged. Monitoring of furnace data as well as commanding and reprogramming of the facility is to be accomplished via the Eureca communications links. Some tentative performance characteristics for the MFA are:

– Number of furnaces	up to 30
– Mass of system	about 200 kg
– Power consumption	180 W continuous/500 W peak
– Cooling	liquid

Automatic Gradient Heating Facility (AGHF)

The AGHF is an electrical furnace designed for melting and controlled re-solidification of material samples housed in long cylindrical cartridges (Fig. 5). Temperatures of up to 1500°C will be available, as well as a range of thermal gradients along the longitudinal axis of the cartridge. The gradients will depend on the geometry and physical properties of the respective samples. The desired sample solidification rate will be achieved by controlled relative motion of cartridge and furnace, while keeping the furnace temperature constant. A handling and transport mechanism will allow sequential processing of up to 30 samples during any one mission. Some tentative performance data for the AGHF are:

– Number of cartridges	up to 30
– Cartridge wall temp.	1500°C max.
– Sample dimensions	200 mm long × 15 mm dia (max.)
– Length of isothermal zone	100 mm (grad. smaller 1 K/cm)
– Thermal gradient	up to 100 K/cm (depending on solidification temperature, thermal conductivity and sample geometry)
– Solidification rate	0.002 – 0.2 cm/min

Botany Facility (BF)

The BF is proposed as a multi-user life-sciences facility (Fig. 6), intended to support investigations into the zero-g behaviour of higher plants and fungi. It

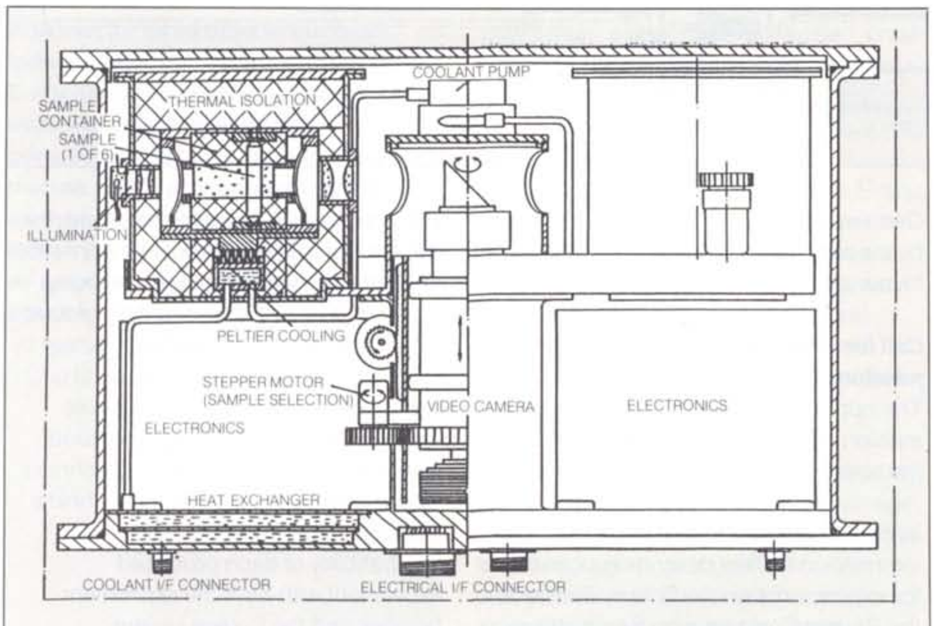


Figure 4 – Possible concept for the Protein Crystallisation Facility (PCF)

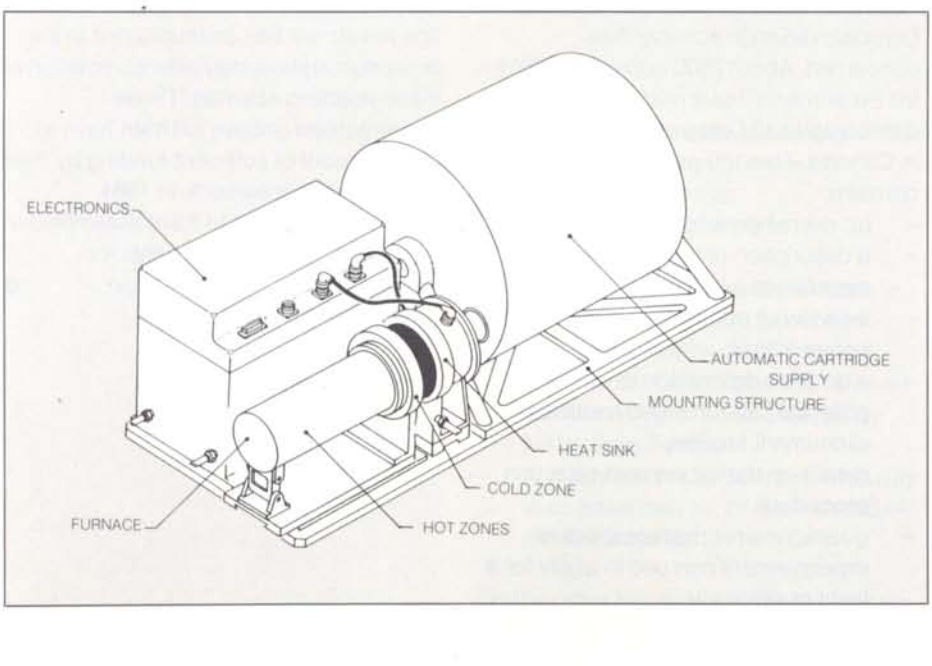


Figure 5 – Possible concept for the Automatic Gradient Heating Facility (AGHF)

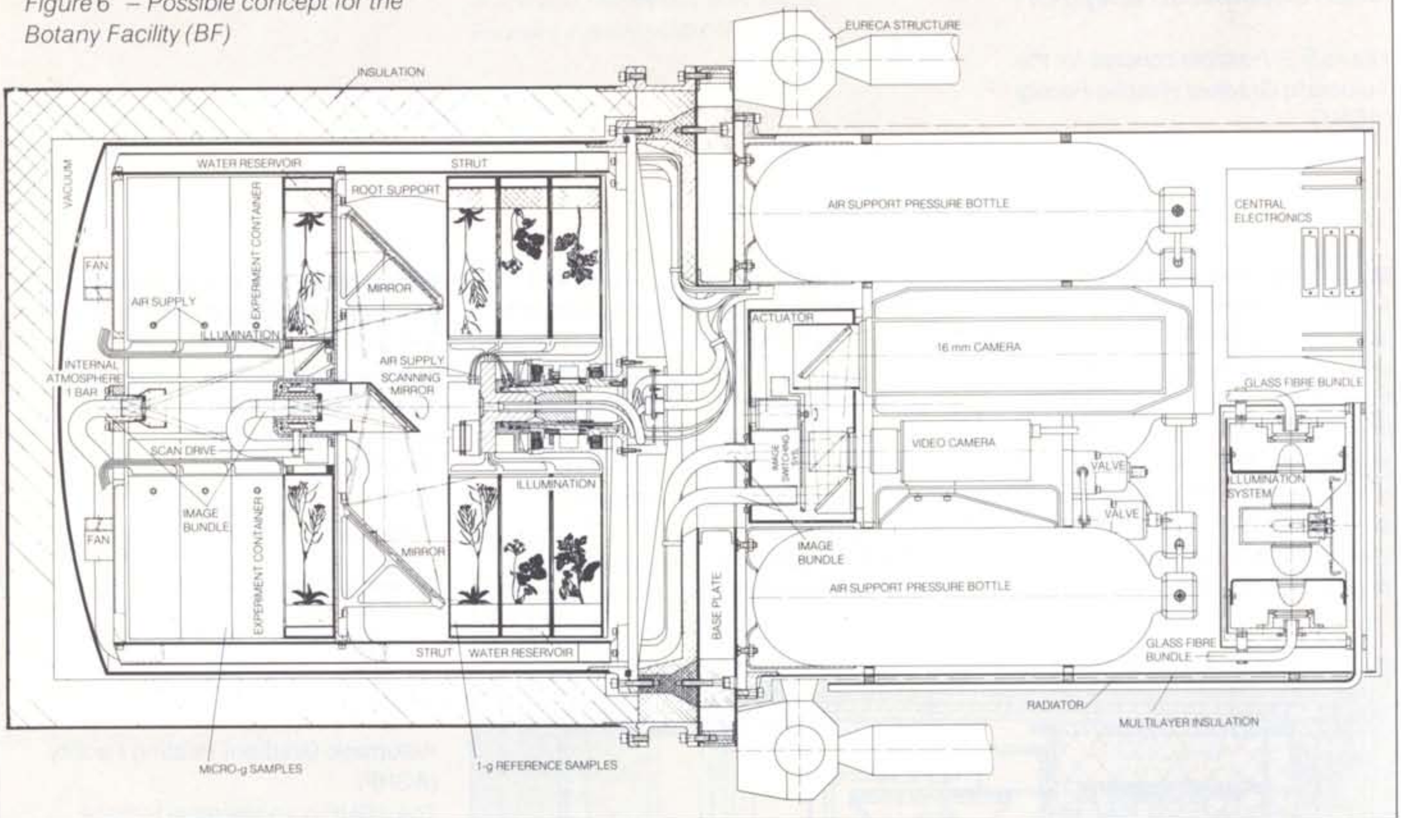


Figure 6 – Possible concept for the Botany Facility (BF)

will consist of an experiment module, which is effectively a single temperature-controlled chamber to contain all experiment equipment and samples, and a service module, providing life support, illumination, data handling, etc.

The present design concept provides for 16 sample containers within the experiment module, in which a microgravity environment will be maintained. Terrestrial conditions will be simulated with respect to atmospheric pressure (including humidity and CO_2 content) and temperature and illumination (including day/night variations).

A video system will provide two-dimensional or stereoscopic images of the biological specimens inside the chamber. To facilitate comparative assessments and, in particular, to differentiate between the influences of low gravity and cosmic radiation, it will be possible to grow samples in a 1 g environment. To this end, a centrifuge will be included within the experiment module. Its size and speed of rotation will be chosen such that an acceleration of 10 m/s^2 will prevail at root level while the gravity gradient will not exceed 5%/cm. It is planned that biological samples for the BF will be provided in the form of seeds or spores. Germination will then be initiated in orbit by the addition of liquid and provision of favourable temperature conditions.

Call for Experiments for the first Eureca mission

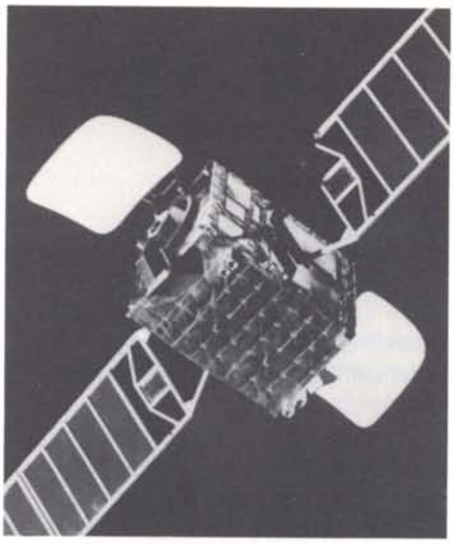
The opportunity to participate in the first mission has already been publicised in the scientific literature.

In parallel, some 2000 advance information leaflets describing possibilities for experiments on the Botany Facility and the Protein Crystallisation Facility have been sent to the members of the European science communities concerned. About 2500 copies of a 'Call for Experiments' have also been distributed in 13 European countries and in Canada. This 100 page document contains:

- an overall description of the mission
- a description of the carrier's capabilities and interfaces
- a review of potential payload compositions
- a detailed description of the six potential ESA-provided multiuser experiment facilities
- details on the experiment-selection procedure
- questionnaires that prospective experimenters can use to apply for a flight opportunity.

The deadline for receipt of proposals for the first Eureca mission was 30 April 1983. The proposals received are now being assessed by small scientific peer groups (ad-hoc panels of scientists appointed by ESA) and evaluated on the basis of such criteria as space relevance, scientific value, probability of achieving desired results, etc. In addition, an ESA technical evaluation team will judge the technical feasibility, safety aspects, and compatibility of each proposed experiment with both the experiment facilities and the Eureca system.

The results will be communicated to the proposers immediately after completion of these selection activities. Those experimenters chosen will then have to provide proof of sufficient funding by their respective organisations. In 1984, therefore, we expect to have assembled a fully defined set of experiments for flight on the first Eureca mission.



The Sophia Antipolis Workshop on the Relationship between ESA and Industry

W. Thoma, Contracts Department, Directorate of Administration, ESA, Paris

In June 1982, approximately eighty representatives from space industry and ESA met for three days to discuss industrial-policy problems within the European space industry. The prime objectives were: to study the competitiveness of European industry; to discuss ESA's procurement policy; to analyse the structure of European space industry; and to elaborate on ESA's role as a sponsor and promoter of European space industry.

Competitiveness

'...to watch the Agency's Ariane rocket take off (or, as happens more often, crash to the ground) from Guyana, one of the less pleasant parts of South America'.

from: New Scientist, 10 February 1983.

This might sound witty, but it is not. Firstly, the statement is incorrect, since three of the five Ariane launches from French Guiana have been a complete success (four were test launches in any case). Secondly, it needlessly undermines Europe's efforts to become a competitive force in global space activities.

Probably it is wishful thinking, but the day will hopefully dawn when press coverage of this nature will be replaced by objective and accurate reporting on the achievements of European industry, scientists and institutions in space activities.

It is fact that:

- Europe has already successfully developed a large number of satellites – scientific, telecommunications and meteorological;
- several cooperative programmes, in particular with NASA, have been successfully carried out, the most spectacular being Spacelab, with an additional flight model ordered by NASA from Europe;
- in many key areas European industry is as advanced as, or even ahead of, its US competitors.

On the other hand, in a number of recent international tender actions (e.g. from Australia, Brazil and Mexico), European industry has not been successful, only the building of Arabsat, which is also to be launched by Ariane, going to a European/US consortium. What are the reasons for the modest percentage? Will European industry be capable of obtaining a considerable share of this rapidly expanding market in the future? During the Workshop, at which European industry was fully represented, an attempt was made to answer these and related questions.

In many cases, space projects are so expensive that they become objects of political pressure. There is no general recipe for overcoming this obstacle, which is completely estranged from technical or financial competitiveness. Industry has to analyse the situation on a case-by-case basis and coordinate its approach with its respective government. In this context, the Agency is politically powerless and has no role to play.

Clearly, competition between European and non-European industry on the world market is a David and Goliath struggle. The US market is far larger than its European counterpart, particularly the highly protected US defence sector, and this gives a considerable advantage to US firms. It helps to provide them with the technology, and it leads to greater productivity to an extent Europe can only dream of. It is therefore crucial that Europe increase its efforts to develop new technologies through a coordinated approach. ESA has an important role to play in this domain.

This brings us immediately to the question of whether European industry should make bids *with* US firms or *against* them. At the Workshop there were clearly two schools of thought, but the answer is rarely black or white. There are situations in which collaboration with US firms could be initially beneficial. There are also projects, particularly within Europe, where combinations of European and US companies would certainly not be desirable. It seems logical that:

- where Europe has difficulty in penetrating the highly protected US market (military in particular); and
- where European industry has to face fierce competition on the world market outside the USA,

priority should be given to ensuring a lead in the European market. European industry clearly expects ESA to provide appropriate support in this domain.

Such support cannot consist of subventions which are contrary to the spirit of free competition. European industry has to learn to survive unprotected. The Agency's support has to be directed at supporting industry in critical technical areas and at aiding customers when defining their requirements.

Another topic connected with competitiveness discussed at the Workshop was the problem of geographical-return requirements. Is this a handicap for European competitiveness? At the present moment, we are not in a position to quote statistics and it would be difficult to quantify the real situation. The American concept of a predominant prime with various equipment suppliers seems persuasive, but the European approach has other advantages, notably the ability to draw upon a multitude of different resources, ideas and concepts. The main goal must be to combine efforts, to establish cohesion between the teams involved, and to optimise the concepts under development.

ESA procurement policy

'...to exploit the advantages of free competitive bidding in all cases except where this would be incompatible with other defined objectives of industrial policy.'

ESA Convention: Article VII c.

Free competition is the basic rule and this is normal for a procurement agency. Nevertheless, we should not ignore the facts. For technical or political reasons, the majority of contracts have now to be negotiated directly. This implies that a tighter control mechanism will have to be employed to verify costs, and more pressure will be put on industry to perform adequately.

It was encouraging to hear from industry during the Workshop sessions that they are not afraid of competition, provided the ground rules are known in advance. This is only fair and must be adhered to.

An additional problem discussed in the same context was the initiation of programmes. The present ESA procedure is rather orthodox: Phase-A studies, Phase-B in competition, etc. With the increasing complication and consequently increasing cost of projects, the continued validity of this somewhat mechanical process, dating from the Sixties, is becoming questionable. One of the most interesting proposals emanating from the Workshop was that this initiation process for new projects should be reviewed and that the exchange of views with industry in this regard should be continued.

Industrial structures

During the Sixties, there were three principal consortia within European space industry:

COSMOS: with Aerospatiale, CASA, ETCA, MBB, MSDS, SAT, Selenia
MESH: with Aeritalia, ERNO, Fokker, HSD, INTA, Matra, Saab
STAR: with BAe, Contraves, Dornier, FIAR, Laben, LM-Ericsson, Sener, SEP, Thomson-CSF.

The existence of these Consortia guaranteed a competitive spirit within the European space market at system level. The groupings provided a good mechanism for fulfilling geographical-return requirements, although the lack of competition at subsystems and equipment level also had disadvantages. This was compensated for by the fact that companies learned to work together on a regular basis, and most projects were the subject of real team work.

This industrial structure is now threatened with extinction, for the three main reasons:

- Industrial mergers, which will seriously handicap consortia;
- Geographical-return constraints in optional programmes, which undermine consortium cohesion;
- Lack of sufficient programmes to keep the consortia running in parallel.

There are a number of recent examples of ad-hoc industrial groupings being formed for specific projects. Experience has shown that more time and effort is required in such cases to set up an industrial structure and to put the wheels in motion. A weakening of the consortia would reinforce the polarisation process around the prime contractor, a process that can be mitigated by letting more and more subsystem and equipment contracts in open competition under the Agency's bidding procedure, with full visibility for the Agency.

Another interesting evolution might occur in terms of the large electronic companies as suppliers of payloads. The present consortia concentrate mainly on space platforms. A restructuring of European space industry might shift the balance towards payload aspects.

Finally, with an eye on the now rapidly progressing commercialisation of space activities, it would probably be a mistake to maintain what could be termed 'artificial' industrial structures for ESA programmes which would not be compatible with the rest of the market. We should therefore leave room for natural evolution and abstain from intervention, to avoid turning back the clock.

ESA as a promoter of European space industry

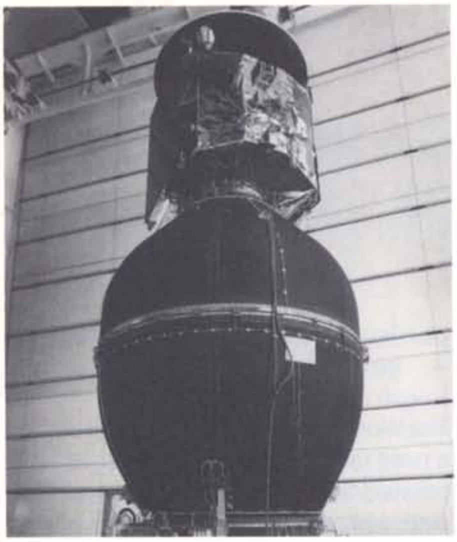
As stated earlier, European space industry feels that it requires ESA's support to keep it competitive. This means, in the first instance, support in the field of technology. Presently, there are three kinds of technology programme:

- The Technological Research Programme (TRP)
- The Advanced Systems and Technology Programme (ASTP)
- Preparatory programmes.

The Workshop attendees felt that there is a need for a more intensive dialogue between the Agency and industry as a means of anticipating and identifying the requirements for future programmes. Industry also underlined the need for large-scale expansion in the ESA technological programmes in the face of competition from the USA, where technological knowhow is continuously being updated.

A further issue was the approach to be taken towards support activities (test facilities, consultancies), in order to reduce costs and thus compensate for the advantage that US companies possess in having larger, national and commercial markets.

The final conclusion drawn as regards ESA's role in applications programmes was that there is a wide spectrum of possibilities, ranging from the Agency serving as a consultant to its acting as the supplier and operator of complete systems (Meteosat). A general rule cannot be established, but the maximum of support from ESA is very much relied upon by European industry.



Préparation des campagnes de lancements doubles à Kourou

A. Masson, Département Ariane, ESA, Kourou

L'optimisation économique de la famille des lanceurs Ariane (AR-1, 2, 3, 4) a été basée principalement sur le concept des lancements doubles. Ce concept, justifié par le marché potentiel des satellites identifiés pour la décennie 1980-90, a abouti à la définition d'un ensemble de lancement et des installations associées d'intégration des satellites. Celles-ci sont compatibles avec des campagnes de lancements doubles, dont le rythme, bimestriel à partir de 1983, pourra devenir mensuel à partir de 1985, date à laquelle le deuxième Ensemble de Lancement (ELA-2) sera mis en service, le lanceur AR-4 devenant opérationnel en 1986.

Le présent article se propose de faire ressortir les contraintes qui découlent du concept de lancements doubles, et la structure opérationnelle mise en place au niveau du champ de tir pour les satisfaire efficacement.

Avant d'expliciter l'organisation qui régit les acteurs d'une campagne, il est nécessaire d'en décrire le scénario et le cadre dans lequel va se jouer cette campagne.

L'Ensemble de Préparation des Charges Utiles

Un facteur important de toute campagne est la répartition géographique des installations, liée elle-même aux facteurs de sauvegarde. Cette répartition géographique a pour corollaire direct la notion de transfert inter-sites qui est un élément dimensionnant des opérations.

Les Figures 1 et 2 montrent l'implantation des installations qui constituent l'Ensemble de Préparation des Charges Utiles (EPCU).

Schéma des opérations

Les opérations standards sont exécutées en trois phases (Fig. 3):

Phase 1: Préparation et contrôles électriques du satellite
Phase 2: Opérations dangereuses
Phase 3: Opérations en zone de lancement.

Les phases 1 et 2 couvrent les opérations effectuées dans le complexe EPCU et sont indépendantes de celles du lanceur. La phase 3 concerne les opérations combinées charge utile/lanceur en zone de lancement Ariane.

Phase 1

Après arrivée et déchargement en Guyane, le matériel satellite est acheminé au Centre Technique du CSG, dans le Hall de Transit, en zone S1.

Après déploiement du matériel dans les différents sites, les opérations en zone S1 comprennent essentiellement:
- l'installation de baies de contrôle satellite
- le déploiement du satellite et des moyens associés en zone propre
- les contrôles électriques
- la préparation du satellite contrôlé, pour son transfert en zone d'assemblage Ariane.

Phase 2

Opérations 'satellites'

Les moteurs à poudre, ainsi que la pyrotechnie, sont préparés dans le bâtiment S2.

Les moteurs à propulsion liquide sont préparés dans les bâtiments S3A ou S3B.

Le remplissage, la pressurisation des satellites, la validation des moyens associés, ainsi que l'assemblage du moteur/satellite sont effectués dans les bâtiments S3A ou S3B.

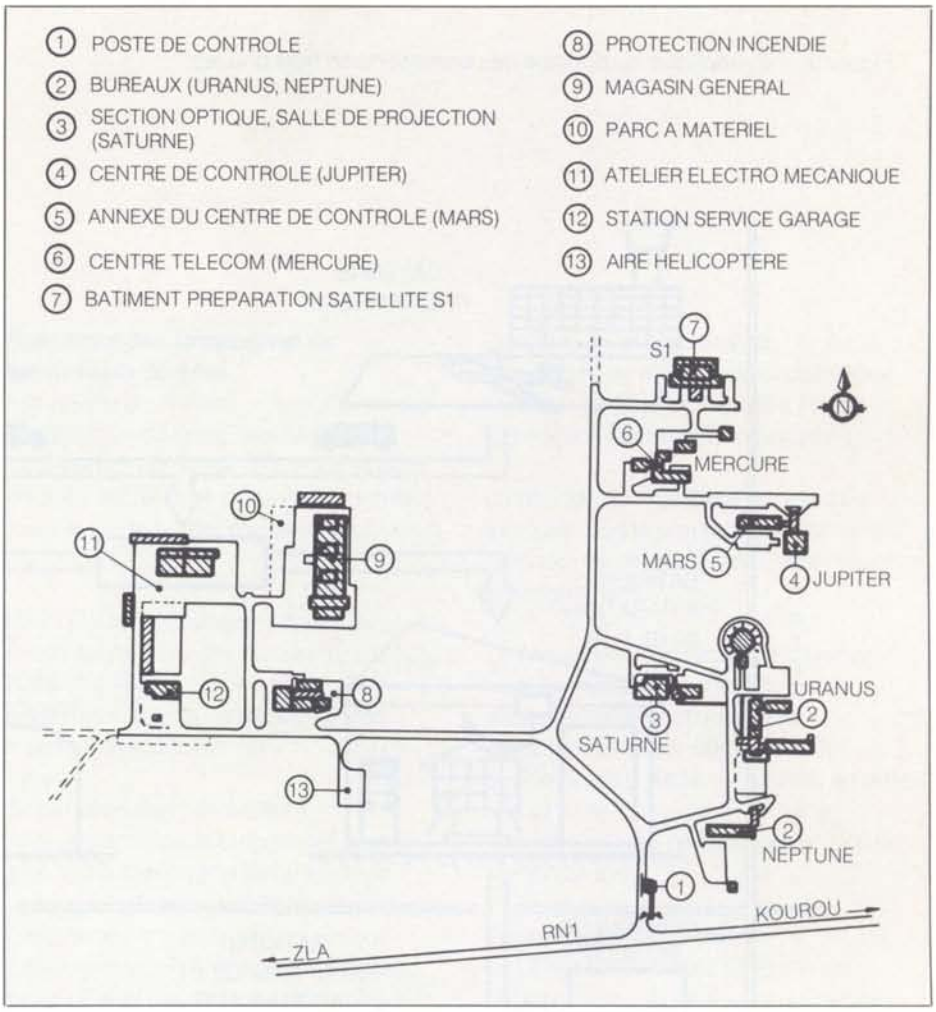
La radiographie des moteurs à poudre est réalisable dans le bâtiment S4.

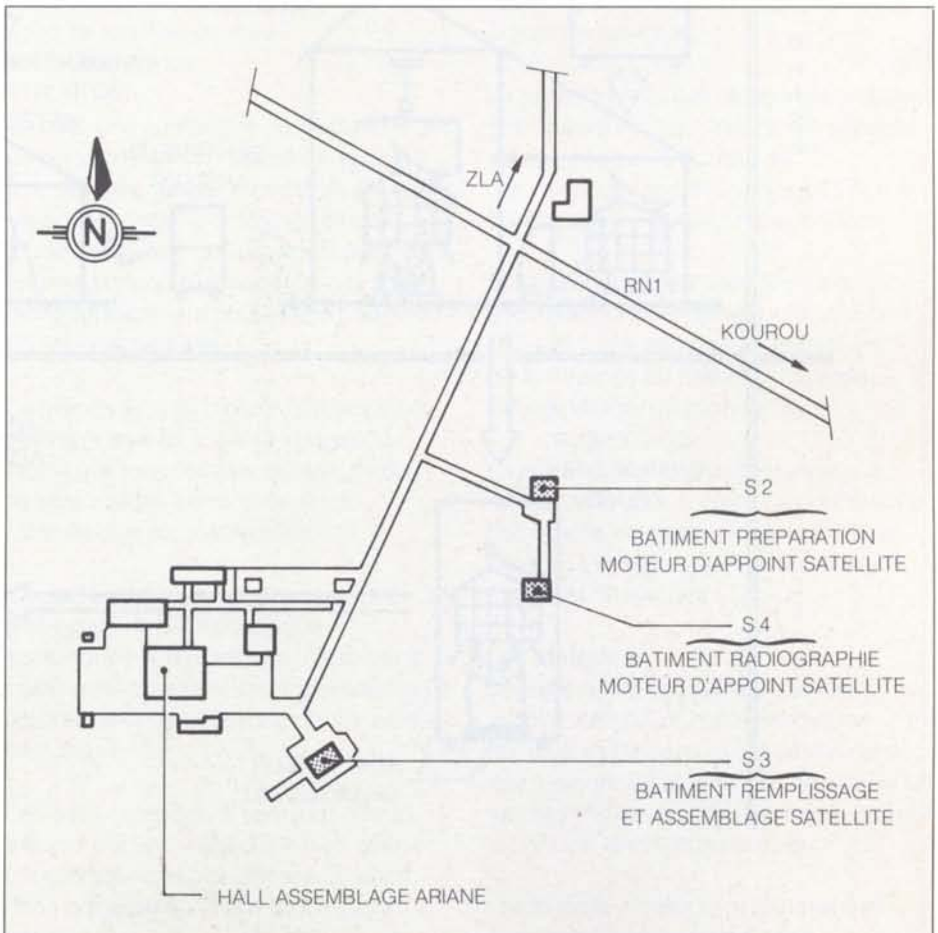
Opérations 'composite' (Fig. 4)

L'assemblage des satellites et du Système de Lancement Double Ariane (SYLDA),

Figure 1 – Le Centre technique du CSG

Figure 2 – La zone d'assemblage Ariane





ainsi que le transfert du composite SYLDA dans le conteneur charge utile (CCU), sont réalisés dans les bâtiments S3A ou S3B.

En configuration Ariane-4, l'encapsulation, c'est-à-dire l'assemblage coiffe/composite, est effectuée dans le bâtiment S3B.

Phase 3

Ces opérations sont des opérations combinées lanceur/charge utile.

Elles comprennent:

- la validation des équipements sol charges utiles et des liaisons ombilicales,
- le transfert du CCU sur la tour de lancement,
- l'assemblage composite/lanceur,
- la pressurisation finale éventuelle des charges utiles,
- les contrôles finaux sur satellites,
- la chronologie de lancement.

Les contraintes

Les différentes contraintes qui régissent le scénario d'une campagne sont:

- la disponibilité des bâtiments, liée elle-même à la campagne précédente et au recouvrement éventuel avec la campagne qui suit,
- la date de tir et le créneau de lancement,
- les opérations journalières.

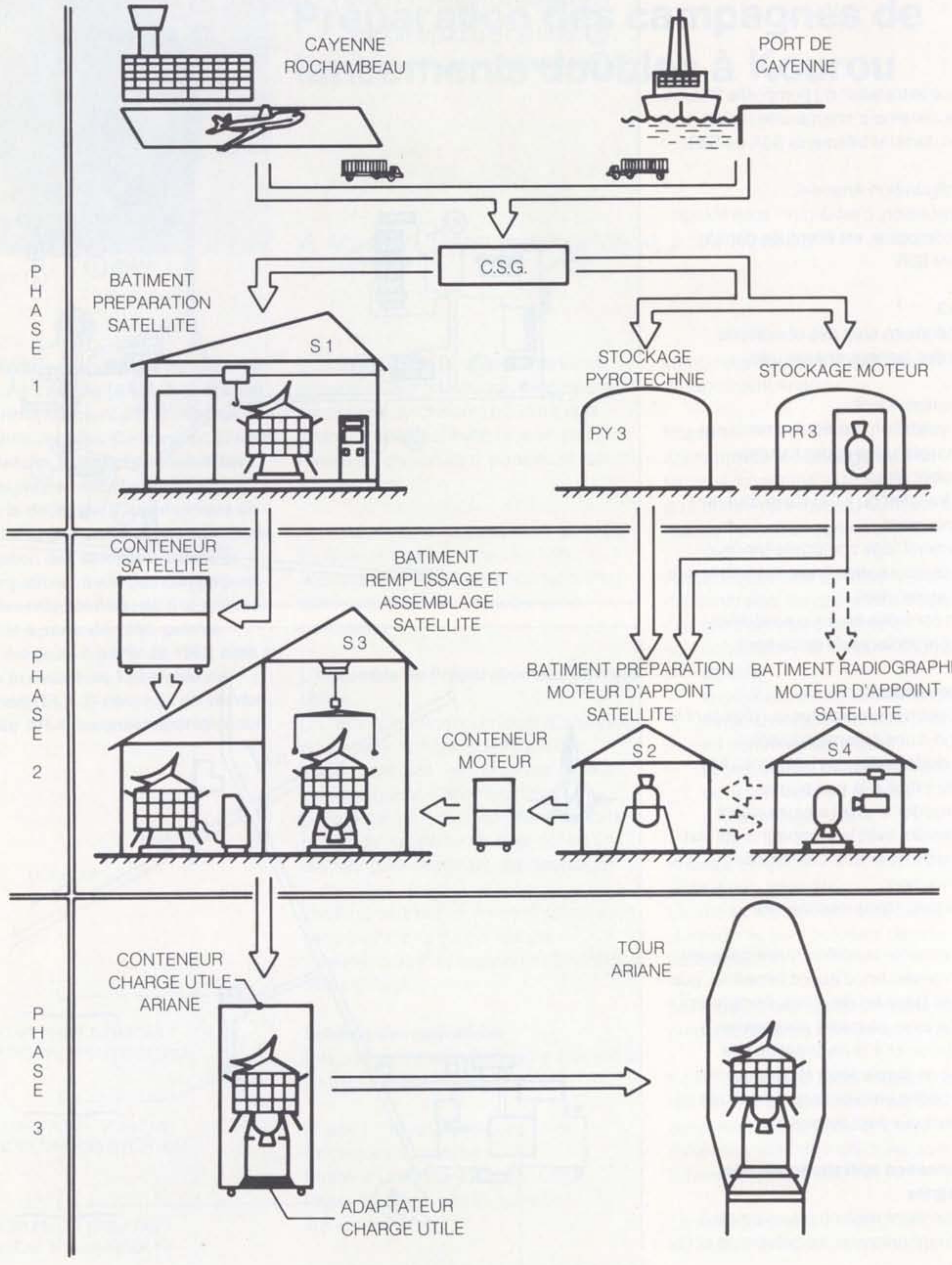
Une contrainte supplémentaire découle du rythme des tirs, d'abord bimestriel, puis mensuel. Dans les deux cas, compte tenu des cinq jours de travail nécessaires à l'évacuation et à la revalidation des moyens de préparation et de lancement, la campagne satellite proprement dite ne peut dépasser sept semaines.

L'organisation opérationnelle des campagnes

La scène étant mise en place, on peut maintenant présenter les acteurs. Ils sont quatre:

- les deux satellites,
- le lanceur,
- le CSG.

Figure 3 — Synoptique du principe des opérations en trois phases



La complexité des tâches, la multitude des besoins, le chevauchement des calendriers et les interfaces techniques entre ces différents acteurs sont tels que la campagne réelle débute environ deux ans avant l'arrivée des équipes sur le champ de tir. Cette phase préparatoire est menée dans son ensemble par le Chef de Mission (CM), assisté, plus particulièrement pour les satellites, par l'Adjoint au Chef de Mission (ACM).

La structure nécessaire pour coordonner ces moyens et ces équipes est animée et dirigée par le Directeur des Opérations (DDO), qui s'appuie sur les équipes CSG et spécialement sur la Division Charges Utiles.

La Direction des Opérations

Sa raison d'être et son souci permanent sont, avant la campagne, de définir dans le détail la planification de ces tâches, d'obtenir la quantification précise de ces besoins, et de veiller en permanence, pendant la campagne à ce que les moyens restent compatibles avec les besoins.

Les documents de base Charges Utiles

Les interfaces sont recensées dans le Document de Contrôle des Interfaces (DCI), les besoins sont exprimés dans la Demande de Lancement (DL), les tâches et leur distribution dans le temps sont gérées par les Plans d'Opérations Satellites (POS), les Plans d'Opérations Combinées (POC) et la Chronologie de Lancement.

Les points de rendez-vous importants

La planification d'une campagne passe par des dates clés, points de rendez-vous importants, qui ont tous ou presque un impact sur la date de tir. Ce sont:

- l'assemblage satellite/moteur d'appoint,
- le remplissage des satellites en hydrazine,
- l'assemblage Composite/SYLDA et le départ vers la tour de lancement,
- la répétition générale,
- le démarrage de la chronologie de lancement.

Spécificité des campagnes de lancements doubles

Elle résulte de l'utilisation simultanée des installations du complexe EPCU actuellement uniques au CSG, par deux équipes satellites et, dans les 15 derniers jours avant le tir, de l'équipe d'intégration du SYLDA.

Bien que ces installations soient doublées avec l'avènement des installations EPCU-2, l'unicité à l'échelle d'une campagne existera toujours à cause du rythme mensuel des lancements.

Séparation des paramètres

Afin de permettre le respect des dates clés, toute campagne de lancement double est planifiée par séparation des paramètres, en définissant des sous-campagnes qui n'ont pas d'interfaces entre elles, et qui se terminent toutes sur une date clé, étape qui est en fait le point de jonction de deux sous-campagnes.

En effet, une campagne de lancement qui ne comporte qu'une charge utile, peut être planifiée suivant un schéma linéaire série. Par contre, le critère spécifique d'une campagne de lancement double est bien la nécessité de définir des sous-campagnes, et leur planification, suivant un schéma parallèle.

La préparation du moteur d'appoint est l'exemple type de sous-campagne, de même que les contrôles électriques du satellite intégré. La date clé étant l'assemblage moteur/satellite.

La planification a donc pour but essentiel, d'une part, de définir ces sous-campagnes et, d'autre part, d'assurer la compatibilité temporelle de la présence de deux équipes satellites pour chaque sous-campagne.

Ces sous-campagnes sont, par ailleurs, associées à une installation bien définie (cf. définition des phases) et se prêtent donc parfaitement à une planification parallèle.

Contrôle de la planification

Deux types de réunion de coordination sont prévus pour ce contrôle, l'une journalière, l'autre hebdomadaire.

La réunion journalière a pour but de s'assurer que la planification des sous-campagnes est respectée ou nécessite un aménagement.

La réunion hebdomadaire concerne le traitement des incidents. Elle peut, d'ailleurs, se tenir de manière exceptionnelle, à la demande. Elle concerne, plus particulièrement, les dates clés et traite de tout impact sur le planning intégré de la campagne dans son ensemble.

Structure opérationnelle

Le DDO est aidé dans sa tâche de coordination, par l'Adjoint au Chef de Mission (ACM), qui fait la synthèse des plannings satellites.

La mise en place des moyens nécessaires aux opérations journalières des satellites est assurée par le Bureau de Coordination Opérationnelle (BCO), qui édite un télex opérationnel quotidien.

La gestion des différents plannings (journalier, hebdomadaire, global à l'échelle d'une campagne, annuel, etc.) est centralisée au niveau du Bureau Central de Planification (BCP).

La liaison avec les équipes lanceur, au niveau de la coordination des opérations combinées, est planifiée par le BCP par l'interface avec la COPA (Coordination Planification Ariane).

Les marges

Les différentes contraintes que nous venons d'expliciter imposent que les documents de base soient définis dans leur moindre détail, ceci afin de réduire les marges d'aléas au strict minimum, suivant le principe des marges actives.

Les marges d'aléas sont parfaitement quantifiées en temps, mais non

Figure 4 – Plan d'intégration de la charge utile double

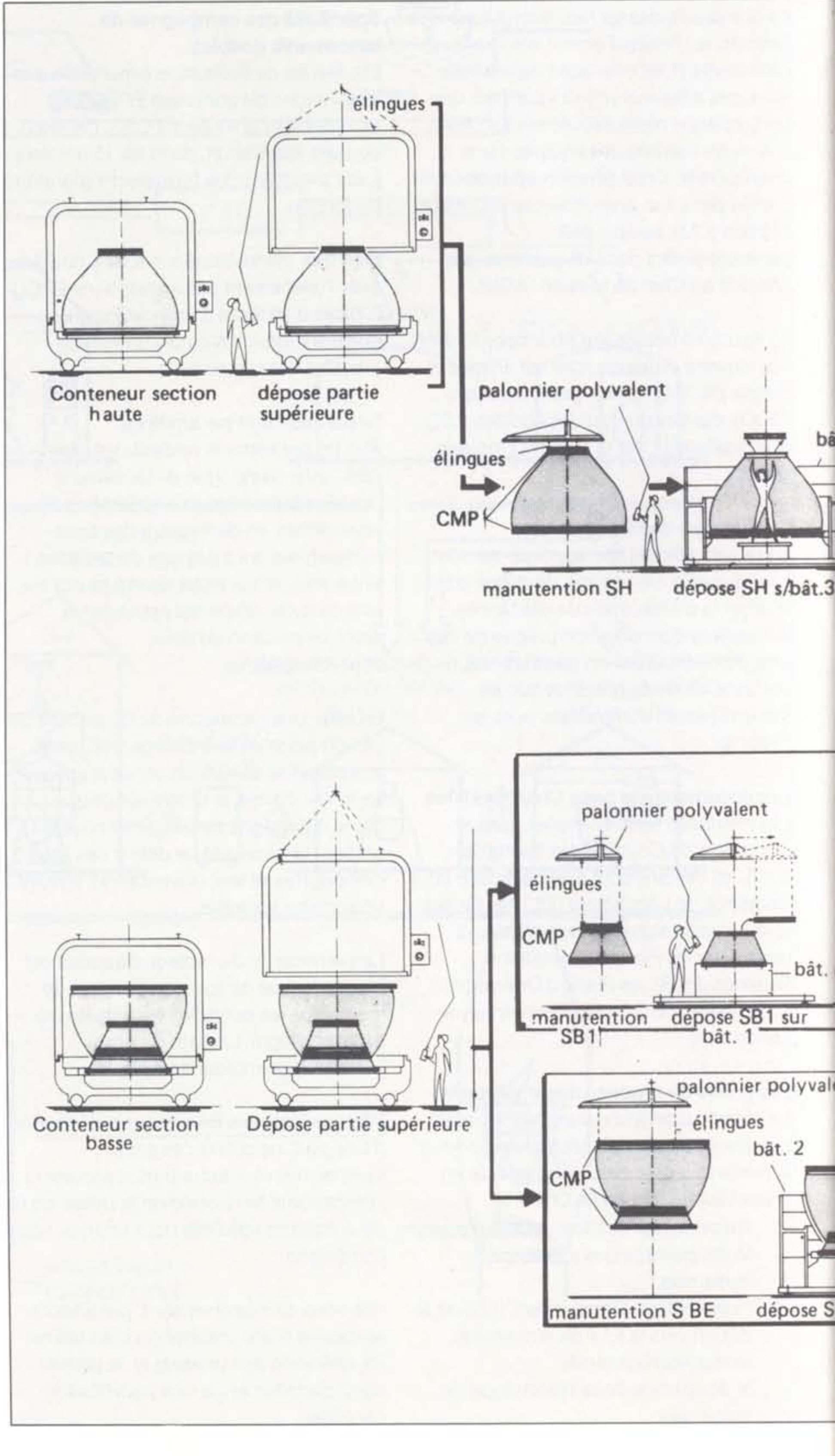
qualitativement distribuées par tâches, et consommées en fin de campagne, donc sans surcoût financier dû à un arrêt momentané des opérations.

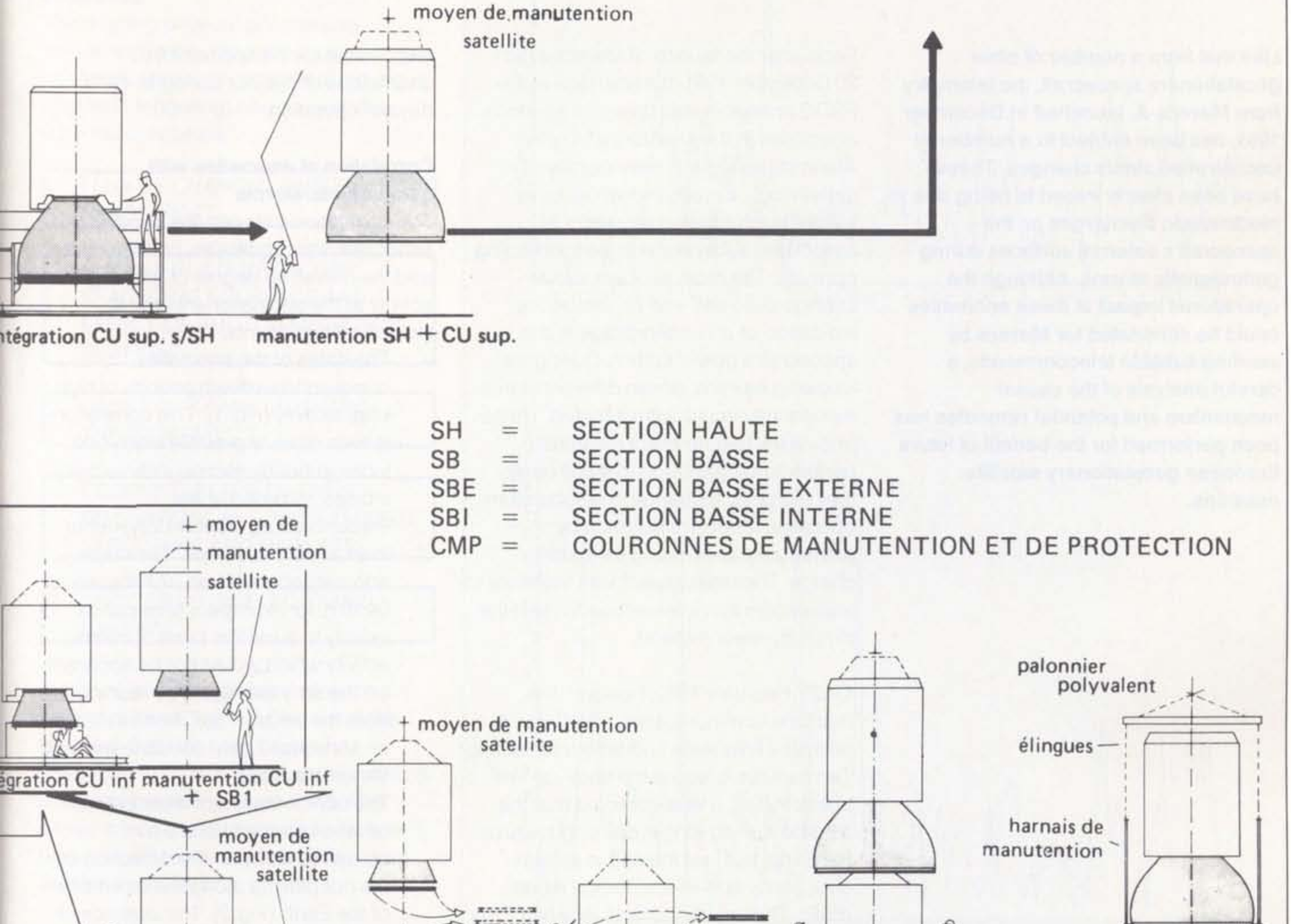
Conclusions

Cette présentation, concise et synthétique, ne peut rendre compte de l'aspect humain d'une campagne. Ce ne sont pas des concepts qu'il s'agit de planifier, mais des hommes, qu'il faut faire vivre et travailler ensemble, plusieurs centaines, de nationalités différentes, dont le but commun est *le lancement à l'heure prévue.*

Les relations opérationnelles entre tous ces acteurs sont, bien sûr, en cours de rodage. Mais les imperfections ont été identifiées et les résultats des campagnes précédentes sont là pour le prouver. Les rendez-vous n'ont jamais été manqués pour des incidents en campagne.

L'année 1983, année charnière pour cette organisation opérationnelle, est porteuse d'espoir pour l'année 1984 qui sera cruciale.





moyen de manutention satellite
intégration CU sup. s/SH
manutention SH + CU sup.
SH = SECTION HAUTE
SB = SECTION BASSE
SBE = SECTION BASSE EXTERNE
SBI = SECTION BASSE INTERNE
CMP = COURONNES DE MANUTENTION ET DE PROTECTION
moyen de manutention satellite
intégration CU inf
manutention CU inf + SB1
moyen de manutention satellite
moyen de manutention satellite
bât.2
présent.CU inf
SBI s/SBE
dépose couronnes
assemblage SBI et CU inf dans SBE
assemblage SH et CU sup. sur SB et CU inf
palonnier polyvalent
élingues
harnais de manutention
manutention composite charge utiledouble

The Electrostatic-Discharge Phenomena on Marecs-A

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Like that from a number of other geostationary spacecraft, the telemetry from Marecs-A, launched in December 1981, has been subject to a number of uncontrolled status changes. These have been clearly traced to being due to electrostatic discharges on the spacecraft's external surfaces during geomagnetic storms. Although the operational impact of these anomalies could be eliminated for Marecs by sending suitable telecommands, a careful analysis of the causal mechanism and potential remedies has been performed for the benefit of future European geostationary satellite missions.

Soon after the launch of Marecs-A on 20 December 1981, the attention of the ESOC operators was drawn to spurious anomalies in the satellite's telemetry. Alarm status signals were displayed in certain logic circuits though all other available information showed the associated subsystems to be functioning normally. The most frequent status change observed was an erroneous indication of an undervoltage in the spacecraft's power system. During the following months, eleven different status-monitoring circuits were affected. These anomalies had no effect on satellite performance, although in some cases they triggered a change in a subsystem operating mode, for instance by prematurely terminating the battery charge. The main impact was therefore to require operator intervention to reset the circuit by telecommand.

On 27 February 1982, however, the maritime communication and C-band telemetry links were suddenly interrupted. Ten minutes later, via the back-up VHF telemetry link, it was observed that the satellite was no longer pointing towards the Earth, but was instead in its safe, emergency Sun re-acquisition mode (ESR). The spacecraft was returned to its normal Earth-pointing configuration by ground command and thereafter performed normally. Nevertheless, such an unexplained anomaly was considered undesirable for an operational spacecraft, and a special ESA-BAe team was appointed to make a thorough analysis of its origin and remedies. The team's conclusion was that electrostatic-discharge (ESD) events were wholly responsible for the spacecraft's anomalous behaviour during its early days of operation.

Correlation of anomalies with geomagnetic storms

The correlation between the frequent but minor telemetry anomalies on Marecs-A and the prevailing degree of geomagnetic activity at the geostationary orbit is striking on two counts:

- The dates of the anomalies correspond well with periods of high solar activity (Fig. 1). This correlation is even more impressive when one looks at hourly geomagnetic-activity indices, recorded at the Fredericksburg Observatory, rather than at daily averages. The major anomaly observed on 27 February at 04:13 h, for example, corresponds exactly to a narrow burst of intense activity which would not be apparent on the daily average. The readings from the electron-flux monitors flown on Meteosat-2 also correlate well with these observations.
- The concentration of most events between midnight and 9 a.m. correlates well with the deflection of the hot plasma along the dawn side of the Earth (Fig. 2). The absence of events during eclipses also led the investigation team to look for differential charging effects between the dark and illuminated sides of the spacecraft, rather than for abrupt changes in average potential.

Other firms and agencies operating geostationary spacecraft were also contacted during the investigation, as a source of additional information on ESD anomalies. It is interesting to note that, despite the improvements that have been made in satellite design, almost all current geostationary-satellite programmes are still affected by spurious switchings in their telemetry and low-level logic circuits.

Detailed analysis of Marecs-A anomalies

The differing physical phenomena intervening in the anomaly cause (magnetic substorm) and effect (spurious electronic triggering) chain are shown schematically below.

1. *FLUX OF CHARGED PARTICLES ON SPACECRAFT.*
2. *CHARGE BUILD-UP ON THE SPACECRAFT SURFACE AND EFFECT OF PHOTO-EMISSION IN SUNLIGHT.*
3. *ONSET OF SPARK DISCHARGE IN THE MATERIALS.*
4. *COUPLING BETWEEN THESE DISCHARGES AND THE SATELLITE STRUCTURE AND HARNESS.*
5. *TRIGGERING OF ELECTRONIC CIRCUITS.*

The most poorly understood links in this chain are items 3 and 4. Despite all the progress that has been made in investigating items 1 and 2, there is still no means of predicting or reconstituting where the discharge occurred and how it was coupled to the spacecraft structure and electrical cabling.

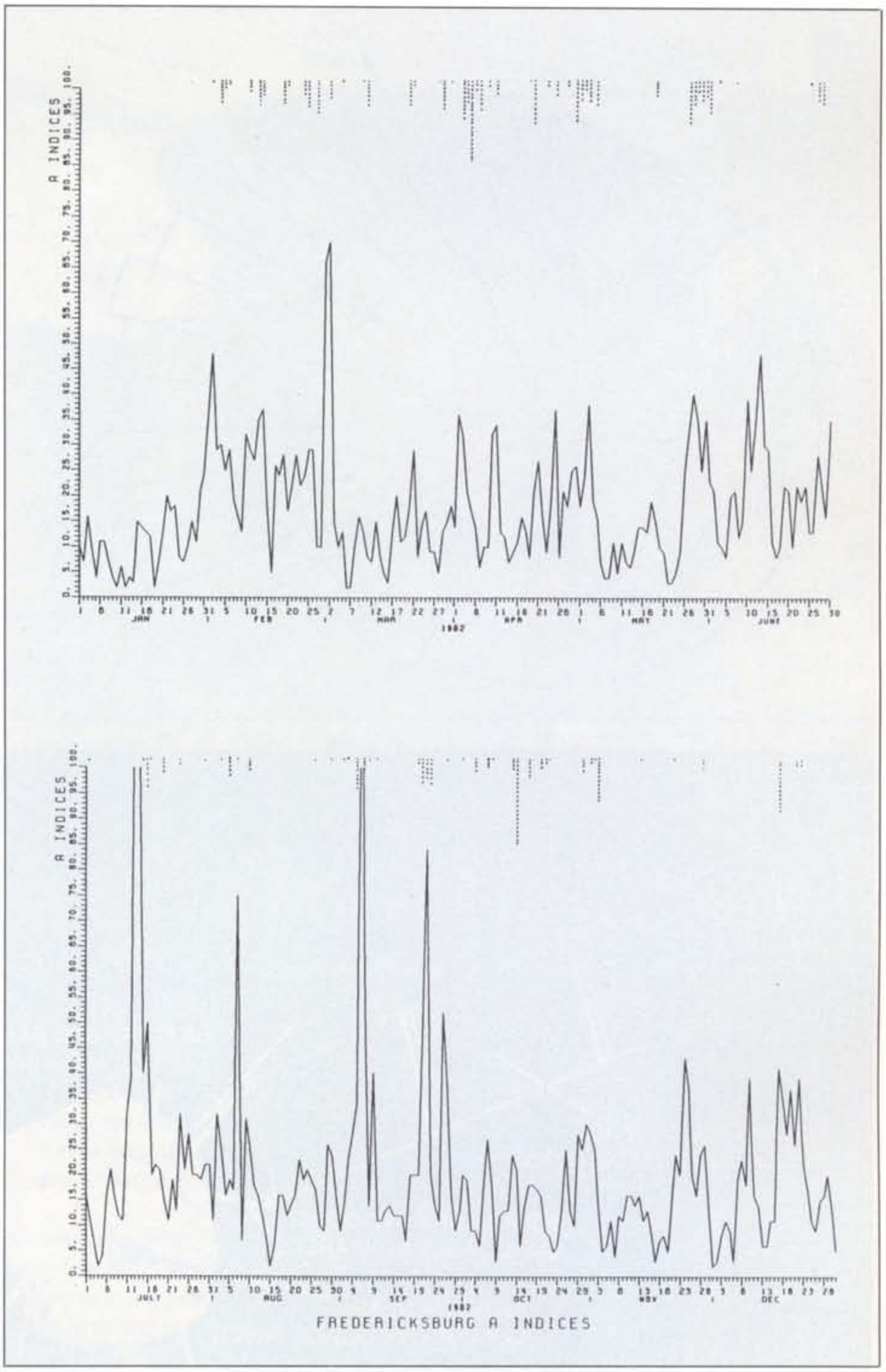
The analysis of the Marecs-A anomalies had therefore to be carried out indirectly by a combination of:

(i) careful study of the satellite's telemetered data and its response to ground instructions,

(ii) a detailed materials test programme, and

(iii) electrical tests at unit and system level.

Figure 1 — Plot of observed anomalies in 1982 as a function of geomagnetic activity. The dots represent individual telemetered 'events'.



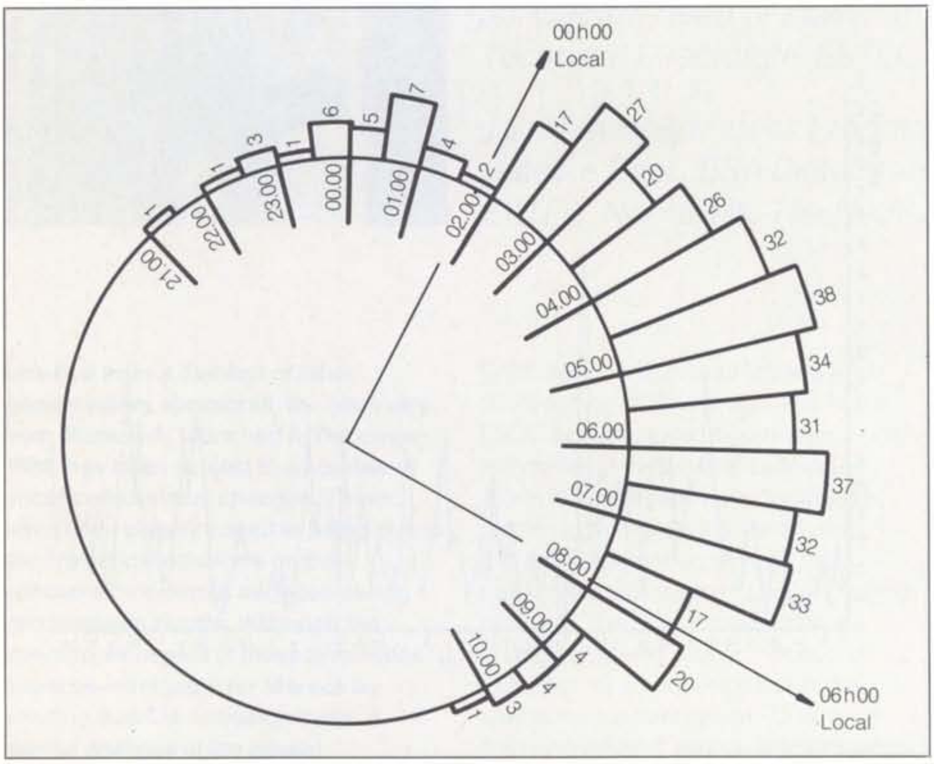
These efforts, covering a period of about four months, involved approximately 100 different tests or qualification activities, and contributions from some fifty experts. It is therefore possible to summarise only the main conclusions here.

Charging of external surfaces

Consideration of the spacecraft's geometry and its orientation with respect to the Sun during the event could not provide a precise indication of the location of the discharge on the satellite.

Figure 2 – Observed electrostatic discharges as a function of time of day (GMT). The two radii indicate local noon and local midnight (satellite time).

Figure 3 – The surface materials of the Marecs spacecraft.



A change in the relative incidences of the various types of anomaly between the summer and winter solstices confirmed, however, that there were several different discharge locations.

It was therefore necessary to make a detailed study of the 20 or so different types of sheet materials used for spacecraft cladding (Fig. 3). An extensive test programme was initiated during which samples of the materials or even complete areas of the spacecraft walls were submitted to electron-beam testing in vacuum. The main conclusions reached were:

- By far the largest discharge currents (up to 1400 A) are observed in the thermal blankets used to cover a large area of the spacecraft's outer surface.
- These high currents are due to the choice of an unfortunate combination: that of a thick

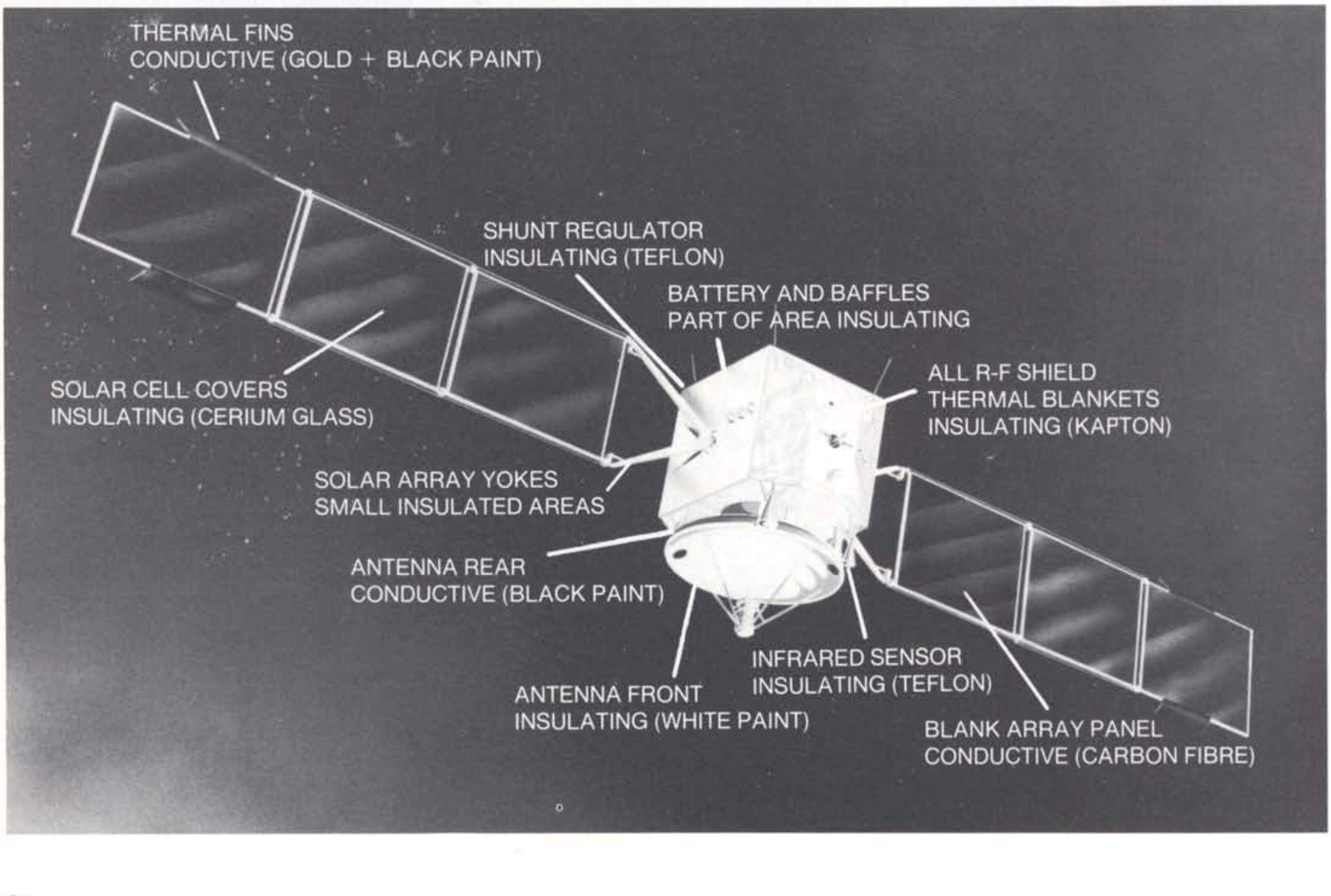
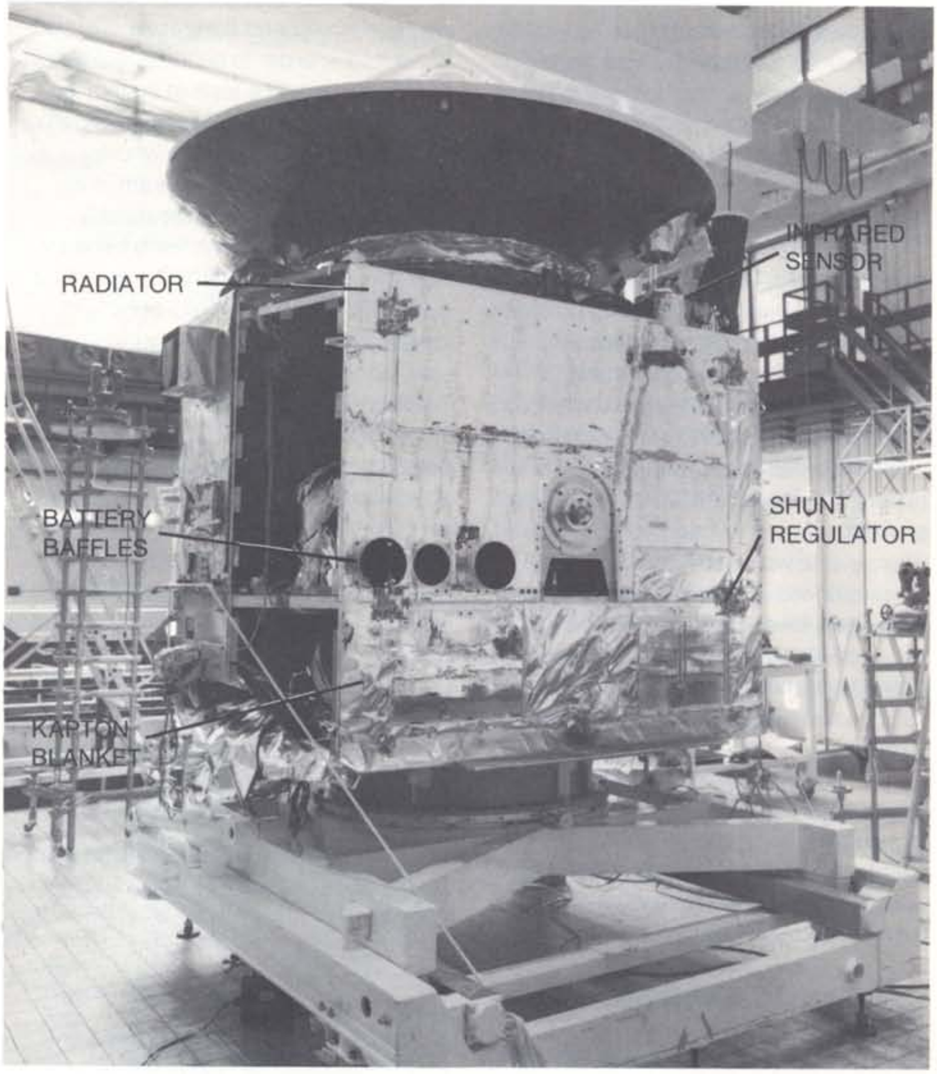


Figure 4 — North wall of the Marecs spacecraft, showing the shunt regulator, battery baffles, and infrared Earth sensor.



insulating outer layer of kapton (75 μm), backed by a substrate of aluminium sheet. The latter sheet was introduced after a steady degradation in the thermal properties of the OTS blankets was observed. This was traced to the erosion of a thin, vapour-deposited aluminium layer. Providing Marecs with a much thicker aluminium layer surely halted this thermal degradation process, but unfortunately markedly increased the intensity of electrostatic discharges. Experience in the USA with this type of blanket seems to indicate, however, that after one or two years in orbit the discharges tend to degrade the kapton layer. It is therefore quite possible that the frequency of the anomalies on Marecs will gradually decrease as the spacecraft ages.

- The shunt regulator and batteries, which have one face exposed to space, have also exhibited significant discharge currents (Fig. 4). For the shunt in particular, this could be traced to the use of aluminised teflon, a material often used to replace second-surface mirrors on small areas.
- Other possible causes of the anomalies are the infrared sensors and the solar array, due essentially to the direct coupling of these equipment items to sensitive circuits.

Coupling with electronic circuitry

The tracing of the exact coupling path between a discharge on the spacecraft surface and its effect on the logic circuits was a far more difficult task, because:

- the location of the discharge and therefore its path through the structure are unknown
- a large number of units (up to 7) can be affected and the harness linking them is extremely complex (up to 800 interfaces in the case of a single unit such as the Electrical Integration Unit)
- the very narrow structure of the ESD transients (typically less than 100 ns rise-time) makes them practically impossible to reproduce with available test equipment, and any cable inductance or stray capacitance becomes significant.

Despite these difficulties it was possible for the investigating team to conclude that the spurious triggering of these units was due to two main factors: the excessive sensitivity of several interface circuits to very narrow or repetitive pulses, and the referencing of some inputs to two different grounding points.

Implementation and validation of the remedies

By the time that the discharge anomalies were observed on Marecs-A, both Marecs-B and ECS-1 had been integrated and were undergoing system-level tests. It was therefore difficult to propose major design modifications, which could hardly have been justified anyway considering the limitations of the diagnosis.

Instead, the approach taken was one of applying changes to the external surfaces as if no changes were to be made in the electronics, and vice-versa. This 'belt-and-braces' policy provided reasonable confidence that a definite improvement would be achieved, a prediction that it has, unfortunately, not yet been possible to verify due to the unsuccessful Marecs-B launch.

Changes to external surfaces

More than 20 different changes were introduced, both in the choice of the materials used for external surfaces, and in the manner of mounting and grounding them.

Perhaps the most important was the introduction for the first time on an operational spacecraft of a thin, conductive layer of vapour-deposited indium-tin oxide on the spacecraft blankets. This material was submitted to a complete qualification test programme, mainly to ensure that, unlike the OTS generation of blankets, its thermo-optical properties would not degrade significantly after several years in space. A suitable grounding technique was also qualified. The improvement in electrical-discharge properties is dramatic, the discharge current observed during electron-beam testing dropping from 1600 A to less than 2 A.

Other major changes consisted of using grounded, indium-tin oxide coated, second-surface mirrors instead of teflon sheets, and the replacement of insulating black paint by a conducting substitute.

Changes in electronic circuits

For the reasons mentioned above, the electronic modifications had to be very simple, and in fact limited to two or three components (diode limiters, decoupling capacitors, R-C delay circuits). Theoretical evidence of the improved noise immunity was obtained and a number of unit tests proved that there would be no adverse effects. Typical improvement factors exceed 40 dB in voltage sensitivity, or a factor of 100 in response time.

One of the circuits, the undervoltage status 'flag', was deliberately left unmodified to allow it to be used as a convenient reference in system testing and when in-orbit.

Validation of improvement

During the investigation of the Marecs anomalies, a thorough literature survey was performed and several experts were consulted in order to define a reliable set of ESD acceptance tests at system level. One of the obvious methods considered consisted of subjecting the whole spacecraft to an electron beam in a vacuum chamber. This was quickly confirmed as unrealistic, firstly because it was very difficult to isolate the spacecraft such that the charge build-up would not be distorted, and secondly good simulation would have needed the presence of sunlight and deployment of the solar panels. In addition, there was a risk of stressing or damaging the spacecraft's electronics.

The absence of a system test for electrostatic charging was compensated, however, with a number of electron-beam tests at unit level and by a computer simulation using the NASA program NASCAP. This simulation not only showed the improvements due to the modifications introduced, but also drew attention to the risk of introducing new discharge mechanisms through unconsidered changes in the average spacecraft potential (Fig. 5).

Similar difficulties were met in defining system-level tests for the susceptibility of the electronic subsystems to discharges. A number of rather empirical techniques were tried which involved the generation of an external discharge with a high-voltage power supply. The most successful attempts were based on direct injection of current pulses into the structure and the coupling of a sharp

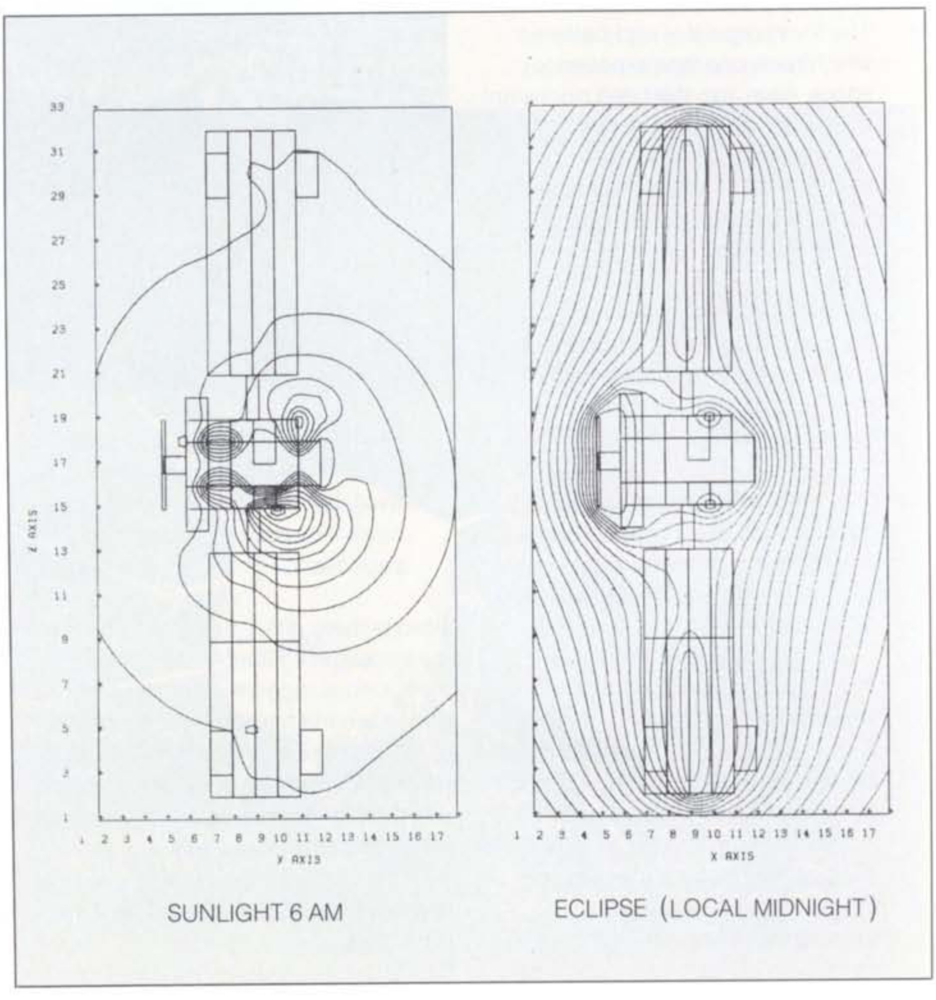


Figure 5 — Simulation of spacecraft charging with the NASCAP program. The iso-potential contours show a concentration of potential gradients at the edges of the kapton blankets in sunlight (left) and a much more uniform potential (approx. 6 kV) in eclipse (right).

voltage transient via a capacitor plate mounted on the solar array. On the other hand, relatively poor results were obtained with magnetic-field pulses. Finally, arbitrary limits had to be placed on the amplitude of the pulses injected into the satellite, as there was a risk of stressing components: in most cases, however, a fair number of anomalies could be triggered with current pulses of between 50 and 200 A.

Although test results appear to depend strongly on minute changes in the test set-up and spacecraft grounding, reliable information could still be obtained on the efficiency of the electronic improvements. On the unmodified Marecs-B and ECS satellites, the tests were able to trigger four or five anomalies. Repeating the same tests on Marecs-B after the changes to the electronics had been introduced did not trigger any anomaly other than that involving the undervoltage indicator.

This relative success must, however, be treated with caution. Some of the anomalies observed in-orbit could not be reproduced and there is therefore no guarantee that all coupling mechanisms were tested at meaningful levels.

Recommended precautions for future ESA projects

Although the anomalies observed on Marecs-A were relatively minor or could be overcome by appropriate commands from the ground, it was felt that the Agency's approach to ESD design and testing had to be reconsidered.

Table 1 summarises the recommendations made for the benefit of other ESA geostationary satellite projets, and Hipparcos and L-Sat in particular. Advice has also been requested by and accepted for several national telecommunications satellite projects.

It cannot be guaranteed that their implementation will avoid all ESD problems in the future. The recommended policy on the space hardening of electronic devices could be very costly and its use should therefore be limited to critical interfaces. The subsystem emergency logic circuits should certainly be treated, as by definition they have a high priority level vis-a-vis all other spacecraft functions, and a malfunction in this area can therefore have disastrous effects.

In future, the Agency will devote more attention to the design, protection and inhibit capabilities of these circuits. In this respect, Marecs-A was well designed in that the emergency Sun re-acquisition anomaly could be inhibited.

Table 1 — Recommendations for future ESA policy

Advice for geostationary satellite projects

Overall:
- In addition to the grounding of external surfaces, improve the electronic immunity to transients (belt-and-braces concept).
- Do not rely too heavily on ESD system tests.

External Surfaces:
- whenever practical, use conductive, grounded material
- never use a material without first conducting an electron-beam irradiation test and tests at predicted extreme temperatures
- pay particular attention to sensors, external wires and holes in the spacecraft walls
- use a computer model to simulate overall charge distribution and pay particular attention to the solar array.

Electronic Interfaces:
- adopt a sound grounding philosophy and improve it for high frequencies (local decoupling)
- reduce the number of interfaces between units and the number of separate units
- do not use fast circuits when not needed and beware of C-MOS gates
- be very cautious with protection circuits and provide them with telecommand override.

Further ESA research needed

- definition of a sound system test philosophy (MIL-STD-1541 is obsolete), if possible by comparative tests on a real spacecraft model
- develop and qualify conductive materials (flexible SSMs and conductive white paint)
- improve basic understanding of the mechanism of a discharge, in particular by testing and provision of spacecraft instrumentation

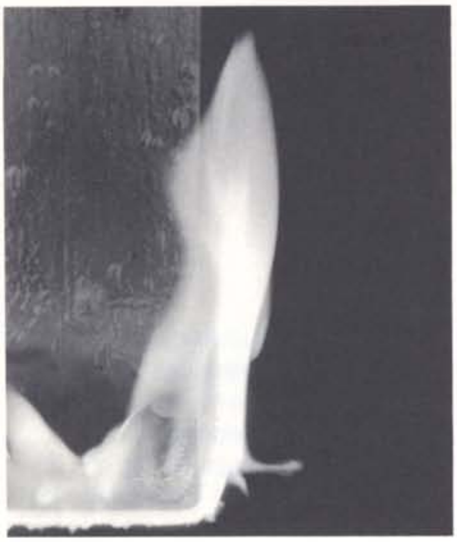
On the other hand, significant improvements in the grounding of external surfaces must be pursued. The approach recommended is regarded as the most cost effective, and new techniques are available which can reduce ungrounded areas to a minimum. In this respect the lesson of having to validate any material changes has been very valuable; the relatively minor change in the thermal blankets between OTS and Marecs-A was probably responsible for the large degradation of the latter's ESD behaviour.

Finally, as the table shows, further research is needed in several areas and the Agency will make the necessary arrangements. Related research activities in the USA will also be monitored.

Acknowledgements

The authors wish to thank all the members of the task force created to investigate and (hopefully) solve the problems encountered by Marecs-A. The strong spirit of co-operation with industry, particularly at BAe and Matra, was much appreciated. The very accurate reporting by ESOC of the events observed on the satellite also merits special mention.

Finally, the invaluable help provided by Mr. J. Stevens (NASA) in setting-up a NASCAP surface-potential model is gratefully acknowledged.



Flammability Testing

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With the advent of the Spacelab programme, European space industry suddenly found itself confronted with a whole new range of materials requirements. Of these, perhaps the one requirement that seemed the most daunting was that which necessitated the use of nonflammable materials. With Spacelab having been delivered to NASA and with the European element of the First Spacelab Payload (FSLP) going through the acceptance process, now would seem an appropriate moment to review some of the lessons learnt and to try to clarify some of the misconceptions surrounding the subject of flammability testing.

Flammability testing remains one of the black arts where a university degree in alchemy may still be one of the most useful qualifications. There are a plethora of different test methods, with, in most cases, no correlation between them. It has been said that if a manufacturer wishes to label his materials 'non-flammable'* then there is bound to be, somewhere, some test that will enable him to obtain the necessary evidence of nonflammability. There is also a marked degree of ignorance in understanding the complexities of the flammability data available. Many of the fires investigated every year have been shown to be due to the misuse of supposedly nonflammable materials in applications for which the test data are no longer valid.

The first step, therefore, is to define the appropriate test method. For the Spacelab programme this was a relatively straightforward process since suitable test methods, amply demonstrated on the Apollo and Skylab programmes, already existed. These are defined in NASA Specification NHB 8060.1 and were originally designed for the testing of materials in atmospheres containing up to 100% oxygen at reduced or elevated pressures.

* Some confusion may arise due to our use of the word flammable to describe something that burns, whereas in both English and French it is more common to use inflammable as having this meaning. It has now been universally accepted that the correct scientific usage is: flammable = capable of burning, and nonflammable = incapable of burning.

The change to a normal-air atmosphere, required for the Orbiter and Spacelab programmes, made necessary some modifications to the basic test methods, but in principle NHB 8060.1 was taken as the standard. It should be added that, in parallel, other test methods were evaluated at ESA to see whether or not another, more widely known test could be utilised. It was concluded that a test known as the 'Critical Oxygen Index' (ASTM 2863) was suitable and that, in particular, a correlation appeared to exist between data obtained by both this and the NHB 8060.1 tests. However, at the present moment data obtained by the ASTM 2863 test are not accepted by NASA and so the bulk of the flammability testing at ESTEC is still performed according to the NASA Specification.

Test methods

The NASA Spec. NHB 8060.1 lists a whole range of tests depending on the material's application. Some tests are mandatory and give precise accept/reject criteria, whereas others are more of an informative nature and the data obtained are used purely as an aid to the relative rating of materials.

For the Spacelab and First Spacelab Payload (FSLP) programmes, a slightly different approach was used whereby considerable emphasis was placed on the usage configuration of a material. The prime screening test, Test 1 of NHB 8060.1, was retained as being the test that a material must pass in order to be considered acceptable for unrestricted use. However, if a material fails this test, it can still be considered for use subject to its passing a configuration test whereby the material is tested in a form that accurately represents the usage application. Tests 2 and 3 of NHB 8060.1, which are normally performed by NASA on materials that fail Test 1, were not conducted for the Spacelab programme since it was considered that, firstly the data obtained are of little value to the equipment designer, and secondly configuration testing is the best and most direct method of determining acceptability or otherwise.

Wire insulations are a special case and must meet not only the requirements of Test 1 of NHB 8060.1, but also those of an additional test specifically designed for this type of material. Although, as some wire manufacturers contend, a very strong case can be put forward that this test is unrepresentative of real-life situations, it does enable the comparison of different forms of wire insulation. Recent changes to the NHB 8060.1 test method have, however, raised some further doubts about this test, but this is not a subject for discussion here.

The test methods are as follows:

Upward Propagation Test: Test 1 of NHB 8060.1
As its name implies, this is a test in which the rate of propagation of a flame is measured on a sample held vertically and ignited at the bottom. This is very much a worst-case test, in that the flame front heats the material above it, rendering it more likely to burn.

Acceptance is based on a material either not igniting or self-extinguishing before 15 cm of the sample's length has burned. The material is also not considered acceptable if it burns for longer than 10 min, or if it drips or sputters burning material.

The sample is normally 30 cm long, 6.5 cm wide and of usage thickness. If, in normal use, the material is applied to some substrate, it must be tested in this form.

Configuration Test: based on Test 10 of NHB 8060.1B*
In essence, a sample representative of the flight configuration is ignited by either an open flame and/or wire overload, and the extent of burning recorded. The extent of flame propagation to adjacent materials is particularly important.

Because of the importance of this test, the sample configuration must be agreed beforehand by all parties concerned, with the involvement of the test personnel. This ensures that there can be no dispute afterwards about the validity of the test. In order to ensure full documentation, detailed colour photographs are always taken of the sample before and after test. In addition, the test is normally recorded on either 16 mm cinefilm or, more usually these days, on video.

Wire Overload Test: Test 4 of NHB 8060.1 (also Test 4 of ESA PSS-01-721)
This test consists of taking a bundle of seven wires of a defined length (30 cm) and electrically overloading one of them. In Rev. A of 8060.1, the overloaded wire was on the outside of the bundle, whereas in Rev. B it is on the inside.

The initial current applied to the wire is 75% of the nominal fusion current of the particular gauge of wire under test, and this current is increased in 5 amp steps at 1 min intervals according to 8060.1 Rev. A, or by an amount depending on gauge size according to Rev. B. At present it is unclear what effect the changes incorporated in Rev. B have had on existing test data, and this whole test method is therefore the subject of much discussion. Suffice it to say that at ESA, for the Spacelab and FSLP programmes, all testing was performed according to NHB 8060.1 Rev. A.

Test equipment
The equipment consists of a large chamber (ca. 150 l) which can be evacuated to ca. 0.1 torr for the removal of combustion products. The chamber has the necessary feedthroughs for lighting and power and has a large viewing port for observing the samples during testing. A removable sample holder is used in the Upward Propagation Test to clamp the sample vertically over the igniter.

Ignition, with an open flame, is normally accomplished by electrically overloading a solid igniter (Solidox B). This gives a flame lasting approximately 25 sec and generating a temperature of approx. 1000°C.

For the wire-overload tests, a power supply able to deliver up to 300 A is used.

Because the chamber must be completely isolated during the test, some oxygen depletion takes place as the burning proceeds. To measure the extent to which this occurs, a paramagnetic oxygen analyser is built into the system so that the residual atmosphere in the chamber can be analysed after the test.

Examples of flammability tests performed at ESTEC
Nowhere is the saying 'one picture is worth a thousand words' more true than in flammability testing. No written test report can fully describe what has happened to a material during a flammability test and in many cases it is impractical to return the sample, or what is left of it, to the person who requested the test. We therefore have to rely heavily on detailed colour photographs to convey the necessary information.

Figure 1 shows a typical upward-propagation test in progress. In this case the material was a gold tape applied to a glass epoxy substrate. The photograph illustrates how ignition is accomplished; the burnt-out igniter is still visible beneath the burning sample. This sample was tested in an atmosphere of normal air (21% O_2), which is the test atmosphere for

* More fully described in Flammability Testing, ESA PSS-01-721, October 1982, Test 5.

any item to be flown in the Space Shuttle's cargo-bay.

The oxygen concentration to be used for testing has also been the subject of much discussion. The requirement for all the tests specified in NHB 8060.1 is that testing shall be performed in the worst-case test atmosphere designated by the Project Office. For Spacelab and FSLP, this was initially designated to be 23.8% O_2, 76.2% N_2 at 14.7 psi total pressure. As a result of problems experienced with the Shuttle's oxygen partial pressure regulators, a wide variety of oxygen concentrations have been quoted in the last two years; such as 24.5%, 24.7%, 25.9%, 27.5% and 30% (this last figure at a reduced pressure of ca. 9 psi). A minor problem, you might think, since it is a simple matter to change the test atmosphere. This is true, but unfortunately a material's flammability characteristics depend absolutely on the oxygen concentration available to support combustion.

This is illustrated in Figure 2, which shows results obtained from an upward-propagation test on the Spacelab trim close-out material (a silicone fabric) under a series of atmospheres with differing oxygen concentrations. There is a considerable increase in burn length between the sample tested in 23.8% O_2 and that tested in 30% O_2. In the latter case, the burn length exceeds that allowed, and hence the material could not be considered acceptable for use in this particular atmosphere.

The point, therefore, is that for a flammability test to be meaningful, the test atmosphere must be precisely defined.

Sometimes a very simple design change can render an otherwise unacceptable material acceptable, or vice versa. Polyethylene terephthalate in the form of very thin metallised foil is widely used as a thermal-blanket material. It is, unfortunately, highly flammable even in normal air.

Polyimide foils, on the other hand, are generally nonflammable. It is therefore a simple matter to make an acceptable thermal blanket by using the cheaper polyethylene terephthalate material for the bulk of the blanket, with front and rear sheets of polyimide to provide flame protection. In addition, the edges should be sealed with a suitable polyimide tape.

One particular sample tested was in exactly this form, but with one major difference in that perforations, some 5 mm in diameter, had been made in the blanket for venting purposes. On testing, the flame penetrated the holes in the polyimide foil causing ignition of the underlying material. Since many such perforations were present, there was ready supply of oxygen to the sample to sustain combustion and the sample burnt to destruction (Fig. 3a).

This problem, however, could be easily overcome in two ways: by reducing the vent-hole diameter (to ca. 1 mm), to stop flame penetration, or by adding an additional polyimide layer, staggered so that the venting holes did not coincide. The result of a test on a sample prepared in the latter manner is shown in Figure 3b, where it can be seen that no ignition occurred.

Figure 1 – Upward Propagation Test on gold tape/glass epoxy

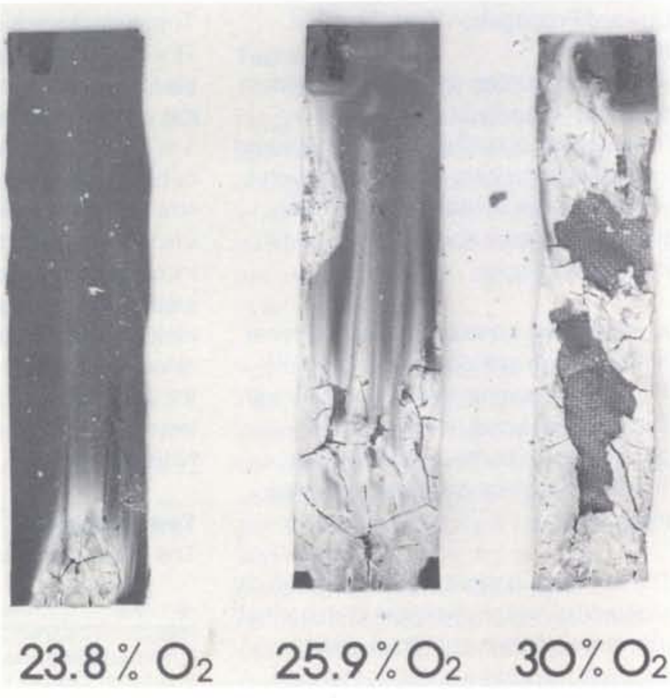
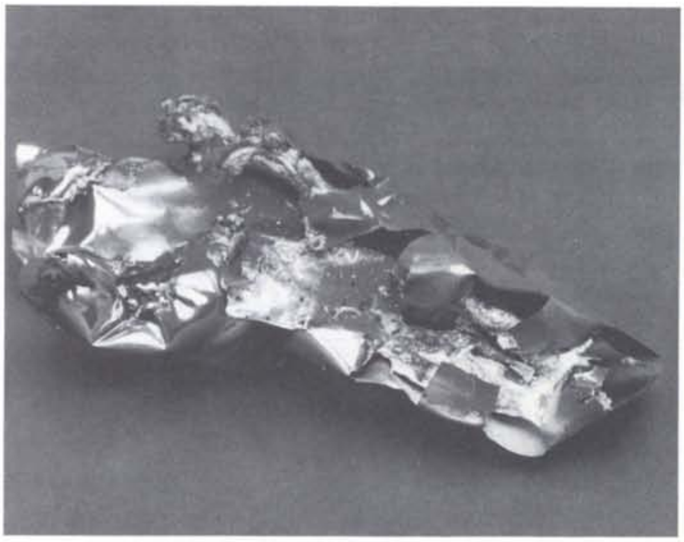
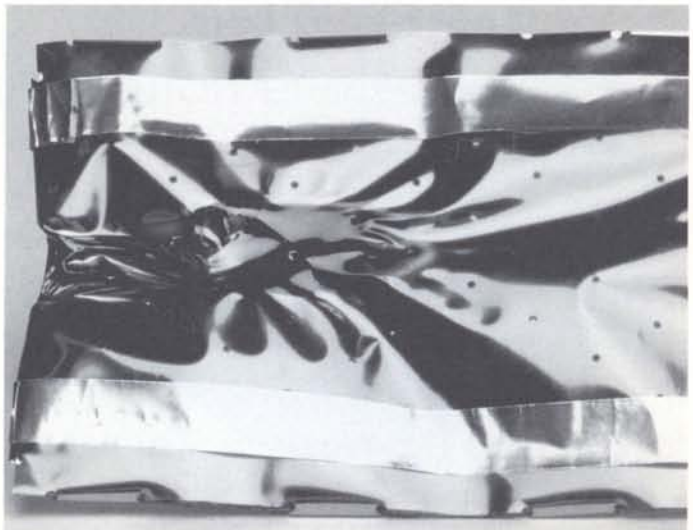


Figure 2 – Upward Propagation Test on trim close-out material under varying oxygen concentrations

Figure 3 — Configuration Flammability Tests on thermal-blanket material

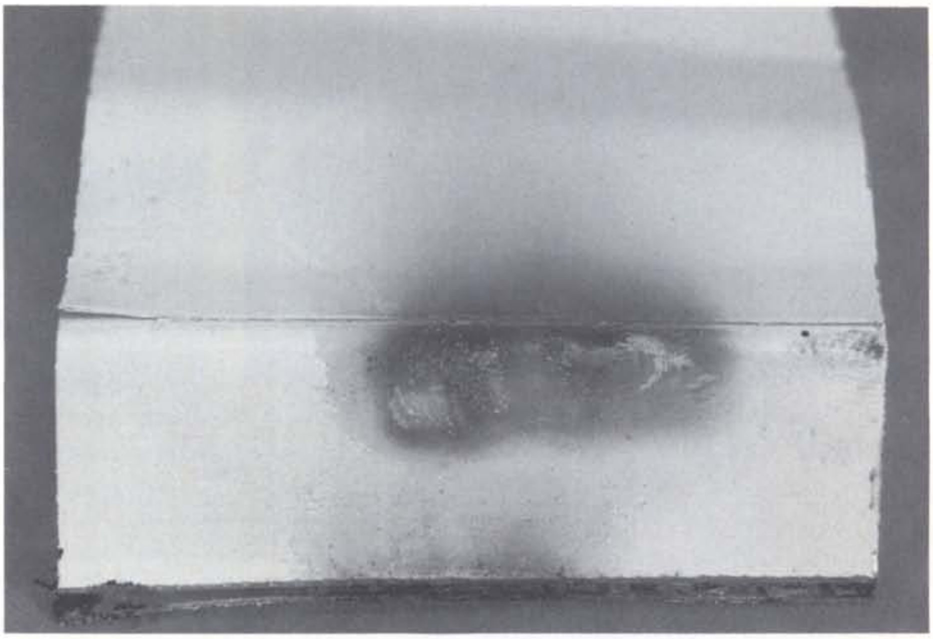


3a



3b

Figure 4 — Upward Propagation Test on white polyurethane paint on an aluminium substrate



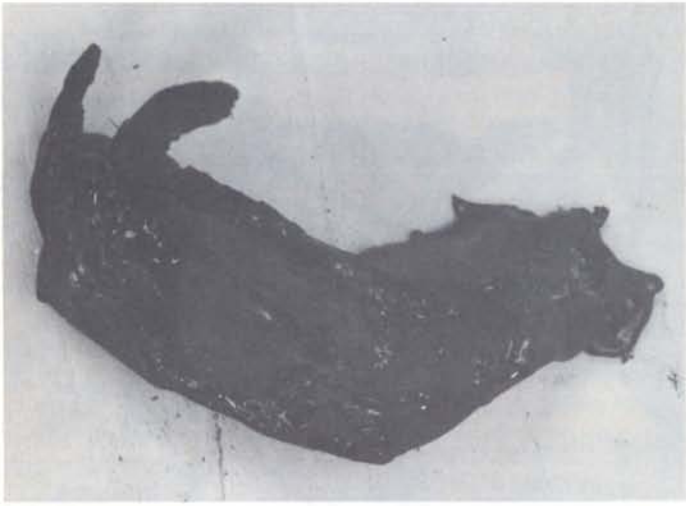
By now the reader will have realised that one other parameter is important in flammability testing, namely the application to which the material will be put. There is little point, for instance, in testing an epoxy resin if its use is to join together two large metal components, since in this application there is no way that this material will burn. When looking at flammability data, many designers tend to ignore the proposed application and can sometimes end up with severe problems. The following example should illustrate this point and, in addition, perhaps illustrate how experience in the flammability properties of materials can sometimes come to the rescue.

A particular white polyurethane paint is used on Spacelab's Pallets to protect against surface corrosion and to provide limited thermal control. It had, of course, been flammability tested on the aluminium substrate to be used and was shown not to ignite in normal air (Fig. 4). Much later it was discovered that another user had also utilised this paint, because of its nonflammability, but in this case the substrate was the polyethylene terephthalate foil referred to above. Needless to say this combination proved disastrous from a flammability point of view, as illustrated in Figure 5a (only a few charred embers remained). As one proposed rebuild alternative, the polyimide foil referred to above with the polyurethane paint was suggested, but this combination too was shown to be highly flammable.

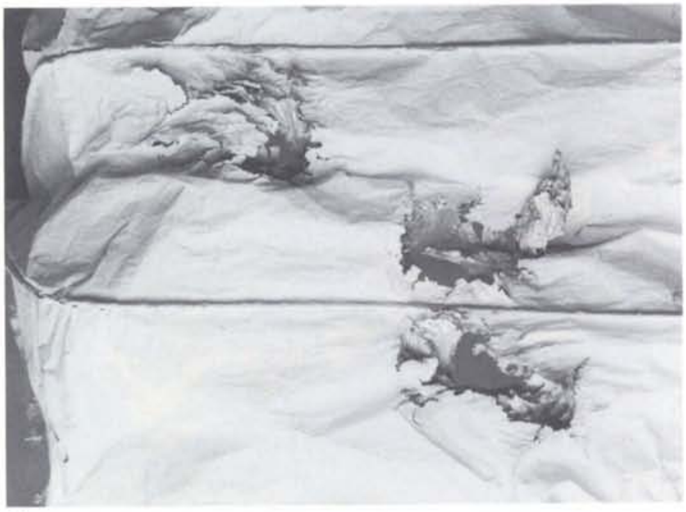
It was therefore evident that a major rebuild or redesign was called for to eliminate this polyurethane paint. There was, however, one further solution possible and although no appropriate test data were available it seemed worth a try. It made use of the simple fact that most silicone materials exhibit good flammability properties. The solution proposed, therefore, was to use the existing configuration and overspray the polyurethane paint with a white silicone paint. On flammability testing of this composite configuration, no ignition occurred (Fig. 5b) even though the igniter flame burnt a hole right through the sample. The configuration could therefore be considered acceptable.

Figure 5 – Configuration Flammability Tests on thermal blanket material plus white polyurethane paint (a) before and (b) after the application of a protective coat of silicone

Figure 6 – Configuration Flammability Test on a wire sample. (a) Before (b) After



5a



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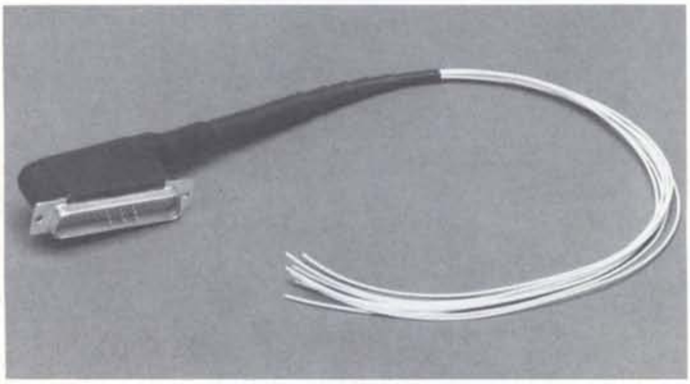
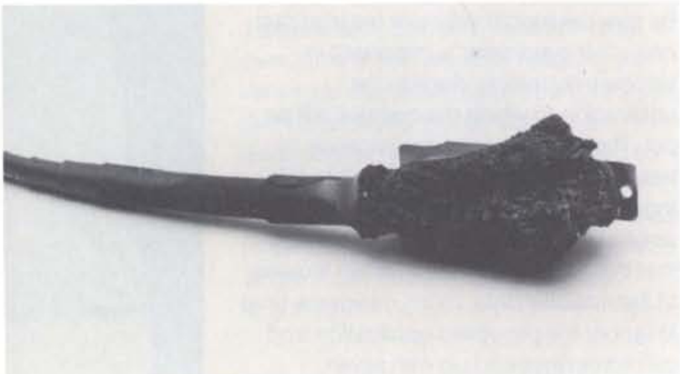


6a



6b

No examples of flammability testing of wires have been shown so far, mainly because these samples are difficult to photograph for black and white reproduction. Figure 6a, does however, show an example of the type of configuration sample frequently investigated, where one has a wire plus connector together with, in this case, a shrink boot covering the crimped or soldered joints. In the case of these samples, ignition would be by both electrical overload, i.e. through the connector and one of the wires, and by open flame on, in this case, the shrink boot. The results of such a test are shown in Figure 6b.

Conclusion

Flammability testing can very rarely provide a simple 'yes' or 'no' answer to the question 'Can I use this material?'. It can, however, answer the question 'Can I use this material in this application under these test conditions?' If the application of a material is not strictly defined, performing any test is a waste of both time and money.

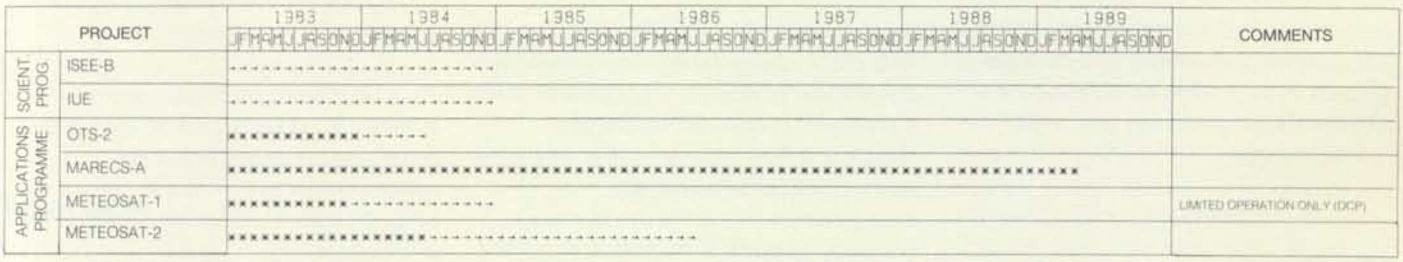
Although, at first sight, the problems brought about by having to meet the flammability requirements imposed by the Space Shuttle may appear daunting, discussions with materials engineers can often lead to materials that appear at first sight to be unacceptable being used in such way that the stringent safety requirements are met.

Acknowledgement

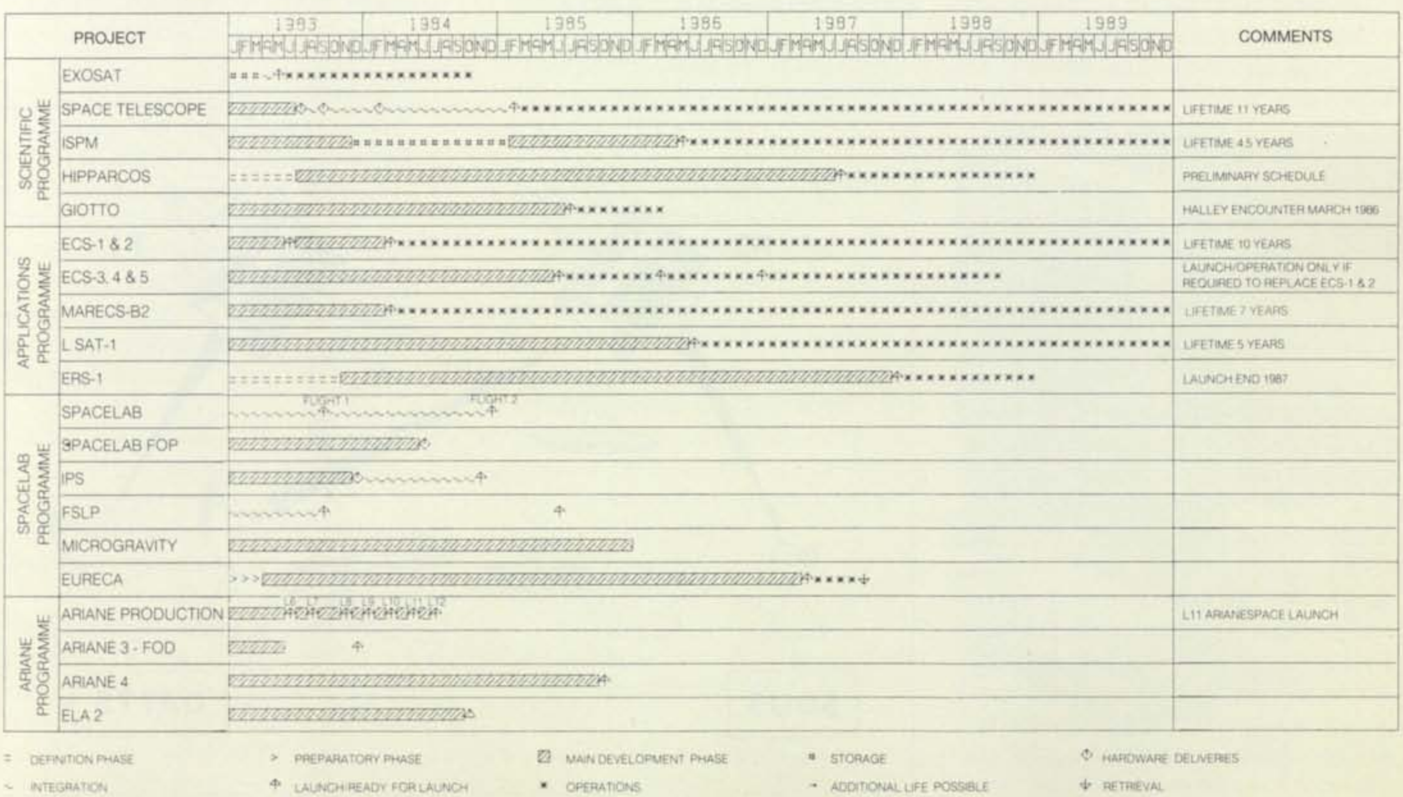
The authors would like to thank their colleagues within the Materials Section for their support. In particular thanks are due to Michel Debeir and Georges Gourmelon who designed and installed much of the test equipment, to Mike Froggatt who prepared many of the samples, and to Simon Vermeer of the Photographic Section at ESTEC for providing excellent photographs.

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

In Orbit / En orbite



Under Development / En cours de réalisation



OTS

OTS-2, qui compte aujourd'hui près de cinq années d'exploitation en orbite, continue de bien fonctionner.

Tous les sous-systèmes de la plate-forme concourent pleinement au soutien de la mission, grâce en partie à une redondance poussée. La charge utile d'OTS est maintenant presque entièrement utilisée pour les transmissions de données entre petites stations terriennes ou pour l'acheminement des signaux de télévision.

La durée de vie en orbite initialement envisagée pour OTS était de trois ans. La marge de masse disponible au lancement a toutefois permis d'embarquer environ cinq années d'ergols. Les réserves restantes semblent toutefois suffisantes pour poursuivre les opérations au moins jusqu'à fin 1983. A titre de précaution, les manoeuvres de maintien à poste Nord-Sud seront interrompues au milieu de l'année afin de conserver une petite réserve d'ergols.

Marecs

A la fin d'avril, le satellite Marecs-A aura terminé avec succès sa première année de service opérationnel pour INMARSAT. Il achemine la totalité du trafic pour les télécommunications avec les navires se trouvant dans la zone de l'océan Atlantique, par l'intermédiaire de la station de Southberry (aux Etats-Unis) et de la station de Goonhilly récemment mise en service au Royaume-Uni.

L'approvisionnement de terminaux à faible facteur de mérite (G/T) est en cours dans le cadre du programme Prosat. Ces terminaux seront montés à bord de petits navires, d'avions et de mobiles terrestres pour des expériences de transmission via Marecs-A, en vue d'évaluer et de valider les caractéristiques systémiques de base que devra présenter le secteur spatial de la prochaine génération pour les télécommunications mobiles.

Après l'échec de la mise en orbite de Marecs-B par le lanceur Ariane L-5, les Etats participant au programme Marecs ont décidé l'assemblage des matériels de réserve et le lancement d'un satellite de remplacement dénommé Marecs-B2, qui répondra aux mêmes normes que Marecs-B. Les négociations sont en cours avec INMARSAT pour la location de ce nouveau véhicule spatial, tandis que les travaux d'assemblage et d'intégration ont été mis en route. Le lancement pourrait intervenir dès janvier 1984.

Météosat

Secteur spatial

Météosat-2 continue de fonctionner de façon nominale; seules quelques anomalies mineures se sont produites. Le taux de contamination saisonnier, comme prévu, a été très inférieur à celui enregistré l'an dernier, et une décontamination a été exécutée début janvier. Météosat-1, maintenant depuis plus de 5 ans en orbite, continue d'assurer le soutien de la mission de collecte de données.

Secteur sol

Grâce à la configuration redondante de l'ordinateur principal, l'équipement calcul a présenté un taux de disponibilité supérieur à 95% pour le soutien de toutes les missions (prise d'images, dissémination et collecte de données). Etant donné que les produits météorologiques sont désormais extraits des données d'image dans le cadre du travail courant et distribués aux utilisateurs soit par le réseau GTS soit par un canal de dissémination du satellite, l'essentiel des efforts porte maintenant sur l'amélioration de la qualité. Le nombre des stations d'utilisateurs enregistrées se montent à 400 environ, comprenant les stations de réception WEFAX, les stations d'utilisateurs des données primaires et les plates-formes de collecte de données.

Programme opérationnel

Le groupe de travail MOPWG a terminé le cycle de ses réunions le 21 février en mettant la dernière main au projet de Convention EUMETSAT et en produisant le rapport de ses travaux pour la 2ème session de la Conférence intergouvernementale.

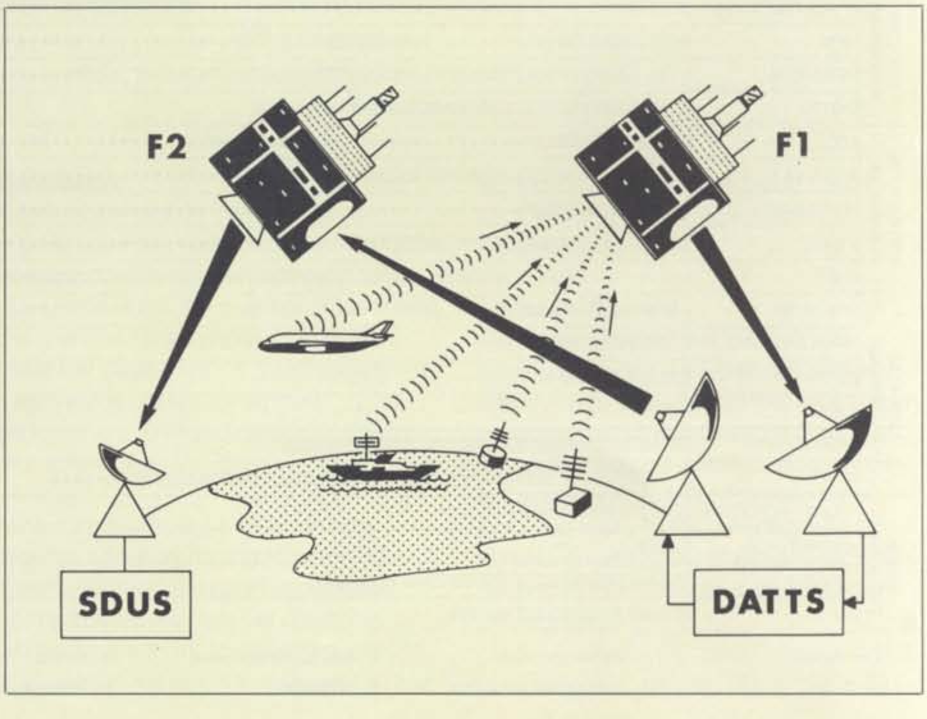
De son côté, l'Agence a terminé la rédaction de la proposition financière et technique du Programme opérationnel.

En ce qui concerne le cadre juridique, trois réunions des Participants potentiels au Programme ont finalisé la Déclaration et le Règlement d'Exécution.

Tous les travaux préparatoires sont terminés et la préparation matérielle de la 2ème session de la Conférence intergouvernementale, qui se tiendra du 21 au 23 mars au Siège de l'Agence, est en cours.

Schematic of the Meteosat DCP mission

Schéma de la mission collecte de données de Météosat



OTS-2

OTS-2 has now accumulated almost five years of service in orbit and continues to perform well. All platform subsystems are still fully supporting the mission, helped by the high degree of redundancy. Most OTS payload use now involves data transmissions between small earth stations or the distribution of television signals.

OTS was originally envisaged for a three-year orbital lifetime. There was sufficient mass margin at the time of launch, however, to load approximately five years worth of propellant on board. The propellant still remaining appears sufficient to continue operating at least until the end of 1983. As a precaution, north-south stationkeeping manoeuvres will be stopped by the middle of the year to maintain a small propellant reserve.

Marecs

At the end of April, Marecs-A will successfully complete its first year of operational service for INMARSAT. It carries the whole of the telecommunication traffic for ships in the Atlantic area via the Southberry station (USA), and the Goonhilly station which recently entered into service in the UK.

Procurement of low-G/T terminals is underway under the auspices of the Prosat programme. These terminals will be installed on-board small ships, airplanes and land mobiles for transmission experiments via Marecs-A, to assess and validate the basic system characteristics of the future-generation space segment required for mobile communications.

Following the failure to place Marecs-B in orbit, the Participating States of the Marecs Programme have decided to assemble the spare hardware and launch a replacement satellite, Marecs-B2, identical technically speaking to Marecs-B. Negotiations are being finalised with INMARSAT for the lease of this new spacecraft, and assembly and integration activities have already started. Marecs-B2 could be ready for launch as early as January 1984.

Meteosat

Space segment
Meteosat-2 continues to operate well, with only a few minor anomalies. The seasonal contamination rate, as expected, was considerably lower than last year, and decontamination was performed in early January. Meteosat-1, now more than five years in orbit, continues to support the data-collection mission.

Ground segment
The redundant configuration of the main computer has allowed the computer to support all missions (image taking, dissemination and data collection) with an availability of more than 95%. Since the meteorological products are now extracted on a routine basis from the image data and distributed to the users either through the GTS or a satellite dissemination channel, the main effort is being directed towards quality improvement. There are approximately 400 registered user stations, including the WEFAX receiving stations, the Primary Data User Stations (PDUSs) and the Data Collection Platforms (DCPs).

Operational programme
The Meteosat-Operational Programme Working Group (MOPWG), completed its series of meetings on 21 February, when it put the finishing touches to the draft Eumetsat Convention and produced a report on its work for the second session of the Intergovernmental Conference.

The Agency has completed the drafting of its financial and technical proposal for the Operational Programme.

To provide the interim legal framework, three meetings of the potential participants in the programme have finalised the Declaration and Implementing Rules.

All the preparatory work has now been done, and practical arrangements for the second session of the Intergovernmental Conference, scheduled for 21-23 March 1983 at ESA Headquarters, are in hand (see page 69 for latest news).

Space Telescope

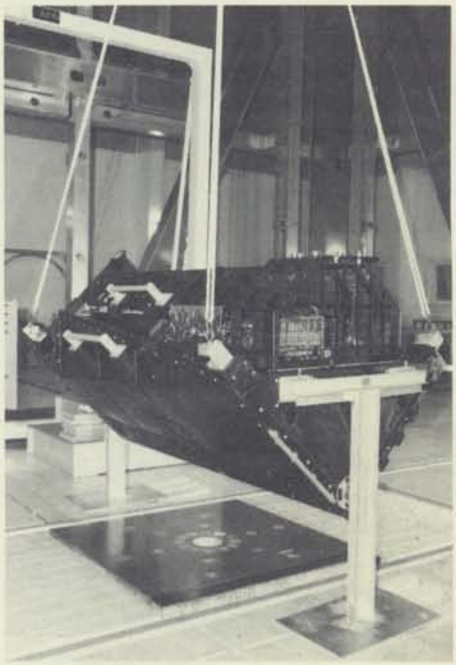
NASA
Some technical problems in the Optical Telescope Assembly programme have led to schedule delays, which will affect the Space Telescope launch date. The extent of the delay is being assessed by NASA.

Solar array
Integration of the second secondary-deployment flight mechanism has been completed and both flight mechanisms are currently under test.

Agreement has been reached with NASA on the design of the solar-array-drive electronics, which have been modified to meet the demanding interactive-torque and settling-time requirements for solar-array slew manoeuvres. The flight-hardware programme has been resumed.

Faint Object Camera
Integration of the electrical model of the Photon Detector Assembly into the flight Faint Object Camera has been finalised and overall FOC system testing started.

Photon Detector Assembly
The first flight detector-head unit has been integrated and testing is in progress. A corona problem occurred in the camera section of the second flight unit, which was found to be due to cracks developing in the potting material. The cause is being investigated. Building of a replacement for this camera section is nearly complete and the new section is due for testing.



La chambre pour astres faibles du Télescope spatial au cours des mesures magnétiques à l'IABG, Munich

Space Telescope Faint Object Camera (FOC) during magnetic measurements at IABG, Munich

Télescope spatial

NASA

Certains problèmes techniques relatifs à l'optique du Télescope ont entrainé des retards par rapport au calendrier, qui auront des répercussions sur la date de lancement. La NASA évalue actuellement l'étendue du retard.

Réseau solaire

L'intégration du deuxième mécanisme de déploiement secondaire est achevée et les deux mécanismes de vol en sont actuellement aux essais.

Un accord est intervenu avec la NASA sur la conception de l'électronique d'entrainement du réseau solaire, à laquelle des modifications ont été apportées en vue de répondre aux impératifs rigoureux concernant le couple d'interaction et le temps d'amortissement dans les manoeuvres d'orientation du réseau solaire; le programme relatif au matériel de vol a repris.

Chambre pour astres faibles (FOC)

L'intégration du modèle électrique du détecteur de photons (PDA) dans le modèle de vol de la chambre pour astres faibles a été menée à terme et les essais 'système' de l'ensemble de la FOC ont commencé.

Détecteur de photons (PDA)

La première tête de détecteur aux normes de vol a été intégrée et ses essais sont en cours. Un problème d'effluves en couronne est apparu dans la section 'chambre' de la deuxième unité de vol, dû à l'apparition de fissures dans le matériau d'enrobage. On en recherche la cause. La fabrication d'un équipement de remplacement pour cette section 'chambre' est presque terminée; la livraison en est attendue pour les essais.

ISPM

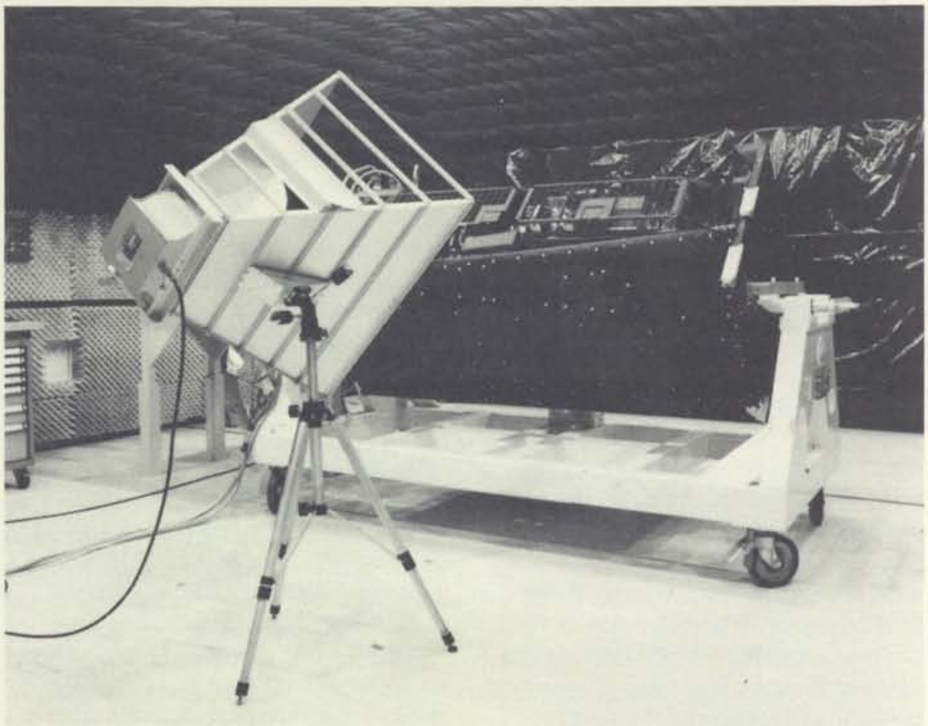
Interfaces avec le lanceur et date de lancement

Le début de l'année a été le témoin d'une intense activité centrée sur l'établissement des diverses interfaces — mécaniques, électriques et opérationnelles — entre le satellite ISPM, le véhicule d'injection interplanétaire Centaur et la Navette. Toutes les parties en présence (cinq centres NASA et l'ESA) ont fait preuve d'une coopération très positive qui a permis des progrès notables. Certes, il reste beaucoup à faire, mais il ne reste apparemment que peu de points importants à résoudre, ce qui devrait pouvoir se faire à l'avantage réciproque de tous au cours des prochains mois.

A la suite de la décision de la NASA de revenir à l'étage Centaur et donc de reporter à 1986 le lancement de Galileo, il s'est avéré nécessaire de rechercher une méthode permettant un partage de la possibilité de lancement entre les deux projets. A cet égard, les solutions sont liées de manière critique aux temps de rotation à l'ETR (Eastern Test Range) et au centre de contrôle du JSC (Johnson Space Center), et aux calendriers du véhicule et du centre de missions du JPL (Jet Propulsion Laboratory). Bien que l'on n'en ait pas encore la confirmation définitive, il semble probable qu'un accord sur les principes généraux soit intervenu entre tous les intéressés. Au cours des prochains mois, les détails relatifs à l'élaboration de ces principes seront mis au point.

Véhicule spatial

Au cours de ces derniers mois, la plus grande partie de l'activité a été axée sur le modèle de vol du véhicule spatial. Son intégration est aujourd'hui terminée à l'exception du sous-système de télémesure/télécommande pour lequel on continue d'enregistrer chez le contractant des retards liés soit au développement soit à d'autres causes. Il est vraisemblable que si ces équipements continuent à faire défaut, le programme d'essai du véhicule spatial devra s'arrêter dans quelques semaines.



Space Telescope Faint Object Camera (FOC) undergoing EMC testing at ESTEC

Essais de compatibilité électromagnétique de la chambre pour astres faibles du Télescope spatial à l'ESTEC

Les travaux de définition des techniques et des équipements destinés au contrôle du véhicule spatial après son lancement se poursuivent conjointement avec le JPL. Dans le cadre de cette activité, un certain de nombre de groupes de travail ont été créés et un examen général des opérations de la mission doit avoir lieu en juin pour évaluer l'état d'avancement et cerner les problèmes éventuels. La préparation du logiciel prend également forme.

Charge utile scientifique

Alors que s'effectue la livraison des matériels de vol, la plupart des chercheurs portent toute leur attention sur la remise en état des unités de qualification pour les transformer en unités de vol de réserve et examinent avec l'ESOC et le JPL leurs besoins en données de maintenance des instruments et en données scientifiques, pour toute la durée de la mission jusqu'en 1990. L'équipe de travail scientifique doit se réunir au mois de juin pour se pencher sur ces problèmes, à l'époque où aura également lieu l'examen des opérations de la mission.

ISPM

Launcher interfaces and launch date

Considerable activity has been under way in the early part of 1983 in establishing the various interfaces – mechanical, electrical and operational – between the ISPM spacecraft, the Centaur interplanetary injection vehicle and the Shuttle. There has been a very positive cooperation evident between all the parties concerned (five NASA centres and ESA) and much progress has been made. Although much work remains to be done, there appear to be very few points of major principle left to resolve. It is anticipated that these should be settled in a mutually beneficial way in the next few months.

Due to the NASA decision to change to the Centaur vehicle and the consequent delay of the Galileo launch to 1986, it has been necessary to find a method of sharing the launch opportunity between the two projects. The possibilities for this are critically bounded by turn-around times at Eastern Test Range (ETR) and the Johnson Space Center (JSC) as well as the vehicle and Jet Propulsion Laboratories (JPL) mission-center time lines. Although final confirmation is still awaited, it seems probable that an agreement on the general policy, involving all interested parties, has been reached. In the next months, the details for elaboration of these general principles will be worked through.

Spacecraft

During the last few months the major activity has been concerned with the flight-unit spacecraft. Integration of the spacecraft is now complete, with the exception of the telemetry/telecommand subsystem, where developmental and other delays at the contractor concerned are still occurring. It appears likely that the continued absence of these units will cause a halt in the spacecraft test programme in a few weeks' time.

Work is continuing on defining jointly with JPL the techniques and equipment to be used for controlling the spacecraft after launch. As part of this process, a number of working panels have been established and a full Mission Operations Review is scheduled to take place in June to assess the status and any problems in this area. Software preparation is also gathering momentum.

Scientific payload

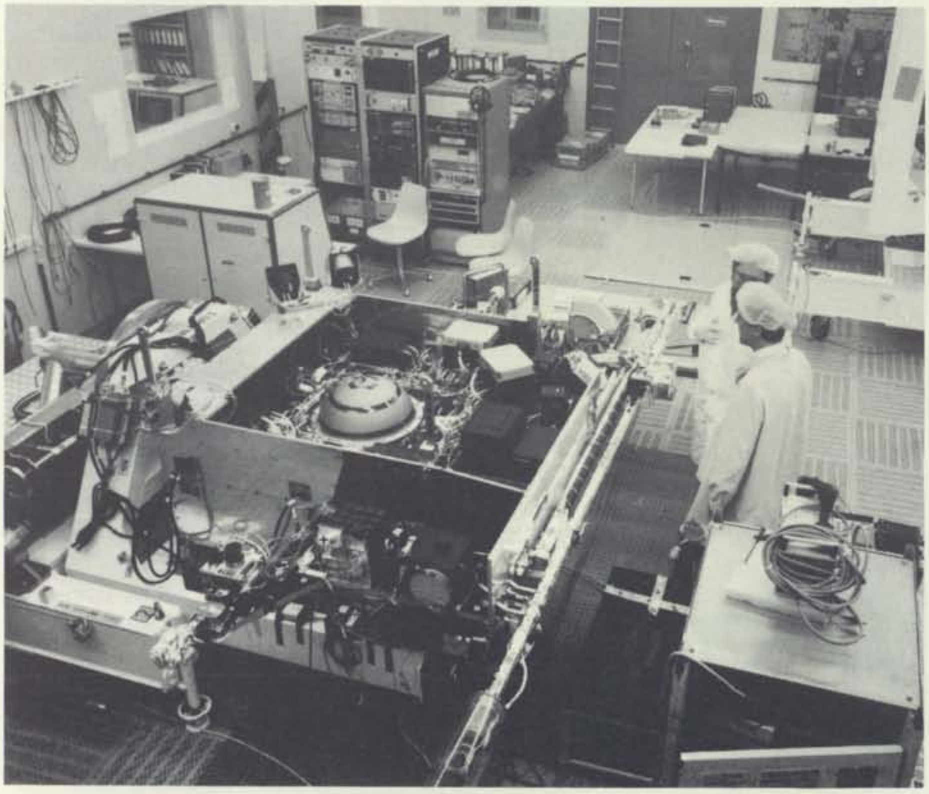
With the delivery of flight hardware, most investigators are now concentrating on refurbishment of qualification units to become flight spares and discussing with ESOC and JPL their requirements for data (for instrument maintenance and scientific) for the duration of the mission until 1990. A Science Working Team meeting, which will concentrate on these areas, is scheduled for June, contiguous with the Mission Operations Review.

Giotto

The Giotto spacecraft development programme is progressing according to schedule, with the spacecraft structural model ready for vibration testing at IABG (Munich). This structural-model programme, whilst mandatory to demonstrate launch survivability of all on-board subsystems and experiments, is proving valuable as an integration-activity 'pipe-cleaner'. The lessons learnt by the integration/test teams will be of direct use in the electrical-model (EM) and flight-model (FM) programmes. The EM programme is proceeding, with structure assembly, alignment, and unit integration scheduled for an April start. The FM programme will begin at the end of the year and delivery of the flight-model spacecraft is expected in January 1985.

The ESA Council recently decided that Giotto should be launched on the Ariane-1 vehicle previously allocated to Exosat. Since this means that the launcher will be dedicated to Giotto, whereas the previous scenario foresaw launch with another spacecraft on an Ariane-3 vehicle, greater flexibility in both launch campaign and launch window is expected.

International activities associated with the exploration of comet Halley are continuing, with more direct ESA involvement in the emphemeris-determination activities of the International Halley Watch (IHW) and continuation of the activities associated with the Inter-Agency Consultative Group (IACG) for Halley. The IACG membership consists of a Soviet, a NASA, a Japanese and an ESA delegation. The aspects it is investigating include the environment of Halley and terminal navigation techniques for Giotto using pathfinder data from the Soviet Vega spacecraft. The last meeting was held in November 1982 and the next is planned for October in Japan.

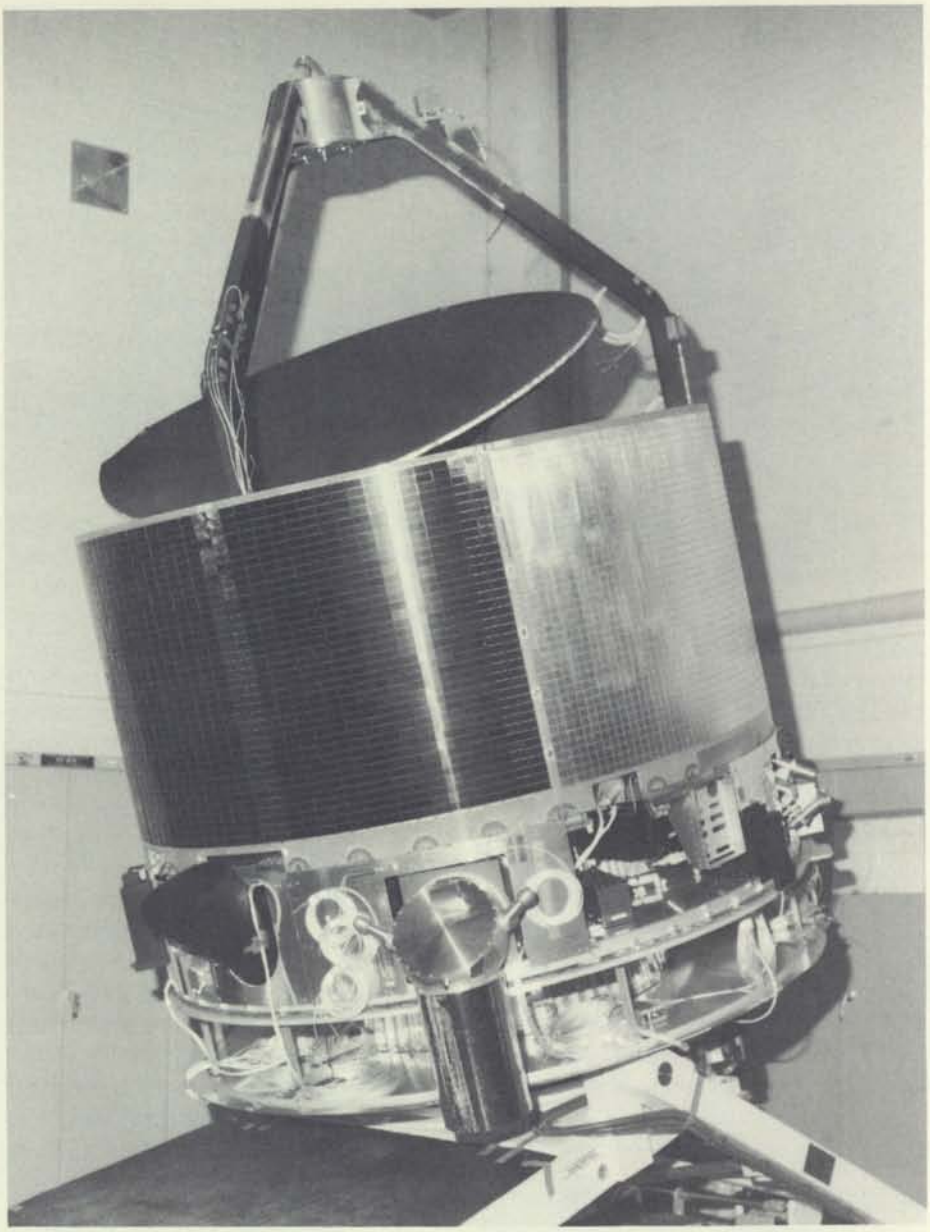


Modèle de vol d'ISPM pendant l'intégration des expériences chez Dornier

ISPM flight model during experiment integration at Dornier System

Giotto structural model being prepared at Dornier System, for testing at IABG, Munich

Préparation du modèle structurel de Giotto chez Dornier en vue des essais à l'IABG, Munich



Giotto

Le programme de développement du satellite Giotto progresse conformément au calendrier. Le modèle structurel du véhicule spatial est prêt pour les essais de vibrations confiés à IABG (Munich). Le programme du modèle structurel, tout en étant indispensable pour démontrer la survie au lancement de tous les sous-systèmes et expériences embarqués, se révèle également être un instrument précieux pour préparer les activités d'intégration. En effet, les enseignements que les équipes d'intégration et d'essais en tirent trouveront une utilisation directe dans les programmes du modèle électrique (EM) et du modèle de vol (FM). Le programme EM se déroule comme prévu: l'assemblage de la structure, l'alignement et l'intégration de l'unité commenceront au mois d'avril. Le programme FM démarrera à la fin de l'année et la livraison du modèle de vol est prévue pour janvier 1985.

Le Conseil de l'ESA a récemment décidé que Giotto serait lancé par la fusée Ariane-1 précédemment affectée à Exosat. Le lanceur étant désormais consacré au seul Giotto, alors que le scénario précédent prévoyait que celui-ci serait lancé par un lanceur du type Ariane-3 en même temps qu'un autre satellite, on peut espérer une plus grande souplesse tant pour la campagne que pour la fenêtre de lancement.

Les activités internationales liées à l'exploration de la comète de Halley se poursuivent, l'ESA s'occupant plus directement de la détermination des éphémérides dans le cadre de la Veille internationale de la Comète de Halley (IHW) et de la poursuite des activités menées avec le Groupe consultatif inter-organisations (IACG) qui est composé de représentants de l'URSS, de la NASA, du Japon et de l'ESA. Ce Groupe étudie notamment l'environnement de la Comète de Halley et les techniques de correction ultime de navigation de Giotto à l'aide de données fournies par les véhicules spatiaux soviétiques Vega (concept de l''Eclaireur'). La dernière réunion du Groupe s'est tenue en novembre 1982 et la prochaine est prévue pour le mois d'octobre 1983 au Japon.

L-Sat

Les négociations relatives au contrat de phase C/D ont abouti fin 1982 à la signature officielle du contrat principal de réalisation avec British Aerospace.

Les activités actuelles du programme dans le domaine industriel sont essentiellement axées sur les examens des bases de référence de développement des équipements et des sous-systèmes, dont l'objet est d'autoriser le passage au stade de la fabrication pour le modèle structurel, le modèle thermique, le modèle de développement du réseau solaire et les modèles d'identification des équipements. L'examen de la base de référence de développement au niveau système est prévu pour le dernier trimestre de l'année. Parallèlement, les négociations relatives à l'approvisionnement du lanceur Ariane-3 se poursuivent, en vue de la signature du contrat au milieu de cette année.

La définition des impératifs relatifs au secteur sol 'opérations' et aux fonctions de contrôle est également bien avancée.

Enfin, les 'Directives d'utilisation pour L-Sat' sont maintenant pratiquement au point après avoir été examinées en détail par les participants au programme.

L-Sat

At the end of 1982, the Phase-C/D contract negotiations led to the formal signature of the main development contract with British Aerospace.

Current industrial programme activities centre around equipment and subsystem development baseline reviews, which are being conducted with a view to releasing the structural, thermal, solar-array-development and equipment-engineering models to the manufacturing stage. The System Level Development Baseline Review is scheduled for the last quarter of the year. In parallel, negotiations for the procurement of the Ariane-3 launch vehicle are proceeding with a view to signature of the contract in mid year.

Definition of requirements for the operations ground segment and control functions is also well advanced.

Finally, the 'L-Sat Utilisation Guidelines' are now practically finalised, having been reviewed in detail by the L-Sat participants.

Sirio-2

At the February Council meeting, the Sirio-2 participants did not agree to the Executive's proposal for the launch of Sirio-2B in 1984. The Executive is therefore studying ways of liquidating the programme, and will make a proposal to Participants at the end of March. The Executive is also studying the possibilities for merging the Sirio-2 missions with other space missions.

Remote Sensing

SAR 580 campaign

All optically processed images have now been delivered to experimenters. However, the distribution of some digitally processed data from DFVLR has been temporarily stopped to permit investigation of a recently identified quality-control problem. Processing at RAE is continuing.

An experimenter Workshop organised by JRC will be held at ISPRA from 11 to 13 April 1983.

ERS-1

The Phase-B Intermediate Review (IR) took place from 9 to 11 February at Dornier System. Many of the important baseline characteristics and requirements are now agreed, although significant effort is still required to complete this programme phase and prepare for the main development phase (Phase C/D).

Most of the foreseen technology activities have been initiated. Discussions are in progress with national delegations concerning the incorporation of existing ground facilities into the ERS-1 ground segment. Preparation of a wind scatterometer campaign is on schedule.

Remote sensing experiments for FSLP

While preparation of these experiments continues, activities are dominated by the recent problems with the Space Shuttle Challenger and the inevitable impact on planning and timeline that will result from the anticipated launch delay.

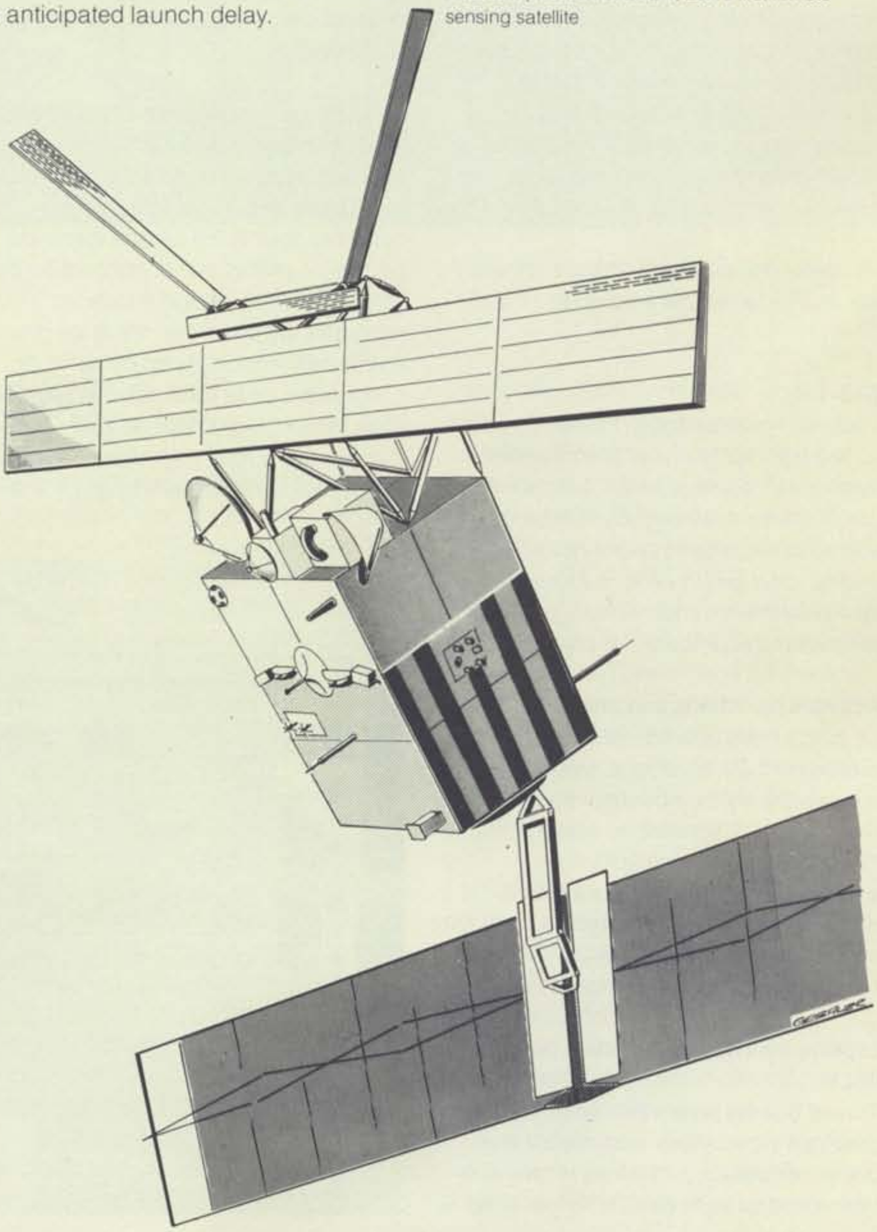
Spacelab

The Spacelab Engineering Model is still being used for trouble-shooting, particularly for software problems.
All Flight Unit-1 hardware has now been delivered and is working correctly. The NASA Verification Flight Instrumentation has been installed and the so-called level-IV testing, in which the experiments are tested with their supporting hardware and software, is now complete. System testing of the integrated Spacelab and Spacelab payloads began on schedule in January, and is proceeding satisfactorily.

The Design Certification Review (DCR), a major NASA activity, took place from 1 November to 15 December. This review,

Vue conceptuelle d'ERS-1, le premier satellite de télédétection de l'ESA

Artist's impression of ERS-1, ESA's first remote-sensing satellite



Sirio-2

A la session du Conseil de février, les participants au programme Sirio-2 n'ont pas suivi la proposition de l'Exécutif concernant le lancement de Sirio-2B en 1984.

L'Exécutif étudie donc actuellement la façon de procéder à la liquidation du programme et présentera une proposition aux participants fin mars. De plus, il examine la possibilité de fusionner les missions Sirio-2 avec d'autres missions spatiales.

Télédétection

Campagne SAR-580

Toutes les images traitées optiquement ont maintenant été livrées aux expérimentateurs. Cependant, la distribution de certaines données traitées numériquement en provenance du DFVLR a dû être temporairement interrompue, pour permettre d'étudier un problème de contrôle de qualité qui a été relevé. Le traitement se poursuit au RAE.

Un atelier des expérimentateurs organisé par le JRC se tiendra à Ispra du 11 au 13 avril.

ERS-1

L'examen intermédiaire (IR) de phase-B a eu lieu du 9 au 11 février chez Dornier System. De façon générale, une bonne partie des caractéristiques et impératifs de référence importants sont maintenant arrêtés, bien qu'un effort notable reste à faire pour mener à terme cette phase du programme et préparer les phases-C/D.

Activités parallèles à la phase-B

La plupart des activités technologiques prévues ont été engagées. Des discussions sont en cours avec les Délégations nationales au sujet de l'incorporation d'installations sol existantes dans le secteur sol d'ERS-1. La préparation d'une campagne portant sur le diffusiomètre 'vents' avance conformément au calendrier.

Expériences de télédétection pour la FSLP

Tandis que les préparatifs se poursuivent pour ces expériences, les activités sont dominées par les problèmes récemment intervenus au sujet de Challenger et les répercussions inévitables du report prévisible du lancement sur le planning et la séquence des opérations.

Spacelab

Le modèle d'identification du Spacelab (EM) sert toujours aux activités de dépannage et en particulier à résoudre des problèmes de logiciel.

Tout le matériel associé à l'unité de vol Spacelab no. 1 a été livré et fonctionne. Les instruments NASA de vérification en vol sont entièrement installés et les essais de configuration de niveau IV, au cours desquels les expériences sont essayées ainsi que le matériel et le logiciel de soutien associés, sont maintenant terminés. Les essais de systèmes du Spacelab intégré et des charges utiles du Spacelab ont commencé comme prévu en janvier et se poursuivent de façon satisfaisante.

L'examen de validation de la conception (DCR) est une activité NASA importante qui s'est déroulée entre le 1er novembre et le 15 décembre. Cet examen, qui constitue pour la NASA une étape-clé, permet de vérifier que la conception du véhicule spatial répond à tous les impératifs, de passer en revue les grands problèmes rencontrés au cours de la conception, de la fabrication et des essais et de délivrer le certificat définitif d'aptitude au vol. Le 13 janvier, le matériel ESA a subi un examen final qui n'a révélé que très peu de problèmes, d'ordre mineur.

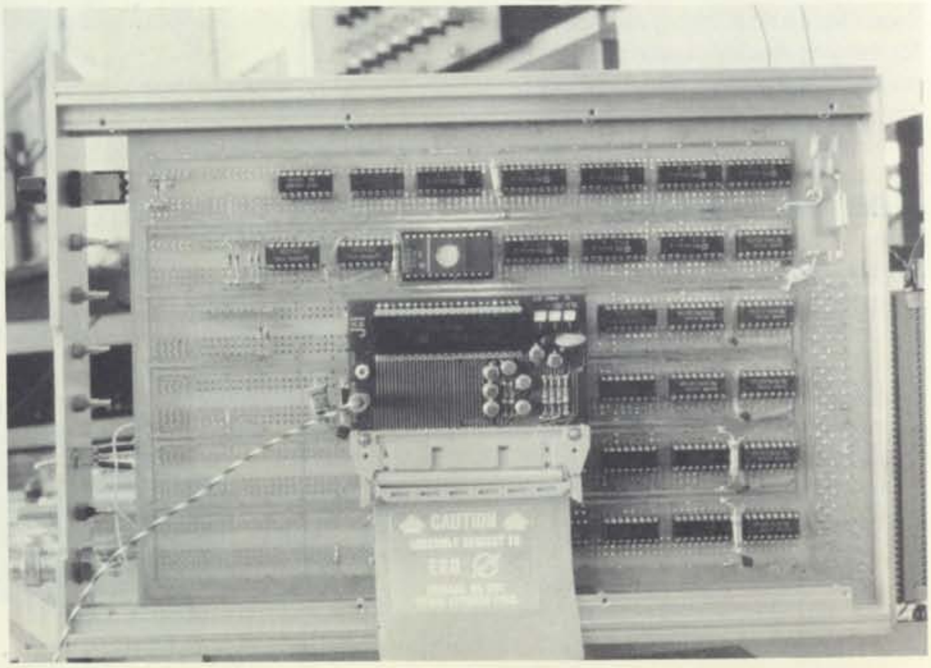
Le lancement de Spacelab 1 (SL-1) est toujours prévu pour le 30 septembre mais de nouvelles fuites ont affecté les tubulures des moteurs de la Navette; il faut donc réexaminer les trois moteurs et il est maintenant fort probable que le lancement sera reporté à février 1984.

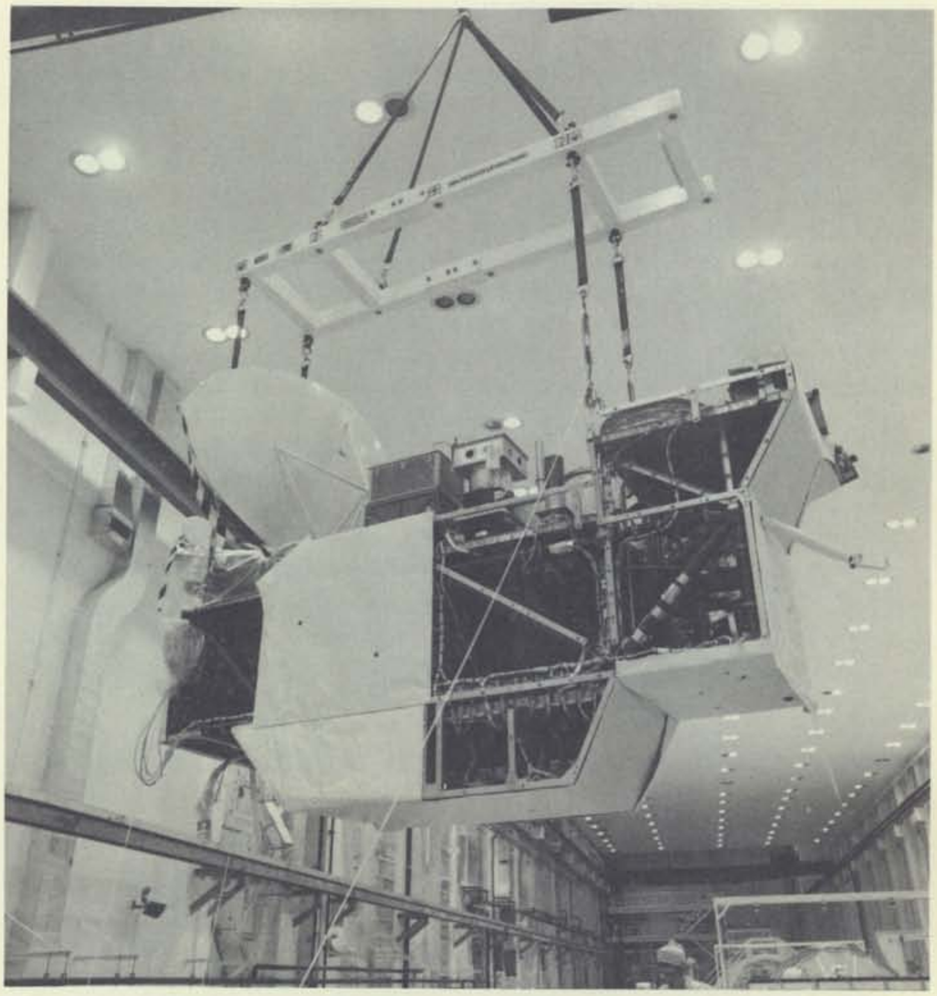
L'unité de vol no. 2 est actuellement entreposée au Centre Spatial Kennedy et les préparatifs de la mission devraient commencer en mars 1983. Un dispositif d'adaptation de l'interface microprocesseur a fait l'objet d'une démonstration réussie sous forme d'un montage sur table. L'examen critique de la conception, prévu pour le printemps 1983, est repoussé jusqu'à l'été mais ce retard ne devrait ni retarder la date finale de livraison ni augmenter le coût global.

Des retards vont affecter la finalisation de l'ensemble de fixation de la charge utile (PCA) qui constitue l'un des aspects du système de pointage d'instruments (IPS). Ces retards, s'ajoutant à d'autres problèmes, ont retardé l'avancement des travaux sur l'IPS à un point tel que l'on ne peut vraisemblablement pas envisager sa livraison avant la date prévue.

Spacelab Processor Interface Adaptor (PIA) microprocessor submodule

Le sous-module microprocesseur du dispositif d'adaptation de l'interface du Spacelab





Porte-instruments du Spacelab-1 au cours des vérifications au Centre spatial Kennedy

Spacelab-1 pallet fit-check in progress at Kennedy Space Center

which constitutes a key milestone for NASA, verifies the meeting of spacecraft-design requirements, reviews major problems during design, manufacturing and test, and finally certifies flightworthiness. A final review on 13 January revealed very few problems with the ESA hardware, and those that there were, were very minor.

The Spacelab-1 (SL-1) launch is still planned for 30 September, but recurring fuel leaks in the Space Shuttle engine manifolds, the latest requiring re-examination of all three of Challenger's engines, mean that there is now a possibility that launch will be delayed until February 1984.

Flight Unit-II is now in store at Kennedy Space Center, with preparations for its mission scheduled to start in March 1983.

The Processor Interface Adapter has been successfully demonstrated in breadboard form. Its Critical Design Review, scheduled for this spring, is now postponed until the summer, but this delay is not expected to affect the final delivery date or to increase the overall cost.

There are delays in finalising one aspect of the Instrument Pointing System (IPS) design, the so-called 'payload clamp assembly'. This, and other past problems, have delayed IPS progress to the point where delays in final delivery are probable.

Follow-on Production

All hardware acceptances foreseen for 1982 have taken place. Four completed Pallets are awaiting pick-up by a single C5A aircraft from Hannover airport on 15 March 1983, for transport to the USA. Seven experiment racks are presently undergoing customer acceptance and being prepared for shipment to NASA by charter aircraft on 30 March 1983.

Work on IPS-FOP has been re-initiated after a planned holding period. Delivery of the IPS-FOP model is scheduled for December 1984.

FSLP

The ESA/NASA combined payload integration and test phase was completed on schedule on 10 December at Kennedy Space Center (KSC). This major achievement ensures that further work on Spacelab-1 will not be held up by payload activities. All experiments have been thoroughly tested and no major sources of interference within the payload have been found.

Payload activities at KSC have subsequently been reduced to a low level. In the period leading up to the second Mission Sequence Test (21 March – 15 April 1983), emphasis is on the maintenance of instruments and the preparation of the test procedures. The mount for the Metric Camera (1EA033) has been installed and aligned with the Scientific Window.

A level-I programme review was held at Marshall Spaceflight Center (MSFC) on 18 January. The principal conclusion was that the payload was in good order, but the availability of two fully checked-out TDRSS satellites for the mission and the ability to maintain the launch date of 30 September 1983 were major concerns.

The Phase-3 safety review for the Material Sciences Double Rack (MSDR) has been successfully completed, and the Rack formally accepted by NASA. Qualification testing has continued in Europe of the experiment samples and cartridges, and preparations have been made for the next MSDR crew training session.

The tenders for the engineering and integration activities for the Sled Payload Element on Spacelab D1 have been evaluated and the contract has been awarded to MBB/ERNO.

The Spacelab Programme Board has not approved the financing requested to provide a new set of flight hardware for the 1ES 201 experiment, and work-around solutions will therefore have to be found.

Spacelab-1 being readied for flight, in the Operations and Checkout Building at Kennedy Space Center

Spacelab-1 au cours des préparatifs au lancement dans le Bâtiment d'Opérations et de Vérification au Centre spatial Kennedy

Production ultérieure (FOP)

Toutes les recettes de matériel prévu pour 1982 ont été effectuées. Quatre porte-instruments terminés sont entreposés à l'aéroport de Hanovre d'où ils doivent être expédiés aux Etats-Unis le 15 mars 1983 sur un seul vol de C5A. Sept bâtis d'expériences sont actuellement en cours de recette chez le client et sont préparés en vue de leur expédition à la NASA par un avion spécialement affrété le 30 mars 1983.

Pour l'IPS, les travaux au titre du contrat FOP ont repris après une période au cours de laquelle il avait été prévu d'arrêter toutes les activités. La livraison du modèle IPS-FOP est prévue pour décembre 1984.

FSLP

La phase d'intégration et d'essai de la charge utile à laquelle participaient conjointement l'ESA et la NASA s'est terminée comme prévu le 10 décembre au Kennedy Space Center (KSC). Cette étape majeure garantit que les travaux ultérieurs sur le Spacelab 1 ne seront pas retardés par des activités de charge utile. Toutes les expériences ont été soumises à des essais poussés qui n'ont permis de déceler aucune interférence importante dans la charge utile.

Par la suite, le niveau d'activité 'charge utile' au KSC a été réduit. Au cours de la période précédant le deuxième essai de séquences de mission (21 mars-15 avril 1983), l'accent est mis sur la maintenance des instruments et sur la préparation des procédures d'essai. Le support de la chambre photogrammétrique (1 EA 033) a été installé et aligné sur la fenêtre scientifique.

Le 18 janvier, on a procédé au Marshall Spaceflight Center (MFSC) à un examen de programme de niveau 1. On a pu essentiellement constater au cours de cette réunion que la charge utile était en bon état de fonctionnement, les participants se souciant davantage de la disponibilité des deux satellites TDRSS entièrement vérifiés pour la mission et de la possibilité de conserver le 30 septembre 1983 comme date de lancement.

Le bâti double de science des matériaux (MSDR) a passé avec succès l'examen de sécurité de phase 3 et a été officiellement accepté par la NASA. Les cartouches et les échantillons d'expériences ont continué à subir des essais de qualification en Europe et on a préparé la session suivante de formation de l'équipage MSDR en mars.

Les offres relatives aux activités d'ingénierie et d'intégration de l'élément Sled de la charge utile sur D1 ont été évaluées et le contrat a été adjugé à MBB/ERNO.

Le Conseil directeur du programme Spacelab n'a pas approuvé le financement demandé pour constituer un nouveau jeu de matériel de vol pour l'expérience 1ES 201; il faudra donc trouver des solutions de rechange.

Microgravité

Biorack

La phase actuelle de conception détaillée progresse de façon satisfaisante sur tous les fronts. La plupart des expérimentateurs ont intensifié le rythme de leurs travaux de conception détaillée et de leurs études de soutien. L'achèvement de la phase de conception détaillée des principaux sous-systèmes du Biorack est prévu pour fin mars, après la conclusion des examens de conception des unités.

Les offres soumises par l'industrie pour la prochaine phase de réalisation et de production (C/D) sont en cours d'évaluation et font l'objet de clarifications avec l'industrie. Les travaux ont démarré en parallèle pour l'établissement d'une demande de prix portant sur la fourniture des équipements particuliers à la mission.

Module de physique des fluides amélioré (IFPM)

L'étude de phase-B portant sur la définition d'un module de physique des fluides amélioré avance conformément aux plans. Cependant, le calendrier reste critique pour le programme IFPM. L'examen à mi-étude a eu lieu le 16 décembre, avec la participation de l'équipage de la FSLP et des représentants du MAC et du MSWG spécialisés en physique des fluides afin d'assurer une coordination optimale. Le modèle d'identification du module de physique des fluides existant a été mis à la disposition de CR-FIAT/Aeritalia en soutien des activités techniques de cette étude.

Compte tenu du calendrier critique du programme IFPM, une solution de secours doit être préparée. L'Exécutif a

Microgravity

Biorack

The current detailed design phase is proceeding satisfactorily on all fronts. Most of the experimenters have stepped up the pace of their design work and supporting studies. The detailed design phase for the major Biorack subsystems is planned to be completed by the end of March 1983, after completion of the Unit Design Reviews.

Offers from industry for the forthcoming development and production phase (C/D) are being evaluated and clarified with industry. Work has started in parallel to prepare a request for quotation for the supply of mission-specific equipment.

Improved Fluid-Physics Module (IFPM)

The Phase-B study for the definition of an Improved Fluid-Physics Module (IFPM) is proceeding according to plan, but the schedule criticality of the programme still remains. The mid-term review was held on 16 December, with participation by the FSLP crew and the fluid-physics representatives of MAC and MSWG ensuring optimum coordination. The engineering model of the existing Fluid Physics Module has been made available to CR-FIAT/Aeritalia to support the technical work.

In view of the programme's schedule criticality, there is the need to prepare a back-up solution. The Executive has initiated a study with Aeritalia for assessment of the impact of refurbishing the existing Fluid Physics Module, after its return from the FSLP, for flight on the Spacelab D1 mission. The possibility of including minor improvements for the experimenters during the refurbishment cycle is also covered.

The Executive has also released a request for proposals for a study of additions to the IFPM to make it independent of the Materials Science Double Rack and to interface it directly with Spacelab. This possibility would be required if the IFPM were to be flown on a mission other than D1.

The above programme alternatives and the Phase-B results will be presented to the Spacelab Programme Board for decision at the end of March 1983.

Sounding-Rockets Programme

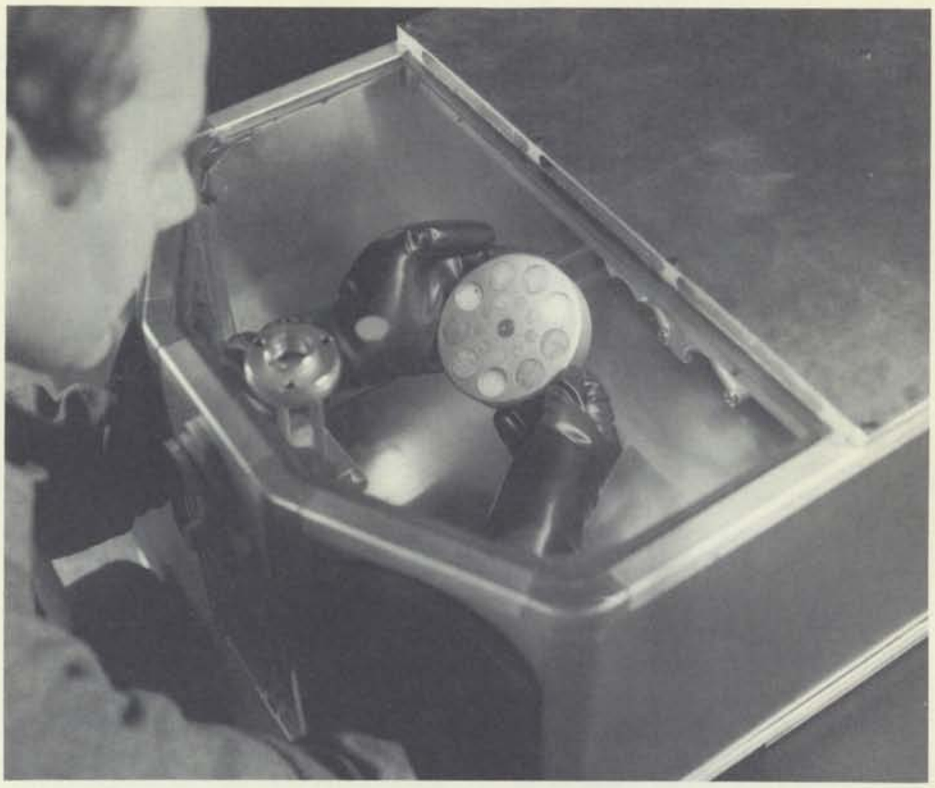
The Spacelab Programme Board has approved the payload composition of 11 experiments proposed by the Executive for the 1983 launch campaign.

The Critical Design Review for experiments using the German experiment facilities during the Texus-VII and VIII flights was held on 13 and 14 December. The December/January period has been mainly dedicated to ground reference tests, the results of which will finally determine flight readiness.

The experiments utilising the Swedish furnaces underwent their Critical Design Review on 11 January. One major change in experiment accommodation concerns the Electrolyte Solution experiment. After laboratory tests and technical assessment by the Project Management, it was concluded that this experiment requires further preparation and that the Texus-VII/VIII schedule (launch April/May 1983) cannot be met. This experiment is therefore now proposed as a firm candidate for the 1984 launch and a reserve experiment (Pötschke, Krupp Research Laboratory – Foam Metal) has been introduced in its place. The Programme Board has endorsed this modification to the payload complement.

Future activities

Following the recent NASA offer for ESA participation in the International Microgravity Laboratory (IML) and the German request to participate in a D-2 or E-2 microgravity-dedicated mission, the Spacelab Programme Board has asked the Executive to prepare, for its next session at the end of May, a proposal for the second phase of the Microgravity Programme.



Modèle de démonstration de la boîte à gants du Biorack

Demonstration model of the Biorack glove box

Eureca

The major results of the first three months of the Phase-A study for the Eureca spacecraft were presented by ERNO (prime contractor) during the mid-term presentation on 14 December 1982. Subsequently, the Eureca-delegated Payload Working Group, at its meeting on 15 December, and later the Spacelab Programme Board on 25 January 1983, endorsed the Executive's recommendation to retain the payload mass and power allocations of 1200 kg and 1700 W, respectively. The SPAS-type configuration was selected as the final structural concept.

mis en route chez Aeritalia une étude sur l'évaluation de l'impact qu'aurait la remise en état du module de physique des fluides existant après son retour de la mission FSLP, en vue de son emport sur la mission D-1. Cette étude porte également sur la possibilité éventuelle pour l'expérimentateur d'apporter des améliorations mineures lors du cycle de remise en état.

L'Exécutif a également lancé un appel d'offres pour l'étude des adjonctions à apporter à l'IFPM pour le rendre indépendant du bâti double des Sciences des matériaux et le raccorder directement au Spacelab. Ce dernier point serait nécessaire si l'IFPM participait à une mission autre que D1.

Les propositions de programme décrites ci-dessus ainsi que le résultat de la phase-B seront présentés au Conseil directeur du programme Spacelab qui devra prendre des décisions à la fin du mois de mars 1983.

Elément fusées-sondes du programme

Le Conseil directeur du programme Spacelab a approuvé la charge utile composée de l'expériences proposées par l'Exécutif pour la campagne de lancement 1983.

L'examen critique de conception des expériences appelées à utiliser les installations expérimentales allemandes au cours du vol Texus-VII/VIII s'est déroulé les 13 et 14 décembre. Le degré de préparation et les mesures restant à prendre ont été déterminés pour chaque expérience. En décembre et en janvier, on se consacrera essentiellement aux essais de référence au sol dont le résultat déterminera finalement l'aptitude au vol.

Les expériences utilisant les fours suédois ont été soumises le 11 janvier à l'examen critique de conception. Un changement important dans l'agencement des expériences a été rendu nécessaire par l'expérience sur la solution électrolytique. D'après des essais en laboratoire et une évaluation technique faite par la Gestion du projet, cette expérience nécessite un complément de préparation incompatible avec le calendrier du lancement de Texus-VII/VIII en avril/mai 1983. Cette expérience est donc proposée comme candidate ferme pour le lancement de 1984 et une expérience de réserve (Pötschke, Laboratoire de Recherches Krupp — Mousse métallique) a été choisie en remplacement. Le Conseil directeur du programme a entériné cette modification de la composition de la charge utile.

Activités futures

En ce qui concerne, d'une part, l'offre récemment faite par la NASA à l'ESA de participer au Laboratoire international de microgravité (IML) et, d'autre part, la demande de l'Allemagne de participer à la mission 'microgravité' D2 ou E2, le Conseil directeur du programme Spacelab a demandé à l'Exécutif de préparer pour sa prochaine réunion, fin mai, une proposition relative à la deuxième phase du programme de microgravité.

Eureca

Les principaux résultats des trois premiers mois de l'étude de phase A du véhicule spatial Eureca ont été exposés par ERNO (contractant principal) au cours d'une présentation à mi-étude qui s'est déroulée le 14 décembre 1982. Les membres du groupe de travail sur la charge utile Eureca ont entériné, au cours de leur réunion du 15 décembre et au cours de la réunion du Conseil directeur du programme Spacelab le 25 janvier 1983, la recommandation de l'Exécutif visant à ce que les allocations de masse et de puissance des charges utiles soient maintenues dans les limites de 1200 kg et 1700 W, respectivement.

C'est une configuration de type SPAS qui a été retenue comme concept structurel final.

Les études de phase-A de ce véhicule se sont terminées par une présentation le 1er mars. La préparation des études de phase-B se poursuit en même temps que l'évaluation des résultats de la phase-A.

Parallèlement au travail de définition du concept de référence du véhicule spatial Eureca, les activités de préparation, de sélection et de démarrage des études de six installations expérimentales à embarquer sur la première mission d'Eureca ont fait l'objet d'un effort intensif. Le lancement de ces activités de phase B s'échelonnera entre le 2ème et le 4ème trimestre de 1983, en fonction de l'achèvement des études de phase A correspondantes.

L'appel aux expériences pour la première mission Eureca a été lancé à la mi-janvier. Les destinataires de cet appel devront manifester leur intérêt avant le 1er mars, et soumettre leurs propositions pour le 30 avril au plus tard.

Ariane

Situation technique du programme

Les recommandations techniques formulées par la Commission d'Enquête, qui portaient sur la qualité des engrenages de la turbopompe et le fonctionnement du système de lubrification (voir Bulletin ESA No. 33, p. 52), ont été mises en oeuvre. Au cours des mois écoulés, des versions des engrenages de la turbopompe et du système de lubrification, éliminant les déficiences constatées, ont été réalisées et essayées. L'ensemble des travaux est soumis à un processus de revue détaillé destiné à confirmer l'aptitude au vol du lanceur L6.

Après rodage et contrôle, la turbopompe du lanceur L6 a été montée sur le moteur du 3ème étage. Les essais de recette à feu du moteur doivent avoir lieu d'ici à la mi-mars, l'assemblage de l'ensemble propulsif, puis de l'étage complet, devant intervenir ensuite et conduire au transport en Guyane du 3ème étage à la fin du mois d'avril. Les deux premiers étages seront acheminés dès le mois de mars.

Parallèlement aux dispositions spécifiques à la turbopompe, une vérification approfondie de certains éléments importants du lanceur a été effectuée (centrale inertielle, système d'alimentation et de pressurisation du 3ème étage), afin d'en renforcer la fiabilité.

Calendrier des lancements

Le Conseil, après avoir pris connaissance de ces éléments, a confirmé, à sa session des 23 et 24 février sa confiance unanime et son soutien au programme Ariane et a fixé le calendrier de lancement suivant: le lancement d'Ariane L6 est prévu le vendredi 3 juin 1983 et les lancements L7, L8, L9 respectivement les 26 août 1983, 4 novembre 1983 et janvier 1984.

Le Conseil, soucieux des intérêts des programmes de l'Agence et de la confiance manifestée par les autres clients d'Ariane, et des obligations calendaires contractées, a pris les dispositions suivantes, destinées à

The Phase-A studies for the carrier were completed by a final presentation on 1 March. Preparations for Phase-B studies (definition phases) for the carrier are in progress in parallel with the evaluation of the Phase-A results.

In parallel with the effort to define the reference concept for the Eureca spacecraft, considerable effort has been expended on the preparation and selection activities for the six experimental facilities to be flown on the first Eureca mission. The Phase-B initiations for these facilities will occur between the second and last quarters of 1983, in step with the terminations of the corresponding Phase-A studies.

The Call for Experiments for the first Eureca mission was published in mid-January. Responses are to be returned by 1 March 1983, and proposals not later than 30 April 1983.

Ariane

Technical status of the programme

The technical recommendations of the Board of Enquiry, which related to the quality of the turbopump gearing and the operation of the lubrication system (see ESA Bulletin No. 33 p. 53), have been implemented. Versions of the turbopump gearing and the lubrication system from which these defects have been eliminated have been developed and tested. All the work involved is being submitted to a detailed review process aimed at confirming the flight-readiness of the L6 launcher.

After running-in and inspection, the L6 turbopump has been fitted to the third-stage engine, due to undergo hot acceptance testing by mid-March. This will be followed by assembly of the propulsion system and then of the complete third stage, which will be dispatched to Guiana in late April. The first and second stages will be shipped in March.

Concurrently with the specific action on the turbopump, certain important launcher elements have been intensively reviewed to improve reliability: namely, the inertial-platform system, and the third-stage feed and pressurisation systems.

Launch schedule

In the light of the foregoing, at its meeting on 23 and 24 February, the ESA Council confirmed its unanimous confidence in and support for the Ariane programme and adopted the following launch schedule: the Ariane L6 launch is scheduled for Friday, 3 June 1983, and the L7, L8 and L9 launches for 26 August 1983, 4 November 1983 and January 1984, respectively.

Mindful of the interests of the Agency's programmes and of the need to preserve the confidence shown by other Ariane customers and of the time-schedule commitments made, the Council has taken the following steps to ensure that all payloads are launched as soon as possible:

- To reproduce a mission profile resembling that of the L5 mission as closely as possible – injection of two satellites into geostationary transfer orbit by means of the Sylda dual launch system – Ariane L6 will launch both the ECS-1 and Amsat satellites.

  For Exosat, the scheduled L7 launch date provides insufficient safety margin vis-à-vis the closing of the launch window and, moreover, there is a risk of certain experiments in the payload deteriorating through storage. Consequently it has been decided to use a Thor-Delta 3914 launcher to place Exosat in orbit, the launch to take place from Vandenberg in late May 1983. The Ariane-1 vehicle remaining available at the end of the promotion series will be assigned to the launch of Giotto, in July 1985.

- The L7, L8 and L9 launchers have been assigned to the Intelsat-V satellites F7, F8 and F9.

The first Ariane-3 launch (L10) is currently scheduled for March 1984. The Agency's satellites ECS-2 and Marecs-B2, the French satellites Telecom-1A and B, the Arab League satellite, Arabsat-1, as well as the American satellites Western Union's Westar-6, Southern Pacific's Spacenet-1 and 2 and GTE's G-Star 1 and 2, will be launched by Ariane-3, the more powerful version of the launcher, capable of injecting two 1195 kg spacecraft into geostationary transfer orbit.

STS – LTPP

Space Transportation Systems Long-Term Preparatory Programme

ESA's STS-LTPP started officially on 14 January, the date on which the contributions received passed the threshold of 75% of total programme cost (11.1 MAU) laid down by the Council.

The aim of this study programme is to explore the various options open to Europe for space transportation systems beyond Ariane-4 and Spacelab Follow-On Development (Eureca). It must supply the participating States with the facts necessary for making decisions on the adoption of a long-term policy and the starting up of new programmes.

These options are to be examined under a study programme comprising three main themes:

- The maintenance in Europe of an independent launch capability to meet the foreseeable requirements of European and other users which will be competitive with the transportation systems existing or planned elsewhere.
- The provision of a European capability to conduct orbital operations (including a return to Earth) by means of an orbital infrastructure developed independently or in cooperation with NASA within the framework of American space-station activities.
- Preserving Europe's access to manned systems opened up by Spacelab by taking part in American space-station activities and giving thought to the evolution of European orbital infrastructures.

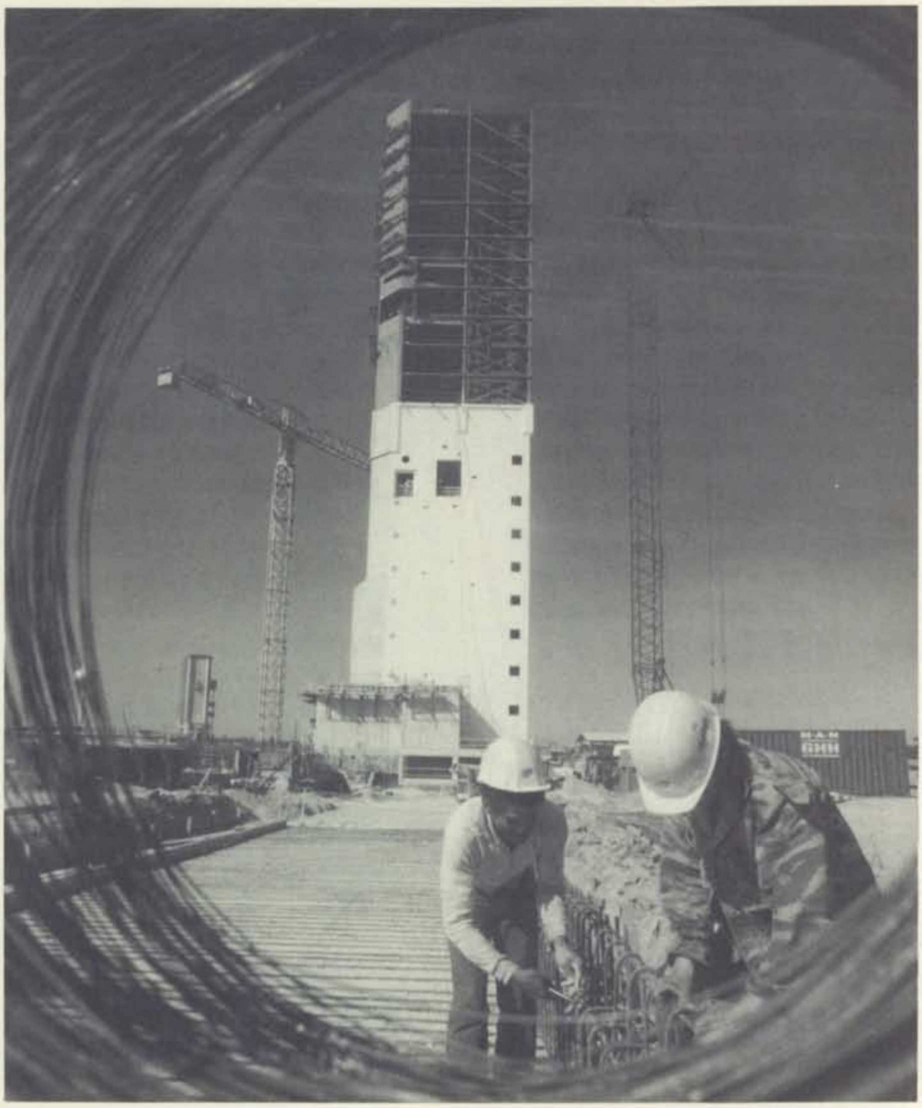
Preliminary studies on each of these themes have already been undertaken by the main European firms. The proper execution of the programme will be monitored by a Programme Committee set up by the Council, which will remain the ultimate authority.

In principle, this programme will be completed by late 1985.

permettre le lancement le plus rapidement possible de chacune des charges utiles:

- en vue de reproduire un profil de mission aussi proche que possible de celui prévu pour L5 (l'injection en orbite de transfert géostationnaire de deux satellites au moyen du système de lancement double Ariane: Sylda), Ariane L6 lancera les satellites ECS-1 et AMSAT,
- en ce qui concerne le satellite Exosat, le Conseil de l'Agence a tenu compte d'une part que la date de lancement prévue pour L7 présente une marge calendaire insuffisante par rapport à la fermeture de la fenêtre de lancement et, d'autre part des risques de dégradation de certaines expériences de la charge utile. Donc, le Conseil a décidé de recourir à un Thor-Delta 3914 pour la mise en orbite de ce satellite; ce lancement doit avoir lieu fin mai 1983 depuis la base de Vandenberg. L'exemplaire d'Ariane-1 excédentaire à la fin de la série de promotion sera affecté au lancement, en juillet 1985, de la sonde Giotto.
- Les lanceurs L7, L8 et L9 sont affectés aux satellites Intelsat-V F7, F8 et F9.

Le premier lancement de la version Ariane-3 (L10) est prévu en mars 1984. Ariane-3, une version plus puissante du lanceur capable d'injecter simultanément en orbite de transfer géostationnaire deux satellites d'un poids allant jusqu'à 1195 kg, lancera les satellites de l'Agence ECS-2 et Marecs-B2, les satellites français Telecom-1A et 1B, le satellite de la Ligue Arabe Arabsat-1, ainsi que les satellites américains Westar-6 de la Western Union, Spacenet-1 et 2 de la Southern Pacific et G-Star-1 et 2 de la GTE.



The new tower under construction at the second Ariane launch pad (ELA-2)

Nouvelle tour en construction sur le deuxième Ensemble de Lancement Ariane (ELA-2)

STS-LTPP

Programme Préparatoire de Systèmes de Transport Spatial à Long Terme

Le 14 janvier 1983, le programme préparatoire pour les systèmes de transport spatial à long terme a officiellement démarrer à l'ESA, les contributions reçues ayant permis de franchir la barre des 75% du montant total du programme (11.1 MUC) fixée par le Conseil.

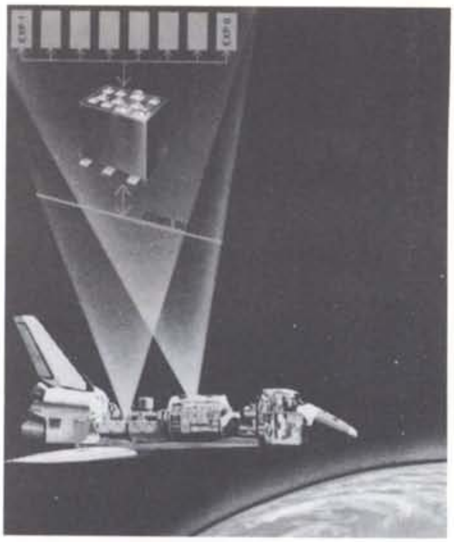
Ce programme d'étude est destiné à explorer les différentes options qui s'offrent à l'Europe en matière de systèmes de transport spatial au-delà d'Ariane-4 et de Spacelab FOD (Eureca). Il doit fournir aux Etats participants les éléments nécessaires aux prises de décisions quant à la sélection d'une politique à long terme et au démarrage de nouveaux programmes.

Ces options seront analysées par un programme d'études qui ont été regroupées en trois thèmes principaux:

- Maintien en Europe d'une capacité de lancement indépendante qui répond aux besoins prévisibles des utilisateurs européens et autres et qui soit compétitive avec les systèmes de transport existants ou prévus ailleurs.
- Fourniture d'une capacité européenne pour effectuer des opérations en orbite (y compris le retour au sol) par le moyen d'infrastructures orbitales développées indépendamment ou en coopération avec la NASA dans le cadre des activités américaines de stations spatiales.
- Maintien de l'accès de l'Europe aux systèmes habités ouvert par le Spacelab en participant aux activités américaines de stations spatiales et en considérant l'évolution d'infrastructures européennes orbitales.

Des études préliminaires sur chacun des thèmes ont déjà été engagées avec les principales firmes européennes. La bonne exécution du programme sera contrôlée par un Comité de Programme mis en place par le Conseil, ce dernier conservant l'autorité finale.

Ce programme sera terminé en principe fin 1985.



Interfacing Spacelab Payloads for the First Mission and the Development of the Processor Interface Adaptor (PIA)

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It is hoped that successful flights by Spacelabs-1 and 2 aboard the Space Shuttle will generate world wide interest on the part of scientists and technologists in flying experiments on future Spacelab flights. These experimenters will tend to use more and more microprocessors in their experiments. The PIA will be an important unit in helping with the interfacing of these experiments by shortening the integration and checkout times and reducing the volume of experiment computer software needed.

* Now with the Hipparcos project

In September this year, the first Spacelab mission is scheduled to take place as part of the Ninth Space Shuttle Mission. The Spacelab Pressurised Long Module and Pallet will be carried into low Earth orbit for a period of nine days. The joint ESA/NASA payload will consist of 24 ESA and 12 NASA instruments and the Materials Science Double Rack (MSDR)*. This Spacelab flight will be followed by further flights at a rate of approximately two per year through the 1980s.

When Spacelab was conceived in the early 1970s, the aim was to provide relatively easy access to space by not enforcing all the space quality requirements existing for satellites and by providing for reuse of hardware. It was also decided to provide Spacelab with centralised data-processing facilities dedicated to the experiments, to simplify the hardware/software to be provided with the experiment. The experimenter was expected to interface his equipment with Spacelab via a simple, discrete digital or analogue interface using a Spacelab-provided, data-acquisition software system, or in a more sophisticated digital serial input/output manner.

The integration of individual suites of experiment application software into this central experiment processor was planned to be assisted by the use of a high-level computer language (Fortran) and dedicated software-development facilities. To ensure that the newly developed and integrated mission-dependent software could not compromise overall mission success, a dual computer system was designed, with one part solely dedicated to Spacelab subsystems management, and remaining essentially unchanged from mission to mission, and the other part dedicated to the experimenters and the responsibility of the mission managers.

* See ESA Bulletin No. 31, pp. 34-45.

All Spacelab data handling and processing was to be the responsibility of the Command and Data Management Subsystem (CDMS), which was designed as a centralised system under the control of its twin independent processors, communicating with peripherals, including the Orbiter, by means of serial data buses.

Since the detailed definition of the CDMS in 1975, however, there has been an explosion in the development of microprocessors, and the realisation that the development of experiment hardware for centralised processing, and software integration, are much more intractable problems than originally thought. As a result, mission managers and experimenters are moving towards a more decentralised approach to experiment processing, and a corresponding evolution in Spacelab hardware is being undertaken to assist this transition, including development of the Processor Interface Adaptor (PIA).

Before describing the new approach, the existing CDMS will be described, and the methods for interfacing 'intelligent' experiments with it. The resulting

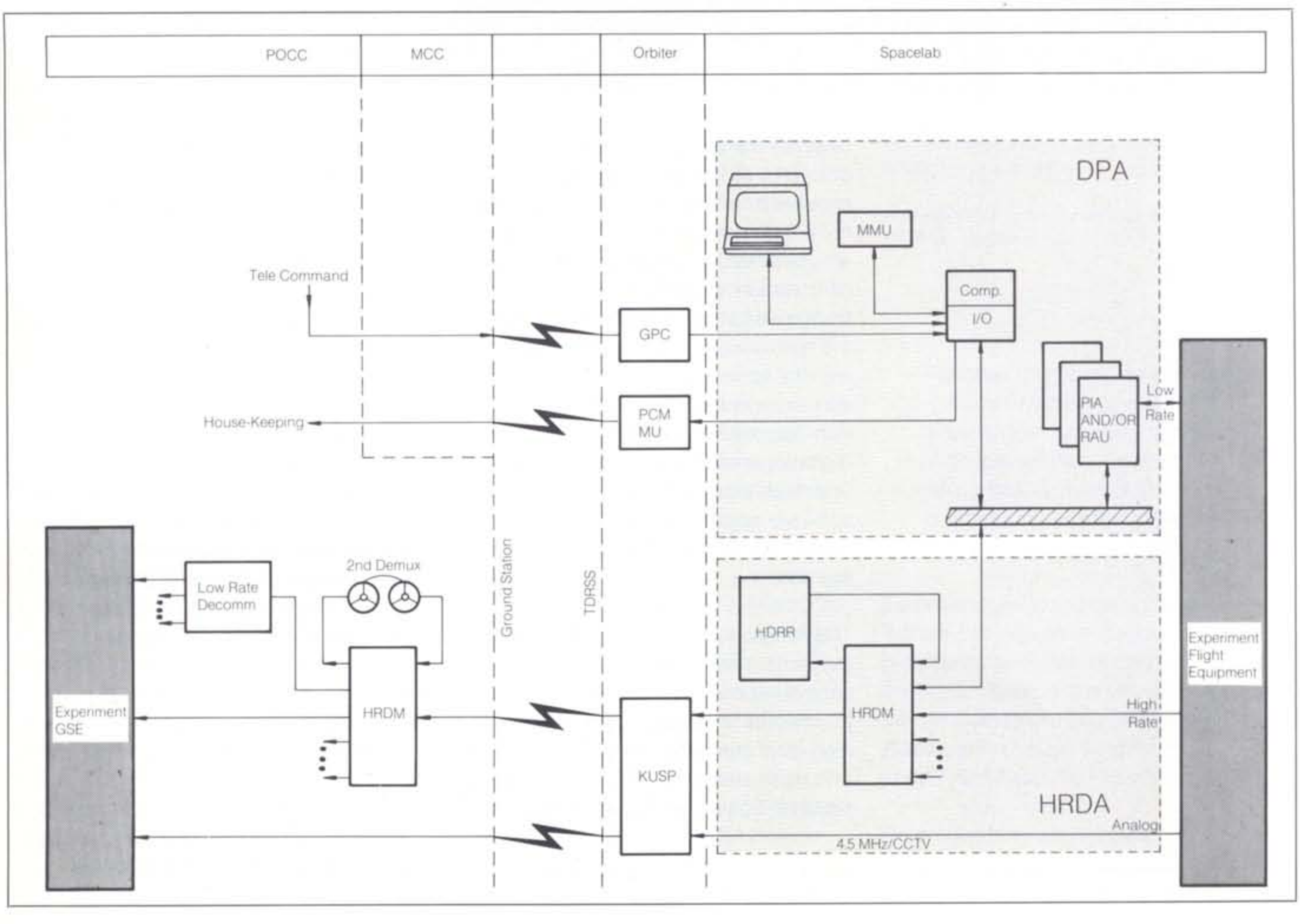


Figure 1 – The Spacelab CDMS user interface

restrictions on the integration of these intelligent experiments are also outlined.

The Command and Data-Management Subsystem

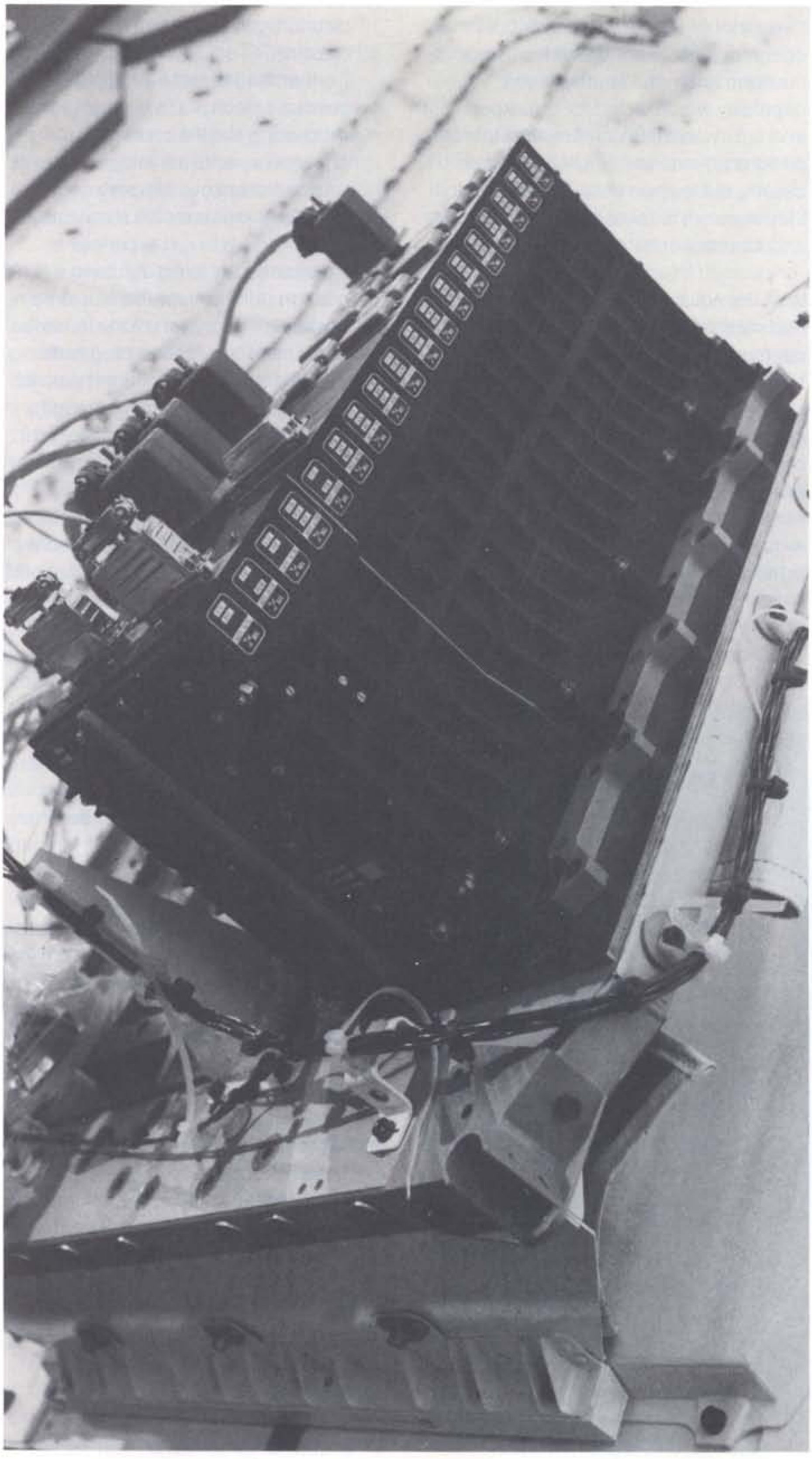
The CDMS can be subdivided functionally into two elements, the Data-Processing Assembly (DPA), which handles command distribution, low-rate data acquisition, and crew interfacing, and the High-Rate Data Assembly (HRDA), which provides for the acquisition, multiplexing and storage of high-rate data (Fig. 1). The DPA is further subdivided into similar, independent, experiment and subsystem elements to ease payload integration and prevent interference between the payload and Spacelab subsystems.

Each DPA consists of a computer, capable of 3.2×10^5 operations per second and with 64 K × 16 bit words of core memory, and an input/output unit which manages the communication with peripherals and the Orbiter via 1 Mbit/s serial data buses. Peripherals shared between the two DPAs include up to three displays and keyboards and a Mass Memory Unit (MMU) (8×10^6 words). The Shuttle Orbiter interfaces include a precision clock and Greenwich Mean Time (GMT) from its Master Time Unit (MTU), commands and data from a Multiplexer-Demultiplexer (MDM), and telemetry to the PCM Master Unit (PCMMU). Interfaces to subsystems or experiments are provided by Remote Acquisition Units (RAUs), which allow the processors to send commands and acquire data (Fig. 2).

Three communication paths are used for data transfer between the DPA and the Orbiter (Fig. 1). Serial data buses are again used which are controlled by the Orbiter and supported by the Input/Output Unit. These paths are between the DPA and the Orbiter MDMs, which permits a dialogue between the DPA processors and the Orbiter's General-Purpose Computers (GPCs), the DPA and the Orbiter PCMMU for the transfer of engineering telemetry data via the Orbiter Network Signal Processor to the ground, and between the Orbiter MTU and the DPA, which provides the time reference and a precision clock for the CDMS and the users.

The HRDA consists of a High-Rate Multiplexer (HRM), a High-Data-Rate

Figure 2 – Flight-unit experiment RAU



Recorder (HDRR) and, on the ground, a High-Rate Demultiplexer (HRDM). The HRDA's role is to multiplex data directly from users with time, voice, and some low-rate DPA-acquired data into a data stream of up to 48 Mbit/s. This is to be transmitted to the ground via the Shuttle's Tracking and Data-Relay Satellite System (TDRSS), where the HRDM is used to demultiplex the original input data. The HDRR provides storage to cover periods when TDRSS transmission is interrupted and can record 1 to 32 Mbit/s for periods of more than 10 h and 20 min, respectively. To allow the stored data to be dumped during the next TDRSS transmission session, the HRM permits the multiplexing of recorded and real-time data. Recorded tape may also be stored on board. Multiplexed data not exceeding 1 Mbit/s may also be stored on the Orbiter Payload Recorder.

User interfaces

The DPA interface to the user experiments aboard Spacelab is provided by the RAUs. These are under software control and have the following capabilities:

- 64 on/off command outputs. The on-state provides 20 mA at approximately 5 V
- 128 flexible inputs arranged in blocks of 16
- 4 serial output channels providing 1 to 32 NRZ-formatted words, including associated burst clock
- 4 serial input channels acquiring 1 to 32 NRZ-formatted words, on user request, with concurrent input/output unit command
- 4 user time clocks (UTCs), and associated 4 pulse/s UTC resets. The 1024 kHz clock is referenced to the Orbiter MTU.

The on/off commands are used to control user hardware, and they may be individually set or reset by asynchronous commands from the DPA. The operating system also provides facilities for pulsing these outputs. For some applications where the DPA has to communicate with an 'intelligent' experiment containing a

Dedicated Experiment Processor (DEP), synchronous data transfer on serial input or output channels may be required.

Serial output channels provide the means for transferring large amounts of data to a user. These can be for Initial Program Load for a DEP for example, or the results of the processing by the DPA of data acquired from that or another DEP, the Orbiter, or another experiment. The transfer may be synchronous or asynchronous and consists of messages of 1 to 32 words. Except for very simple cases the first word will contain information on the nature and magnitude of the message. The maximum practical data transfer rate for all users is approximately 100 kbit/s.

Serial input channels provide a means for acquiring digital data from users. On user request, 1 to 32 words may be transferred to the DPA by the next arriving serial input command to that channel. The maximum practical data rate for all users is approximately 50 kbit/s.

The UTC (User Timer Clock) is continuously available from experiment RAUs whenever the experiment module is 'on'. The user can maintain absolute or relative time with an accuracy of a few milliseconds referenced to Orbiter GMT within his experiment, for tagging his data as required.

Experiment evolution

Spacelab design was started in 1973–1974 when there were no experiments in an advanced state of development and it was considered that its usefulness would be enhanced if a general-purpose processing facility were available to the users. Indeed discussions with potential experimenters seemed to indicate that high-rate processing of experiment data, fast Fourier transformation, data compression and the ability to react to external events in microseconds were mandatory requirements for the DPA. As a result a CIMSA 125 MS computer with a throughput of approximately 300 kilo-operations per second and hardware multiply/divide and floating-point capability was selected for the experiment and subsystem DPA processor. Early DPA designs attempted to meet these user desires, but is soon became clear that they were not feasible because of facility and financial constraints.

With the advantage of hindsight, it is clear that most of these features would have been used seldom if ever, since they also have serious cost implications for experiment development and payload integration. In any case, the rapid development and exploitation of microprocessors has made it feasible to incorporate DEPs into experiments, if required, and this is likely to have significant cost benefits to experiments flown on Spacelab.

There are a number of aspects of centralised processing in the Spacelab context which are major mission cost drivers. These may be summarised as follows:

- All of the facilities provided by the CDMS to the experiment must be simulated during the course of experiment development. If the experiment relies on centralised data processing, this effectively means that the unique experiment software has to be coded twice and errors are quite likely. In addition, the user does not have the opportunity to run a complete experiment in his laboratory, or to optimise his software to the extent possible if the experiments were to be delivered autonomous and selfstanding.
- When using centralised data processing, the user will probably be writing software for an unfamiliar machine. This problem may be alleviated to a certain extent by the use of Fortran for application software, although it is likely that the use of any but Assembler-coded application programs may be discouraged for memory capacity reasons.
- Further, and in fact perhaps the most serious, objections to centralised processing are the problems of application-software integration and payload checkout. Memory limitations mean that in some cases it is not feasible to run experiments simultaneously, although from a mission point of view this would be desirable. Integration of the individual experiment application programs and checkout of the overall payload hardware and software is a lengthy and costly process, made more so if any changes have to be incorporated into an experiment's software.

All of the above aspects have caused the evolution of Spacelab experiment support toward decentralised processing. Indeed, a number of experiments on the First Spacelab Payload (FSLP), and the Spacelab Instrument Pointing System (IPS) incorporate their own DEPs. Experiments on the later missions are incorporating still more processors.

DPA impediments to decentralised processing

The present DPA design was based on the premise that a user would always be ready to accept or transmit data when required. In general this is no problem for analogue or discrete data, but there can be problems for serial data transfer. In an 'unintelligent' experiment, buffers must be provided to accept the serial data from an RAU or to send serial data to an RAU in response to bus commands, and it is not difficult to design interface circuitry to meet these requirements. However, for presently available microprocessors, interrupt response time is not fast enough to allow these data transfers to be accomplished under processor control, so that either dedicated buffers must be provided in addition to the processor random access memory, or direct-memory-access channels must be implemented. Both of these options are an additional complication and expense.

Figure 3 — The breadboard Processor Interface Adaptor (PIA) (centre left) under test

It is desirable that the timing of data transfer in and out of the DPA should be convenient to a wide range of microprocessor configurations to allow the user latitude in selecting the best and simplest devices for his experiment, and not to be driven to an expensive solution because of a complex Spacelab interface.

At this point, timing of the Spacelab interface has been identified as a constraint, but a further, not so obvious, problem has become evident. This is the difficulty that the user has of translating the bare interface requirements specified in the Spacelab Payload Accommodation Handbook into working hardware. The effects of this problem have been ameliorated to a certain extent by the development by ESA/SPICE of an RAU interface simulator, which may be used to mimic faithfully data transfers in a working system, and is used for experiment acceptance. Use of this equipment identifies interface problems earlier, but if FSLP experience is an indicator for the future, then experiment interface development will always be an iterative process. Selection of an industry standard interface could be beneficial in a number of ways: there is a chance that an experimenter could already be familiar with its design; standard specifications for its implementation could be used; 'off-the-shelf' test equipment might be procured; and finally integrated circuits to mechanise the interface might also be available.

With this trend, the difficulty of interfacing a Dedicated Experiment Processor with an RAU has become more acute, and the Spacelab Project decided in 1980 to develop a new unit for interfacing these processors to the CDMS, and work on the Processor Interface Adaptor was initiated.

The Processor Interface Adaptor (Fig. 3)
The objectives of PIA development can be grouped into two main categories: those of simplifying the user interfacing task, and those of taking advantage of technological improvements to increase resource availability, for example by reducing mass and power consumption.

User interface simplification
To increase the DEP response time of 4 to 10 μs to a value more compatible with present microprocessor hardware, the PIA had to incorporate buffer memory to provide temporary storage of data being transferred in each direction. It was decided to require the PIA to be capable of buffering and handling transfers of one asynchronous and one synchronous block (up to 32 words each) in each direction, every 10 ms. One could visualise one PIA servicing all of the 'intelligent' experiments in one Spacelab double rack, or on one pallet. Assuming that these are of some complexity to merit an internal processor, a maximum of eight seemed a reasonable number. The PIA therefore provides intermediate buffering of eight blocks of data in each direction, with a simultaneous reading and writing capability.

An extensive study of current interface standards, including ESA standards, resulted in the selection of a subset of the IEEE-488 standard for the PIA. This is a byte serial interface, widely used for laboratory test equipment, and extensively supported by integrated circuits from most of the major semiconductor manufacturers. It is capable of addressing up to 31 peripherals and incorporates a 'handshaking' protocol which ensures that even the slowest responding peripheral can successfully transfer data.

Technological improvements
A block diagram of the PIA is shown in Figure 4. The objective was to use the state-of-the-art design of digital circuitry to reduce the weight and volume of the PIA versus the RAU, and more importantly to reduce power consumption (Table 1).

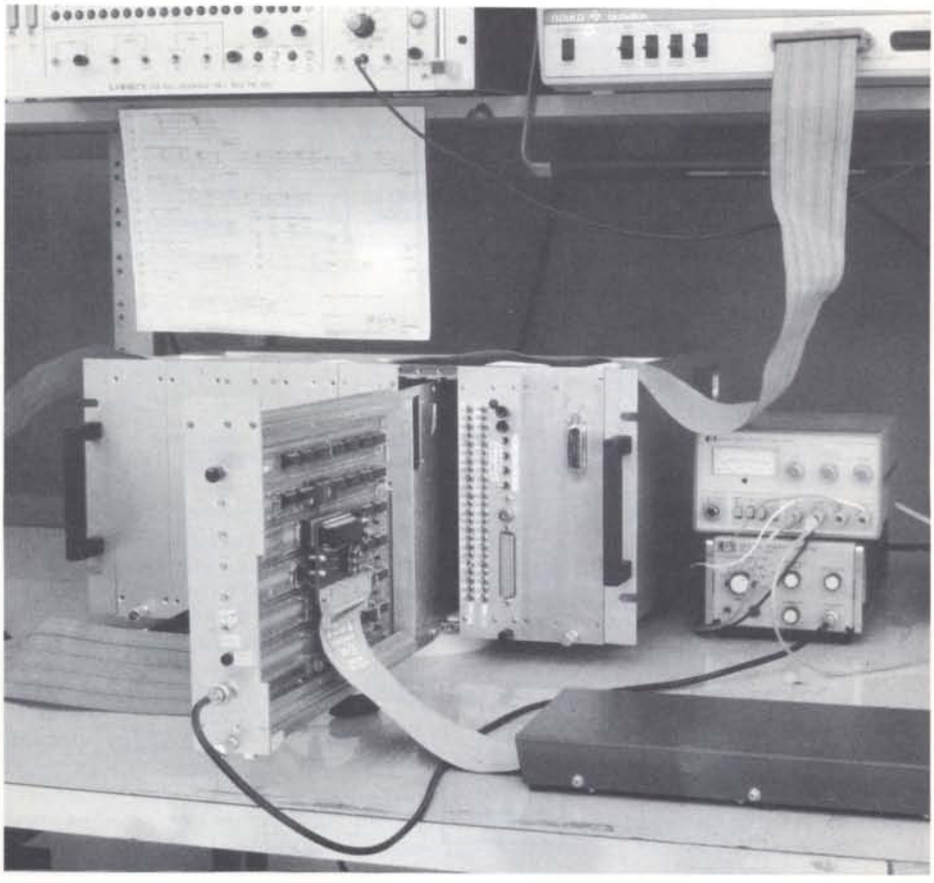
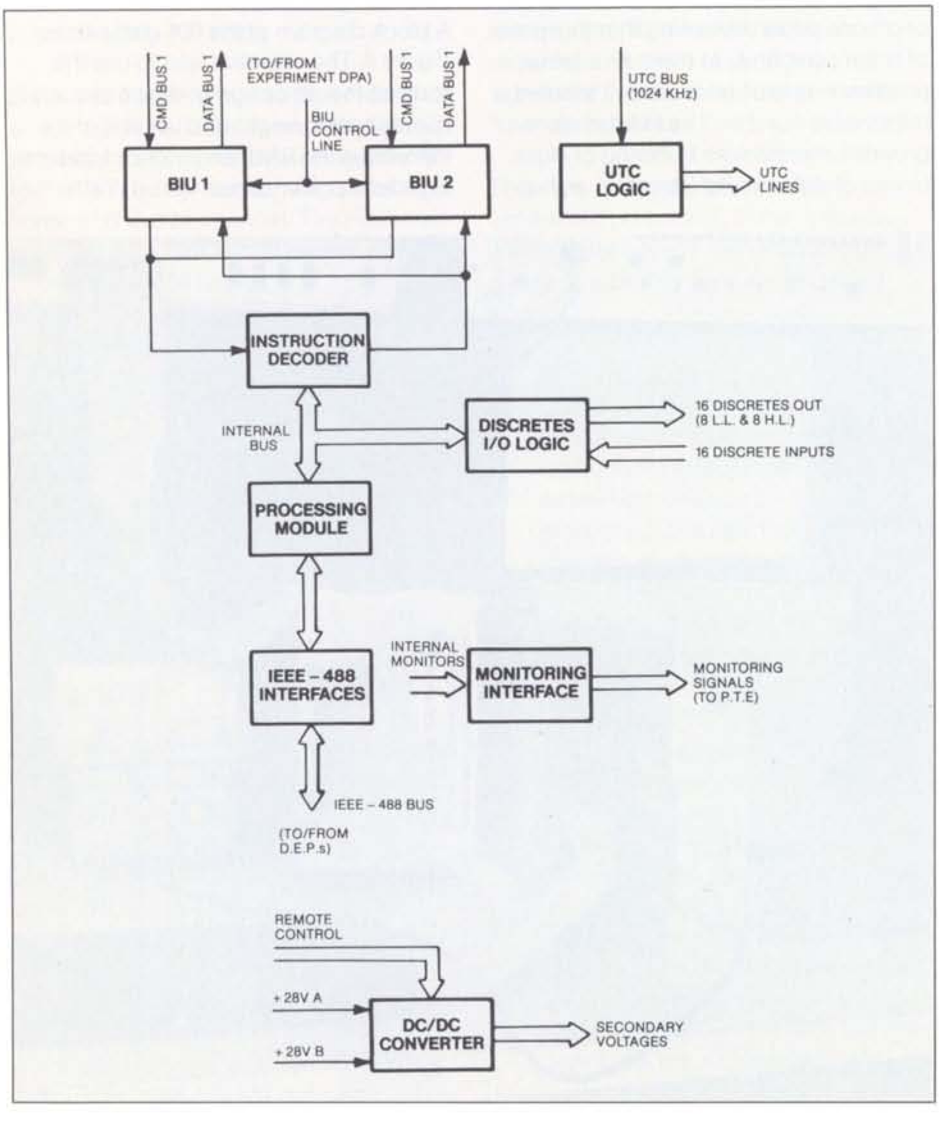


Figure 4 – General block diagram of the Processor Interface Adaptor (PIA)

Table 1 – Comparison of PIA/Experiment RAU specifications

	PIA	Expt. RAU
Mass (kg)	4.5	9.3
Volume (dl)	4.4	12.8
Power consumption (W)		
Standby	6	21
Peak usage	11	26
Dimensions W × H × L (cm)	12.4 × 18.1 × 19.4	17.0 × 18.0 × 41.9
Experiment interface provided		
IEEE-488 byte serial interface	1	–
Serial output channels	–	4
Data input channels	–	4
On/off commands	16	64
Discrete inputs	16	128
User time clocks	1	4



Power consumption has in fact been reduced to less than 6 W in a standby listening mode, with a peak usage of 11 W.

The temperature range and natural and induced environments for which the PIA is specified are those experienced either in Spacelab's pressurised module rack or on the pallet panels and cold plates exposed to vacuum.

Power and size reduction has been achieved by the use of LSI chips for the Manchester Encoder/Decoder (Harris device HD-15530) and use of a microcomputer for managing the data exchange within the PIA [Z-80 microprocessor with 4 Kbyte RAM (Harris device 6504) and 2 kbyte PROM]. The IEEE interface logic is built with discrete C-MOS devices.

The PIA unit itself is designed to have a self-test facility for in-flight assessment of the health of the unit by the CDMS experiment computer. It will also be able to operate with specified ground-support equipment.

The PIA development contract

A contract for the development of the PIA, with appropriate associated software and test equipment, was negotiated with Laben, Bastogi Sistemi, Milan in mid-1981 as part of the main development (C/D) contract for Spacelab with ERNO. This contract covers development of the PIA, hardware and software, associated test equipment and experiment simulation and the delivery of the hardware and software. In particular, 1 breadboard, 1 engineering-model and 8 flight-model PIAs, 2 sets of test equipment, 2 sets of portable test equipment and the Dedicated Experiment Simulators (test DEPs) are to be delivered. The overall schedule is shown in Figure 5. The flight-model PIAs are to be accepted in 1984/1985, when they could be used on the fifth and sixth flights of Spacelab.

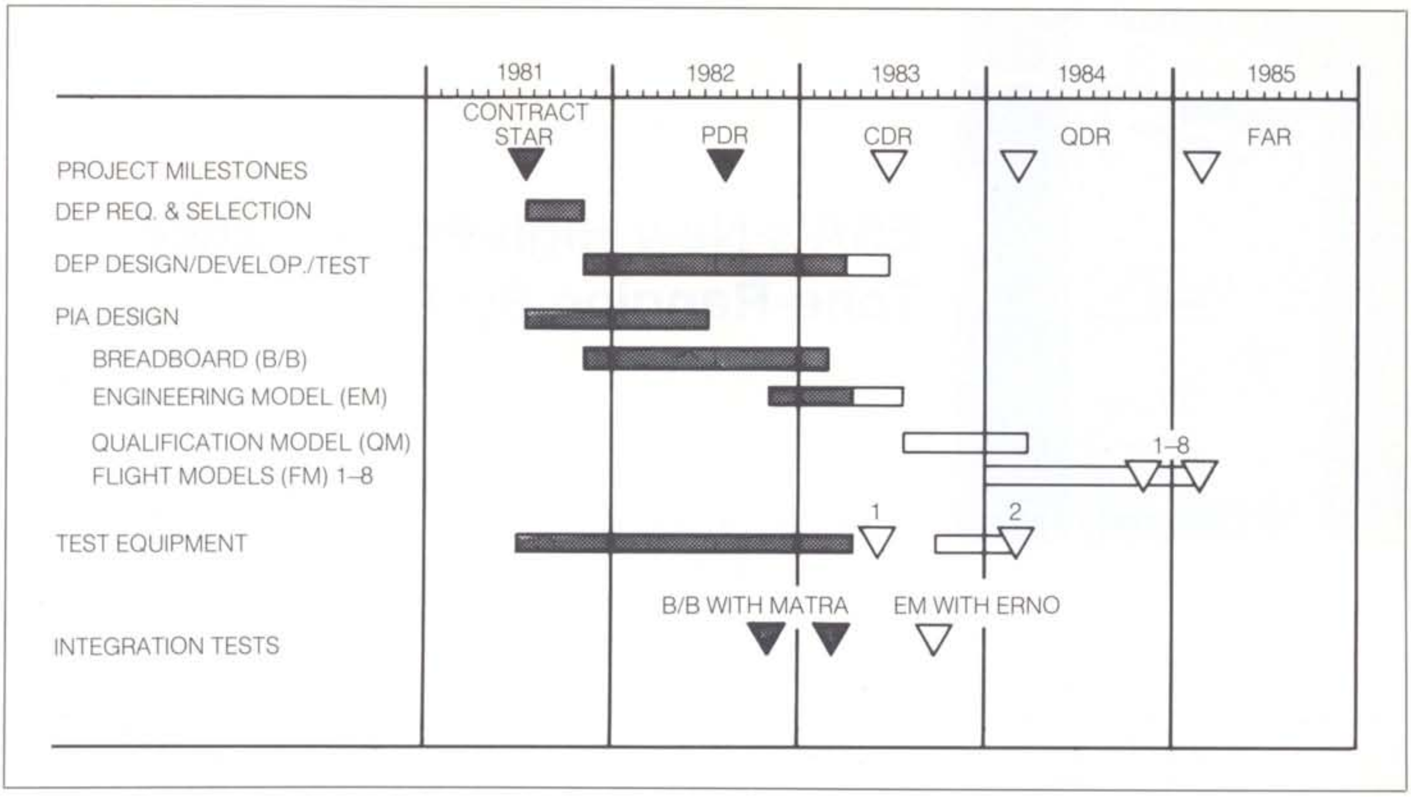


Figure 5 — Development schedule for the PIA

Progress to date

PIA development was begun in 1981. To date, the specification has been agreed (Table 2) and the Preliminary Design Review was carried out last August. The breadboard has been manufactured and was tested with the CDMS set up at Matra last December and with a simulated payload in March. The test equipment is due to be qualified by June this year.

The PIA Critical Design Review is scheduled for June, which will release the manufacture of the qualification model. The EM model will be tested with Spacelab. The flight models will be manufactured after the Qualification Design Review and will be available in 1984/5.

Table 2 – Typical PIA specifications

Overall characteristics

Mass	4.5 kg
Voltage requirement	Nominal 28 V (min. 22, max. 32 V)
Power consumption at 28 V	6 W standby 11 W maximum
Dimensions	
Width	132 mm (incl. feet)
Height	181 mm
Length	194 mm
Reliability	0.995 for 200 h continuous operation

Environmental characteristics

Operating temperature range	−40°C to +70°C
Storage temperature range	−50°C to +90°C
Qualification vibration levels	Random vibration 16 g rms normal to mounting structure and 12.8 g rms in other structure directions
Humidity	
Operating	up to 70%
Storage	up to 95%
Pressure	Vacuum to 1.1 bar

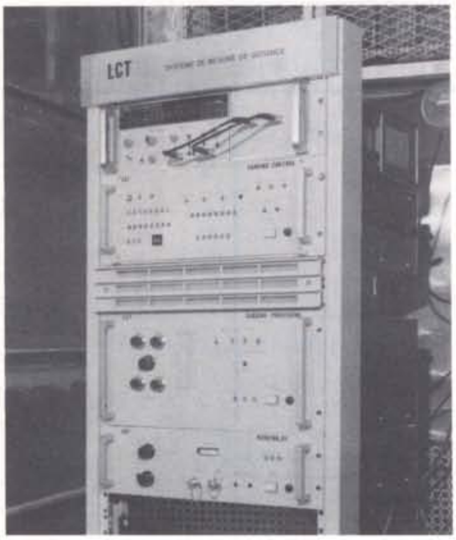
Payload interface characteristics

Data exchange in both directions on the basis of the IEEE-488-1978 standard protocol:
- 8 lines for message bytes in bit parallel byte serial form
- 3 lines for handshake process
- 5 signal lines to control flow of information across interface.

Discretes and on/off commands.
- 8 low-level latched (5 V) commands.
- 8 high-level pulsed (100 ms) 28 V commands, driving up to 100 mA.

Monitoring/data acquisition
- 16 digital input discretes

User time clock: Distributed from CDMS; one continuous 1024 kHz derived from Spacelab clock bus and a reset pattern (4 clock pulses every 250 ms), decoded from incoming clock, for time-code acquisition.



ESA's New High-Performance Tone-Ranging System

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Development of a new generation of tone-ranging subsystems has recently been concluded by industry, and five subsystems have been delivered to ESOC for integration into ESA's ground-station network. These new subsystems are self-contained in that, in addition to low-frequency and digital sections, they also include the intermediate frequency modulation and demodulation sections. They are characterised by well-defined standard interfaces, which facilitates station integration, and by a high degree of flexibility, allowing a variety of mission requirements to be served.

Two of the new subsystems have already been installed and are operational, at the Agency's Villafranca del Castillo (Spain) and Redu (Belgium) ground stations. They will support the Exosat and ECS missions, respectively. The other three subsystems are being integrated into the UHF stations of ESA's Geostationary Transfer Orbit (GTO) Network.

Precise knowledge of a satellite's position is an essential prerequisite for payload operations and orbit-correction manoeuvres. This position can be calculated at any time from a mathematical orbit model, with the aid of existing orbit-determination programs. The orbit model is characterised by the orientation of the orbital plane with respect to the geocentric inertial coordinate system (inclination and right ascension of the ascending node), the position and characteristics of the elliptical orbit in its plane (argument of perigee, semi-major axis and eccentricity), and finally the mean anomaly, which is a linear function of time and fixes the satellite's position in the orbit.

With the variety of forces experienced by the satellite in orbit, the above parameters change with time and require periodic updating. Since some of the forces involved are inadequately known, the theoretical methods available for the updating of the orbital parameters are not sufficiently accurate and need to be complemented with actual satellite tracking data from ground stations.

The two types of tracking data required are:

- ground-antenna pointing directions (azimuth and elevation)
- satellite range, i.e. the distance between the tracking station and the satellite at a defined time.

In the following paragraphs, the tone-ranging method of establishing a satellite's range is outlined and the latest generation of tone-ranging subsystems recently developed by industry to ESA specifications is presented.

Operating principle of a tone-ranging system

This method of determining the distance between satellite and ground station consists of measuring the time delay between a sinusoidal signal transmitted by the ground station to the satellite and the corresponding signal transponded from the satellite and received at the ground station.

The total measured delay is then the sum of: the delay proportional to the two-way distance between ground station and spacecraft; the delay in the signals through the station between a calibrated reference point (normally at the antenna) and the measuring point; the delay in the transponder on board the satellite; and, finally, the additional delay due to atmospheric diffraction of the transmitted and received signals.

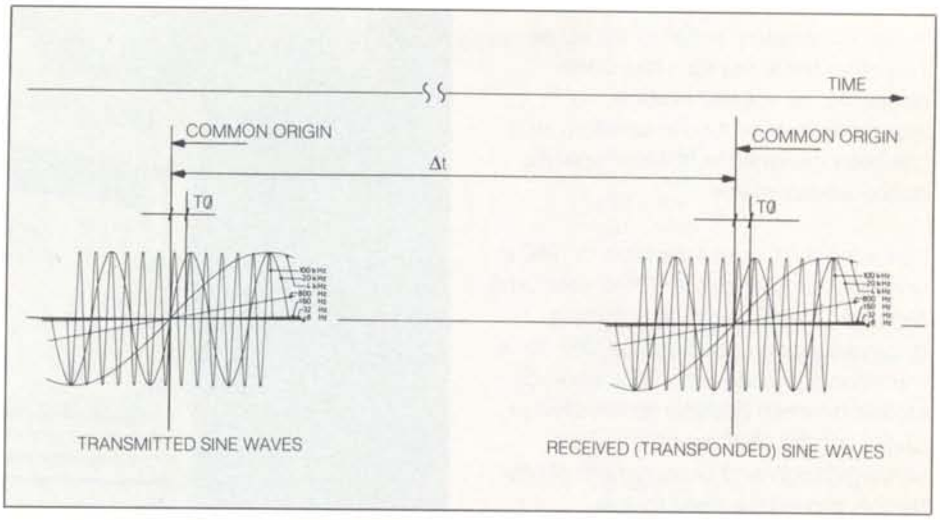
While the delay due to atmospheric diffraction can be calculated once the relative positions of satellite and ground station are known, the delays introduced by the station equipment and the transponder on board the spacecraft are calibrated before the ranging measurement takes place, and before the launch of the spacecraft, respectively.

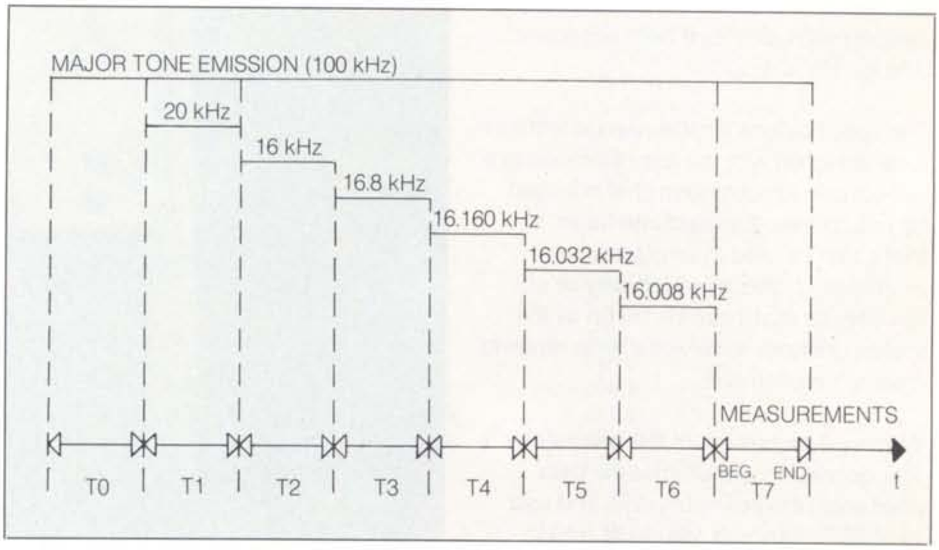
The measurement result, corrected for the above additional factors, can be expressed in metres, and represents the two-way distance between the satellite and the calibrated reference point at the tracking station.

Figure 1 – Correspondence between transmitted and received tones

Figure 2 – Sequence of tones actually transponded

In theory, there are no limitations on the selection of the frequency of the signal to be used in the measurement. Accuracy considerations, however, lead to the selection of a relatively high frequency, the upper limit being imposed by spectrum-occupancy considerations. This implies that more wavelengths of the measuring signal will be required to cover the two-way distance between the tracking station and the satellite. Consequently, before the actual measurement takes place, it is necessary to establish a correspondence between transmitted and received signals, i.e. to provide a means of identification at the receive site of the particular signal period corresponding to the period of the transmitted signal at which the measurement has been started (ambiguity resolution). This is obtained by transmitting in sequence, together with the measurement signal (major tone), a set of lower frequency signals (minor tones) characterised by a common origin with respect both to each other and the major tone (Fig. 1). The correspondence between emitted and received major tones is then obtained by identification at the receive side of the common origin, which will be delayed in time with respect to the transmission side by an amount Δt corresponding to the delay to be measured.





The frequencies used in the tone-ranging system are: 100 kHz (major tone), 20 kHz, 4 kHz, 800 Hz, 160 Hz, 32 Hz and 8 Hz (minor tones). Since each of these tones is obtained from the previous one by simple frequency division, the 8 Hz minor tone serves as the time-base reference for all the other tones. The 8 Hz tone is therefore also called the 'reference tone'.

To limit the transmitted modulation spectrum, the frequencies actually transmitted are 100 kHz (major tone) and 20 kHz, 16 kHz, 16.8 kHz, 16.16 kHz, 16.032 kHz and 16.008 kHz (minor tones).

The sequence of the transponded tones is shown as a function of time in Figure 2.

The time T0 is the time required to lock the station receiver onto the received carrier and the ranging demodulator onto the transponded major tone. T1 to T6 is the time required for ambiguity resolution, during which a reconstituted 8 Hz tone with the time accuracy of the received major tone is derived. The range measurement is then performed during time T7 by measuring the time delay between the reference 8 Hz tone and the 8 Hz reconstituted tone.

Since 8 Hz is the lowest tone used, the above system is characterised by an ambiguity of ± 18 750 km (one wavelength of the 8 Hz tone). In other words, it allows accurate measurement of the satellite's range assuming that its position is known a priori within ± 18 750 km.

The need for a new tone-ranging subsystem

Several tone-ranging subsystems have been developed by the Agency in the past, the last being the VHF* subsystem presently operational at ESA's VHF Transfer Orbit Network ground stations. With the exception of this subsystem, however, previously developed ranging subsystems are characterised by a

* VHF = ITU Band 8, i.e. space-to-earth 136-138 MHz (space operation); earth-to-space 148-149.9 MHz (space operation)

Figure 3 – Ranging subsystem in the climatic chamber at the contractor's (LCT) premises

Figure 4 – Ranging subsystem block diagram

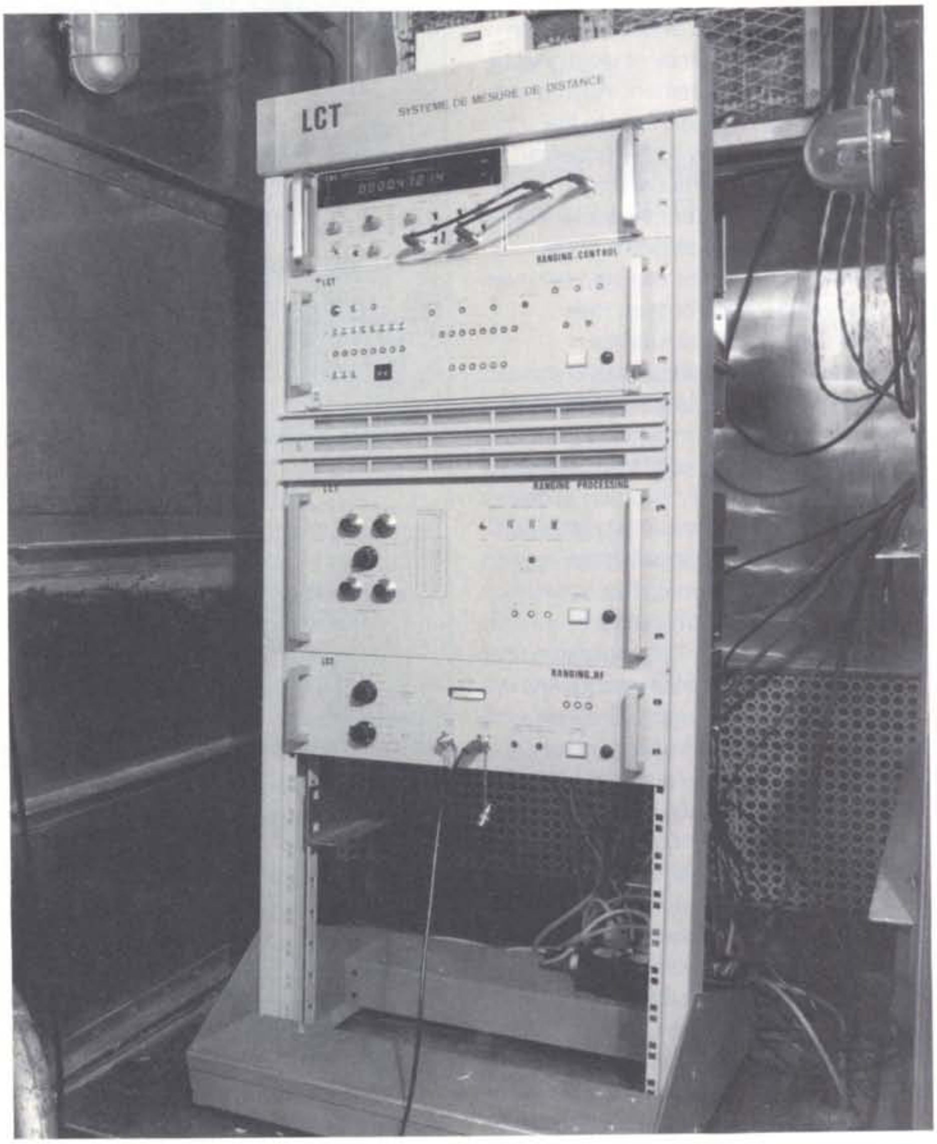
mission-dedicated design in the sense that either the subsystem has been tailored to the specific mission requirements of particular satellites, or it has been designed to fit within specific station environments.

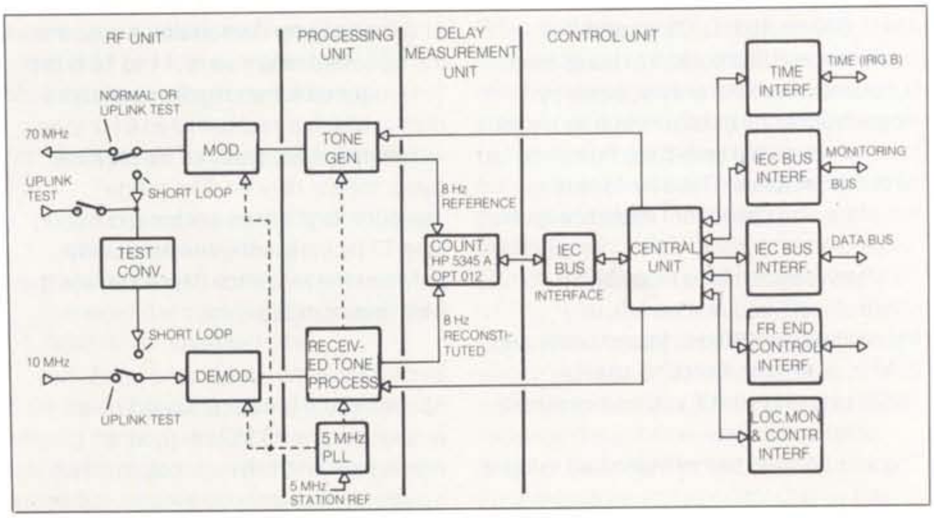
Following the Council decision in 1980 to upgrade the Agency's VHF Transfer Orbit Network to UHF* while maintaining ground-support capabilities at VHF for a transitional phase (until 1990), trade-off studies between possible reutilisation or upgrading for UHF operation of an existing design and procurement of new design, proved the need for the development of a new generation of tone-ranging subsystems on both economic and technical grounds.

The specifications for this new generation were designed with the aim of procuring a self-contained subsystem characterised by well-defined standard interfaces, so that it can be used in any station environment, and by a high degree of flexibility, so that it can be set up by the station operator to service a wide range of mission requirements.

Within the framework of this philosophy, it was decided to standardise the data interfaces between subsystem and user on IEEE** Standard 488–1978, and to select commercially available frequencies for the Intermediate Frequency (IF) interfaces of the subsystem (i.e. 70 MHz uplink IF carrier, 10 MHz downlink IF carrier).

The new ranging subsystem
The subsystem consists of four units designed for standard 19-inch rack





* UHF = ITU Band 9, i.e. space-to-earth 2200-2290 MHz (space research, near-earth space operation) 2290-2300 MHz (space research, deep space)
earth-to-space 2025-2110 MHz (space research, near-earth space operation) 2110-2120 MHz (space research, deep space)

** Institute of Electrical and Electronic Engineering mounting (Fig. 3). The functional contents of each unit are shown in Figure 4, and a summary of the main subsystem specifications is presented in Table 1.

Subsystem management and the handling of the subsystem external interfaces (IEEE buses, front-end control interface and timing interface) are performed by the control unit.

On power-up, the control unit enters a 'standby' mode of operation in which the main tasks performed are monitoring of the state of the subsystem, the handling of the monitoring bus through which the subsystem monitoring parameters are transmitted to the user, and finally the refreshing of the data displayed on the subsystem front panel.

On receipt of a user request via the data bus to perform a series of range measurements (ranging request), the control unit initiates a ranging sequence, the main elements of which are presented in Figure 5.

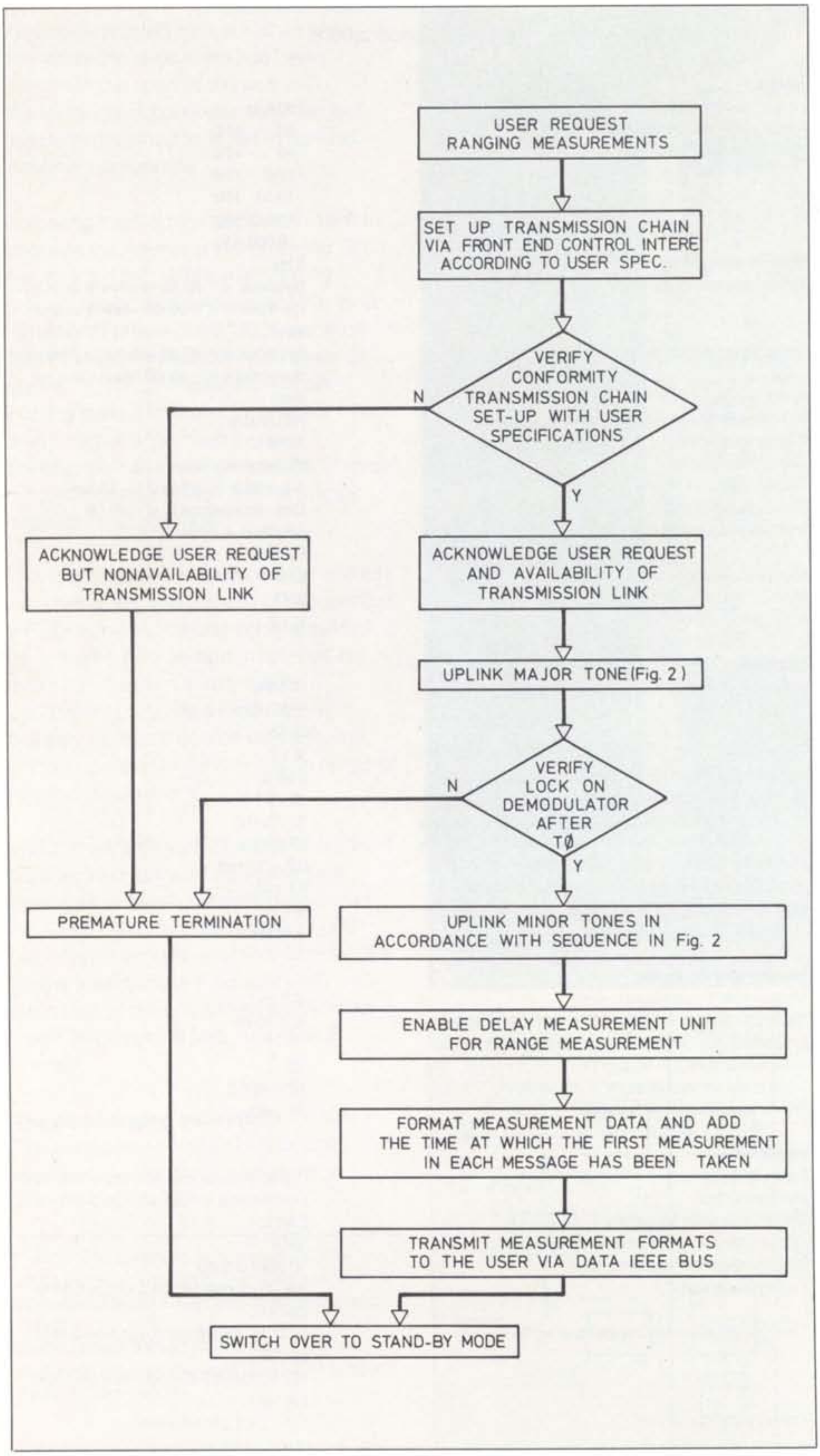
The setting-up of the transmission chain (e.g. selection of transmit polarisation, transmitter on/off, etc.) is done automatically by the control unit via the front-end control interface according to the user specifications included in the ranging request message. The user can also specify in this message the desired number of groups of range measurements, each group consisting of 32 measurements, with up to a maximum of 31 groups. This flexibility allows the user to dimension the number of measurements as a function of the station-spacecraft link characteristics and as a consequence provides him with a useful tool for integration of the noise affecting the link.

The delay-measurement unit consists of a commercial counter operating in start-stop mode. The measurements are equally distributed in time and are started by the reference 8 Hz signal every second period. Every 250 milliseconds, therefore, a

Table 1 – The tone-ranging subsystem specifications

Uplink	
Major tone frequency	100 kHz
Minor tone transmitted frequencies	20 kHz 16 kHz 16.8 kHz 16.16 kHz 16.032 kHz 16.008 kHz
Reference tone frequency	8 Hz
Major tone spectral purity	Spurious ≤ −60 dB relative to tone level Harmonics ≤ −50 dB relative to tone level
Minor tone spectral purity	Spurious ≤ −50 dB relative to tone level Harmonics ≤ −40 dB relative to tone level
Tone levels	Adjustable
Carrier frequency	70 MHz
Carrier modulation	Phase modulation
Carrier modulation index	Adjustable in range 0.1 – 1.5 rad
Modulation linearity	Distortion products ≤ −40 dB
Modulator spurious outputs	Spurious ≤ −55 dBc Harmonics ≤ −55 dBc
Modulator output level	0 dBm ±3 dB
Modulator output impedance	50 Ω
Modulator output VSWR	≤1.2
Downlink	
Input carrier frequency	10 MHz
Input carrier level	−30 dBm ±1 dB
Input impedance	50 Ω
Input VSWR	≤1.2
Input bandwidth	5 MHz
Minimum input carrier-to-noise density	38 dB/Hz
Minimum received major tone power-to-noise density	22 dB/Hz
Minimum received minor tone power-to-noise density	13 dB/Hz
Received major tone modulation index	0.2 – 0.7 rad
Minimum received minor tone modulation index	0.1 rad
Maximum Doppler shift on major tone	±7 Hz
Maximum Doppler rate on major tone	±0.33 Hz
System specifications	
Measurement quantisation error	≤2 ns
Maximum bias error within 100 h from calibration	≤±10 ns
Probability of incorrect ambiguity resolution for the complete acquisition sequence	10^{-4}
Environmental temperature	10° – 40° C
Environmental relative humidity	30 – 80%
Interfaces	
Data interface	Conforming to IEEE standard 488–1978
Monitoring bus	Conforming to IEEE standard 488–1978
Station reference frequency	5 MHz
Station reference frequency impedance	50 Ω
Station reference frequency level	10 dBm ±5 dB
Timing input signal	IRIG-B modulated on 1 kHz or 5 MHz carrier
Timing interface input impedance	50 Ω for IRIG-B modulated on 5 MHz carrier 600 Ω for IRIG-B modulated on 1 kHz carrier
Timing signal input level	1.0 – 1.4 V peak-to-peak

Figure 5 – Ranging sequence



measurement is available to the control unit for formatting. Each format contains the results of 32 successive measurements (one group of measurements) and the time at which the first measurement in the message was started. A summary of parameters indicating the status of the system during the measurement is also included in the format, to provide the user with a means of analysing the system's behaviour in the case of abnormal measurement results.

The time interface is designed to accept and decode a standard IRIG-B signal or an IRIG-B signal modulated on a 5 MHz carrier, depending on the time resolution required. The resolutions obtained in the two cases are 1 millisecond and 10 microseconds, respectively.

The tones to be transmitted are generated in the processing unit by the tone-generator module, which in essence is a programmable frequency synthesiser phase-locked to the 5 MHz station reference frequency. The tone generator also provides the 8 Hz reference signal used as the time reference for the range measurement. The design solutions adopted for the tone generator offer the possibility to phase-compensate nonlinearities in the phase-transfer characteristic of the transponder on-board the satellite. This facility is essential for maintaining the ambiguity-resolution error probability within the specified limits, independent of the transfer characteristics of the transponder aboard the satellite being ranged.

The processing unit also contains the received-tone processor module. Its function is to resolve the ambiguity in the tones received and to derive the 8 Hz reconstructed signal, which is used in the delay-measurement unit for the range measurement itself.

In addition to the modulator and demodulator modules, the RF unit contains a test converter module and a set of relays which enable the user to

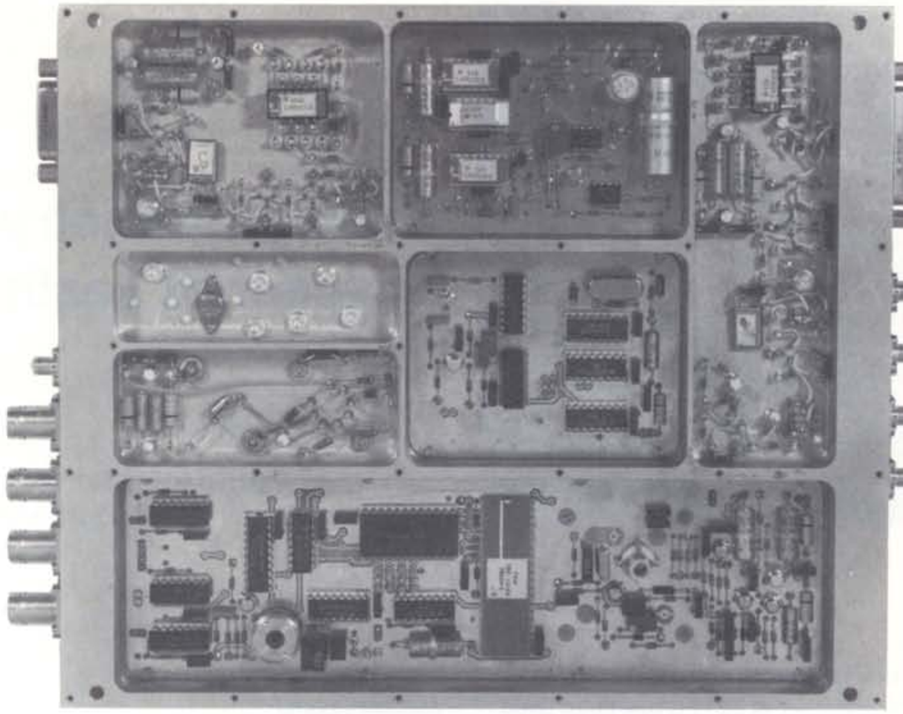


Figure 6 – Example of the technology used in the ranging subsystem: the demodulator module

select the system's operational or test-mode configuration. In the test mode, the relays enable the user to apply to the converter a spectrum centred on the 70 MHz carrier either from the modulator ('short loop' configuration) or from the station front-end ('uplink test' configuration). In both cases the converter applies the same spectrum, centred on a 10 MHz carrier, to the demodulator.

At the converter front panel, a test point is provided from which noise can be injected into the downconverted (10 MHz) spectrum to simulate the real conditions of the station–satellite link at the demodulator input.

For accurate range measurement, it is essential that the signal delay introduced by the station equipment remains within specific limits during the time required to perform the measurement. Since the delay stability of the station system is primarily influenced by narrowband filtering on the receiving side, a design based on the use of intermediate frequency correlation at 10 MHz has been adopted for the demodulator included in the subsystem. This technique avoids the presence of narrow filters in the ranging demodulator and thereby allows the demanding long-term stability specification for the subsystem to be met.

Conclusion

The ranging subsystem that has been described is superior to its predecessors in both performance and flexibility. The results obtained with the minimum specified signal-to-noise ratios (38 dB/Hz on carrier, 22 dB/Hz on major tone, and 13 dB/Hz on minor tones) fully meet the specifications despite the fact that these are more stringent than for previous subsystems. This sound performance is accounted for by the use of the intermediate frequency correlation demodulator and by the user's ability to adjust the transmitted tone phases to the particular mission.

The programmed management of the subsystem allows the user to change operational parameters, such as reducing the ambiguity resolution time or choosing from several types of counter for the delay-measurement unit, and consequently influence the resolution of a single measurement.

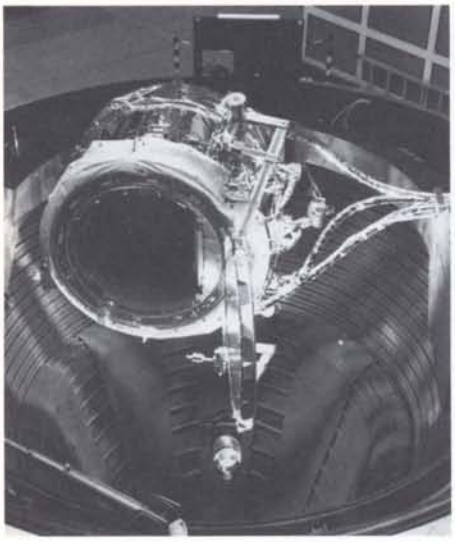
The use of IEEE standard buses for data interfaces and for monitor and control interfaces has proved technically advantageous: a desk-top computer fitted with this type of interface can be used to perform range measurements in a stand-alone mode. This is clearly an advantage for maintenance or in the event of failure of the link between the station and the control centre. Finally, the subsystem can be fully tested using standard test equipment normally available at the station location; no dedicated test equipment is required during normal station maintenance.

The subsystem development work was carried out by Laboratoire Central de Télécommunications (LCT) as result of ESA's open call for tender.

The first two subsystems of the new type, delivered to ESOC during the second half of 1981, are presently installed in the Agency's ground stations at Villafranca (Spain) and Redu (Belgium), to support the Exosat and the ECS missions, respectively. Compatibility testing at Villafranca with the Exosat engineering model and comparative range measurements performed on the OTS satellite with the OTS ranging subsystem and the new ranging subsystem have successfully qualified the subsystem's design in terms of performance and flexibility.

Three additional subsystems of the same type were delivered to ESOC in 1982. The first unit of this second group will be installed in the ESOC reference station, while the other two will be integrated into the Malindi (Kenya) and Carnarvon (Australia) stations to support satellites operated at UHF while in transfer orbit. A further subsystem has been produced by LCT for DFVLR (German Aerospace Research Establishment) and will be integrated into the Weilheim ground station.

Further applications of this new generation of ranging subsystems are being considered for providing ground support to the Agency's L-Sat and first Earth-observation (ERS-1) missions.



Photogrammetry as an Aid to Spacecraft Testing

K. Beckel & E. Grün, Test Services Division, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

Since 1966 the HBF-3 thermal/vacuum test chamber at ESTEC has been used for the vacuum testing of satellites and satellite subsystems, and thermal cycling using a solar simulator to recreate the space environment. With the new photogrammetry system now available, it is also possible to measure very accurately the deformations of such systems under simulated space conditions.

Rationale for deformation measurements

Any spacecraft experiences thermal deformations during its orbital lifetime, as temperature distributions change with changing illumination conditions, due to eclipses, solar-aspect-angle variations, etc. Such deformations can severely degrade spacecraft performance, particularly for those spacecraft carrying optical instruments (e.g. telescopes) or dish antennas. For such antennas, for example, the dish surface must typically remain within $\lambda/30$ of its nominal shape under all operating conditions. For the dish's position with respect to feed horn and subreflector, angular alignments down to a few hundredths of a degree might be required, depending on the application.

To predict such thermal deformations, sophisticated mathematical models simulating both thermal and structural properties are used. This, in itself, however, is not sufficient. Verification by testing at subsystem (antenna) or even system level is necessary because such thermal/structural mathematical models contain many uncertainties. These verification tests are normally performed in large thermal/vacuum facilities, in which orbital conditions can be reasonably accurately reproduced. If the thermal conditions are already well known (e.g. from previous tests), it might be sufficient to perform the test under ambient conditions by driving the temperature distribution to predetermined values, perhaps by means of surface heaters. In all cases it is necessary to measure the deformations during the tests with high accuracy and normally only methods not requiring direct contact with the object under test are acceptable.

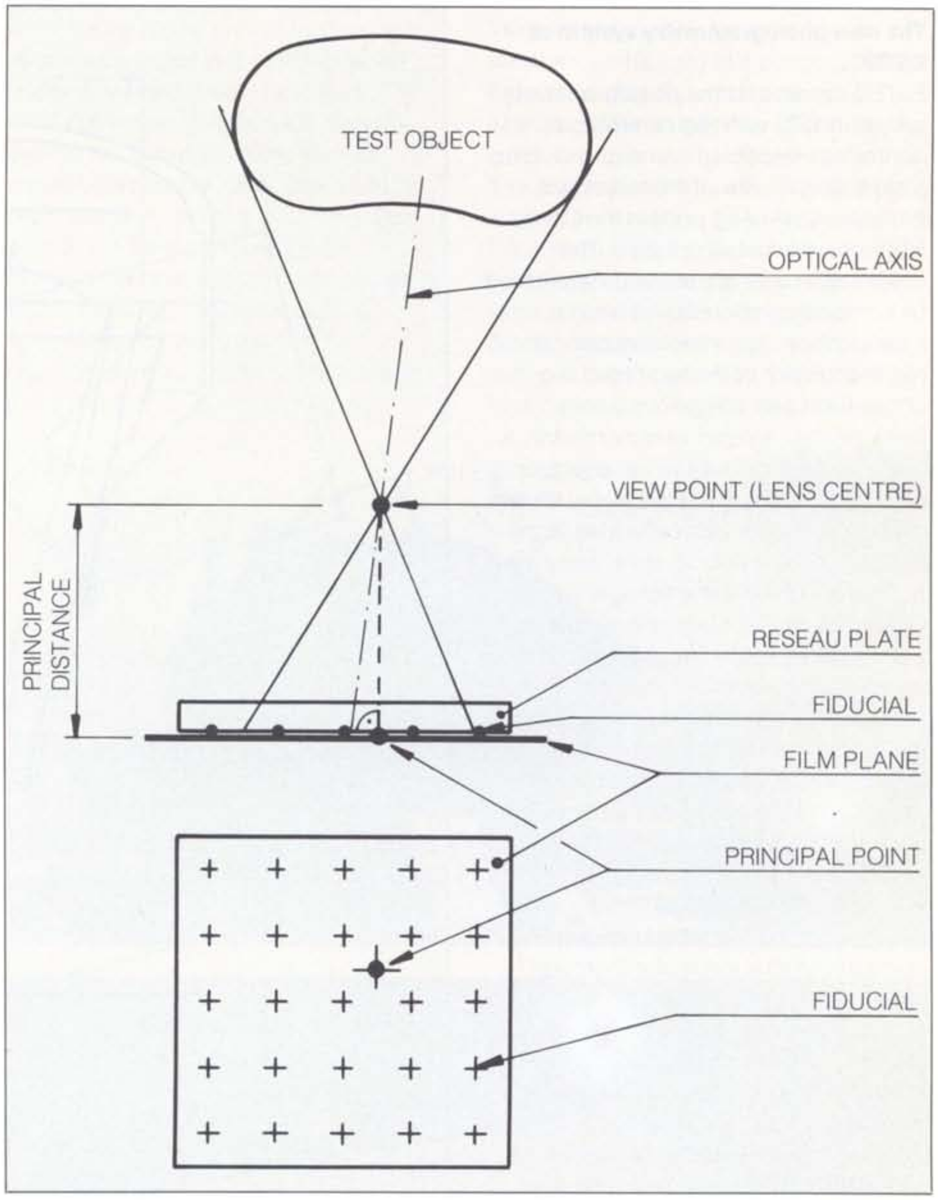
One deformation-measurement method that is simple, versatile, inexpensive, and still gives reasonable accuracy is photogrammetry, by which a three-dimensional representation of an object is provided by taking a stereoscopic view of it using two cameras at different viewing angles.

Principles of photogrammetry

The photogrammetric technique relies on measurements made on photographs. Its purpose is to define precisely the shape, position and size of the limiting surface of an object photographed from different points, called 'view points'. If we consider the object and a single view point, a photograph is a section of a bundle of light rays going from the view point to various points on the object, so that the photograph is a two-dimensional representation of the three-dimensional object. At least two photographs are therefore necessary to define an object uniquely in three dimensions and each photograph has to be associated with the corresponding view point via two main camera parameters, the principal point and the principal distance.

The principal point in the photograph lies at the base of the perpendicular from the centre of the lens to the film-emulsion plane. The principal distance is the length of that perpendicular. The position of the principal point on the image is defined by fiducial marks which are introduced via a reseau plate incorporated within the

Figure 1 – Main geometrical properties of a metric camera



camera between lens and film plane; these can also be used for the correction of film shrinkage

In addition to the principal point and the principal distance, other camera parameters have to be known, such as focal length, lens distortion, intersection of the optical axis and film plane (which ideally should coincide with the principal point). These parameters together determine the 'internal camera orientation'. Cameras with calibrated internal orientations are called 'metric cameras', and these are generally built to the highest quality standards. Their lenses, for example, have extremely small and only radial distortions (Fig. 1).

In addition to the internal camera parameters, the relative positions of the cameras with respect to the test object have to be known exactly; these determine the so-called 'external camera orientation'.

The measurement method consists of taking two simultaneous photographs of the object under test, which is provided with 'target points' to be seen by both cameras. In the case of spacecraft photogrammetry, points on the structure identified by target stickers are used as reference targets.

In the case of photogrammetry with the aid of metric cameras, the external camera orientation can be determined analytically, with the exception of the scale factor, if a minimum of five common points, not lying in a plane, can be seen by both cameras. If the cameras are nonmetric, an additional calibration structure has to be photographed together with the test object and this structure should have as many well-defined target points as possible, well distributed in three dimensions.

Only knowledge of the internal and external camera orientations, together with the coordinates of the target points on both pictures, allows the three-dimensional coordinates of the target points to be reconstructed unambiguously from the photographs taken. Two methods are available for this: an 'analogue' method and an 'analytical' method. In the analogue method each target point in the photograph is examined through a stereo-comparator. The left and right images are brought into coincidence on the point in question. The three-dimensional coordinates of that point are then reconstructed mechanically. Internal and external camera orientations are introduced into the comparator in terms of mechanical dimensions. In the analytical method a stereo- or mono-comparator is used only to determine the X-Y coordinates of each target point on the two pictures and the rest is done by computer processing software. The analytical processing method is more accurate than the analogue method, not only because of limitations in the mechanics of the stereo-comparator, but also because other properties such as lens distortions and film shrinkage can be taken into account.

Figure 2 – Measuring arrangement of the new photogrammetry system in the Heat Balance Facility (HBF-3) at ESTEC

Figure 3 – Simplified geometrical relations between film plane and test plane in the HBF-3 chamber

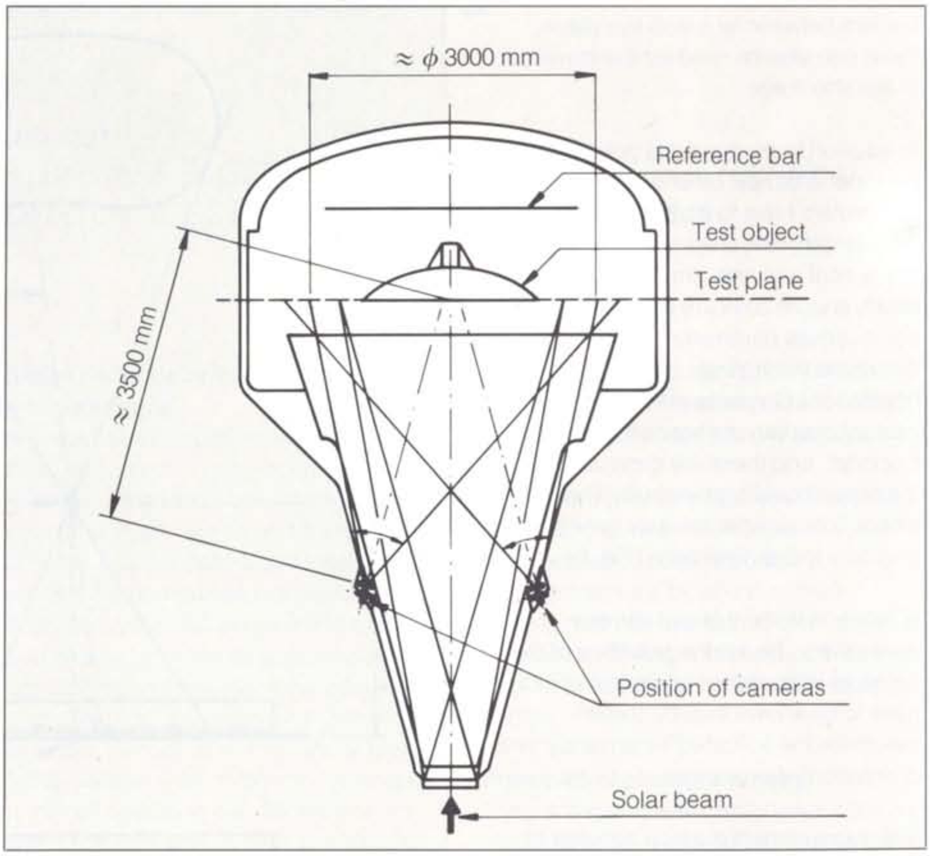
The new photogrammetry system at ESTEC

ESTEC installed its first photogrammetry system in 1973 with two commercial, nonmetric Hasselblad cameras providing a stereoscopic view of the test object through two viewing ports in the Centre's HBF-3 solar-simulation facility. The deformation during a test was determined by comparing (difference of best-fit superposition) two three-dimensional representations of the test object, e.g. under sunlit and eclipse conditions. Because the cameras were nonmetric, a three-dimensional calibration structure consisting of thin, thermally highly stable carbon-fibre bars, with calibrated target points at the bar intersections, was swung out in front of the test article just before film exposure. Geometrical constraints with this structure in the vacuum chamber meant that the internal camera orientations could not be determined with the precision necessary to provide an overall test accuracy comparable to that obtainable with today's more advanced photogrammetry techniques.

The new ESTEC photogrammetry system described in the following paragraphs came about as a result of a thorough investigation of the topic, started in 1979. This new system provides an accuracy of ±0.2 mm in deformation measurements for tests in the HBF-3 facility. Moreover, the system could be applied without major difficulty to other vacuum facilities, such as the ESTEC Dynamic Test Chamber (DTC) and it can also be used under ambient conditions.

Figure 2 shows the new measuring arrangement for the HBF-3 chamber, with two Hasselblad MK-70 metric cameras with Biogon 5.6/60 mm lenses. The two cameras are held in fixed mounts outside the chamber, and view the object under test through the optical windows, for which a refraction correction is applied.

Figure 3 shows the geometry (simplified) of the film plane, lens centre, test plane and optical axis, based on the



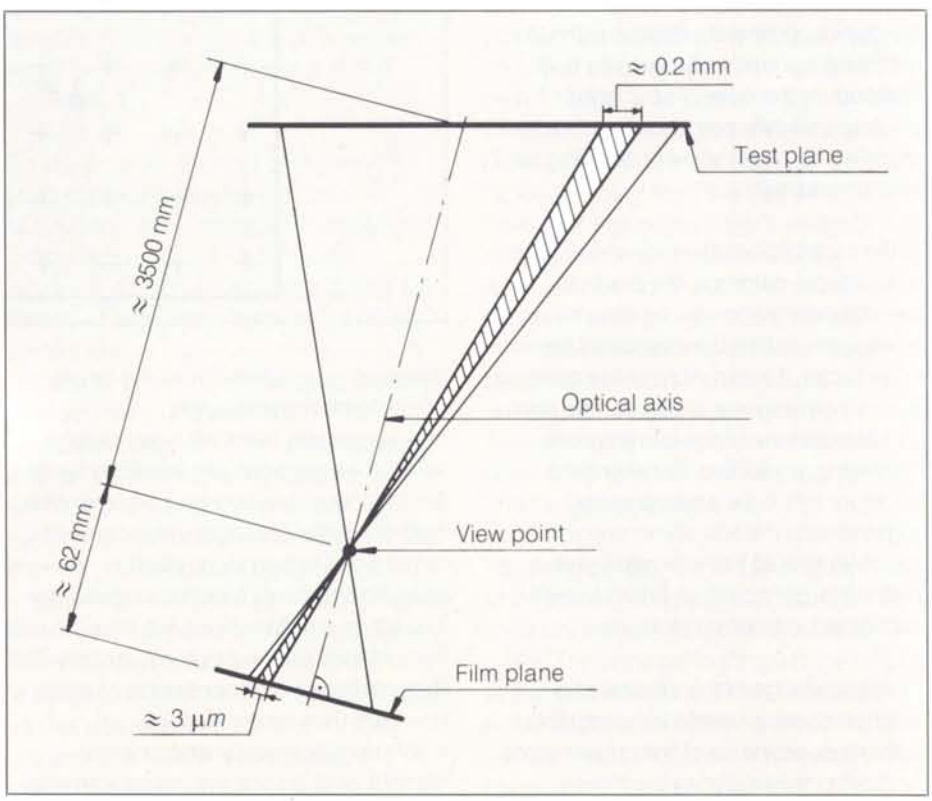


Figure 4 – An antenna being tested under ambient conditions

Figure 5 – Flat radar antenna under test in the HBF-3 chamber

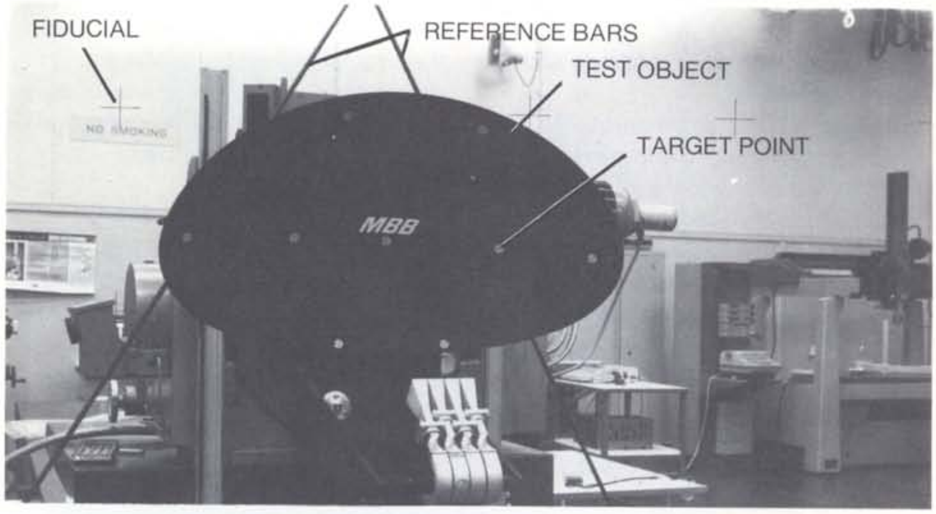
geometrical properties of the HBF-3 chamber and its camera locations. The distances between film plane and lens centre, and lens centre and objective plane are ca. 62 mm and 3500 mm, respectively. Assuming a distortion of 2–3 μm in the film plane, the associated displacement in the test plane is ±0.1 to ±0.2 mm.

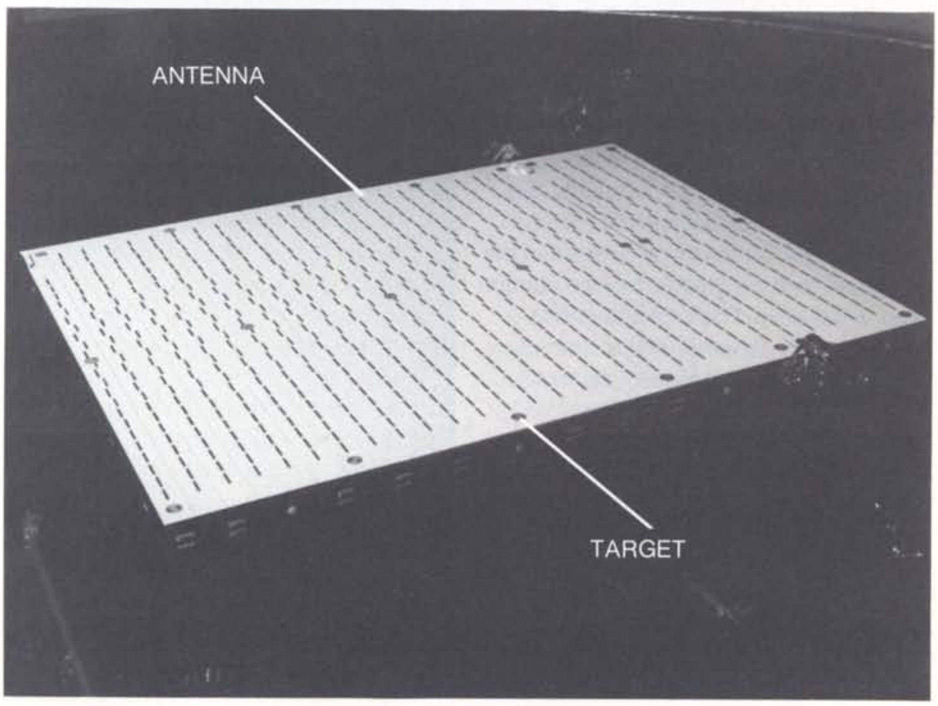
The target and fiducial measurements on the negative film are made with a mono-comparator. Each image of the stereo pair is studied individually. The processed film is placed on the unit's illuminated carrier and the target points and fiducial marks located. As the carrier is moved, optical encoders generate the digital coordinate data (see Fig. 4).

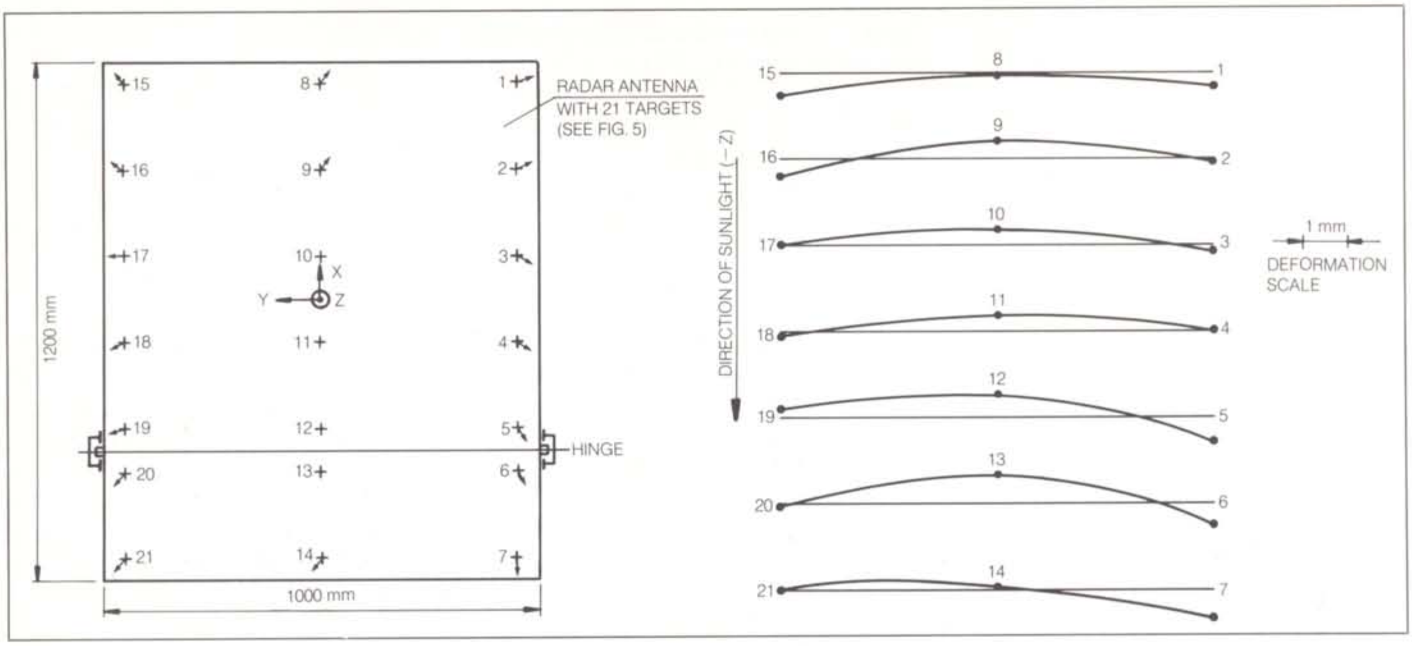
By reading the fiducials and the object target points, the software is able to generate the relative camera orientation with respect to the test object and thence the object shape, with the exception of a scaling factor. To determine the latter, carbon-fibre reference bars with a very low thermal elongation coefficient are used. Their tips are provided with target stickers at precisely known separations. The bars are normally photographed together with the test object (Figs. 2 & 4). The reference-bar readings together with the earlier data allow the software to generate the coordinates of the test-object's target points. The final step is determination of deformations by comparing the absolute test-object coordinates under different environmental conditions (e.g. in Sun and eclipse). This is done by superimposing the two stages in question by means of a least-squares adjustment. The remaining differences between individual points are then defined as deformations. To increase accuracy, multiple readings can be performed for the same test stage.

Practical application of the system
The usefulness of photogrammetric deformation measurements can be highlighted via a recent practical application. The specimen, a flat radar antenna equipped with 21 target points (Fig. 5) was tested in the HBF-3 facility under simulated space conditions. The most interesting stages in the thermal-cycling test occurred at the thermal equilibrium point in the eclipse and the high radiation period a short time after eclipse. It is here that the highest temperature gradient can be expected to occur, causing extensive structural deformation of the antenna. The photogrammetric comparison between these two stages clearly shows the thermal influence on the antenna's structure, in the form of a bending in the Z-direction (Fig. 6), which is also the direction of incoming solar radiation.

The antenna deformation in the X-Y plane is small because the mean temperature of the antenna has increased only slightly between the two stages. However, there exists a considerable temperature difference between the upper and lower surfaces, resulting in plate bending. The asymmetric bending is a result of the







nonsymmetric nature of the antenna's internal structure.

Comparison with other methods and future outlook

Photogrammetry is a comparatively simple, straightforward and inexpensive method for measuring the shapes and/or deformations of surfaces without physical contact. A considerable advantage is that an almost unlimited number of photographs can be taken at little extra cost. The major cost lies in their analysis, which can be limited initially to the essential stages, retaining the additional photographic records for analysis only in the event of unexpected problems.

The method has been developed over the years to a high technical standard. Highly accurate metric cameras and the introduction of the computerised target-data evaluation have increased accuracy to a level that is difficult to improve upon. The limiting factors are now mainly: the distortion and resolution in the photographs, due to the graininess of the emulsion, and the precision of the camera and lens system. The best attainable precisions are currently of the order of 1–2 μm, measured in the film plane.

The only means of further improving overall accuracy would be to use camera lenses with greater focal lengths which would, however, require physically larger cameras. Such cameras (using glass plates) are already in use for aerial photogrammetry, but they are not well suited for measurements in test chambers. The fact that they do not have automatic film transport prevents their use inside the chamber.

Another restriction in photogrammetry is the time needed for test evaluation, an average of 1 min being required for each point and state. Further time reduction seems practically impossible at reasonable cost.

The current tendency to use high RF frequencies for spacecraft, however, calls for increased accuracy in antenna deformation measurements, and application of new test methods may eventually be called for. In principle, alternative methods, such as holography and speckle photography, already exist, but they have a great disadvantage: they require almost perfect stability of the test object in space between consecutive measurements (of the order of a fraction of the wavelength of light), otherwise the test results are invalidated. It will, therefore, be impossible with these methods to measure the deformation of, for instance, an antenna for two different solar aspect angles, as the antenna is rotated. Furthermore, these methods only allow very small deformations to be determined in a single measurement and are therefore generally used for relatively small test items. Also it is not possible to measure the absolute shape of a surface, but only very small relative changes.

Much development work is in progress on these new methods, but their suitability for spacecraft deformation measurements, on structures several metres across and involving overall deformations of several millimetres, has still to be investigated.

Figure 6 – Deformation of the radar antenna between end of eclipse and five minutes after eclipse

Encouraging results have been achieved with antennas by taking deformation measurements over short time intervals (deformation gradients) and integrating them over the total test time, provided the antenna mount is absolutely vibration-free.

These alternative methods are highly accurate, but also highly delicate, in operation. They also require much higher investments than photogrammetry. Photogrammetry will consequently remain the preferred method for measuring spacecraft deformations in its own accuracy range.

In the present photogrammetry application at ESTEC, the two cameras are mounted outside the HBF-3 facility in fixed positions. The system can also be applied for measurements on structures (deformations or absolute dimensions) under ambient conditions. Then, or when working with large chambers, the cameras would be sited inside the chamber, to provide optimal viewing. In a vacuum chamber, however, it is necessary to mount the cameras in thermal canisters provided with optical windows.
A further development would be use of more than two cameras, to expand the area of observation around the test object. This would, however, require considerable expansion of the existing software.

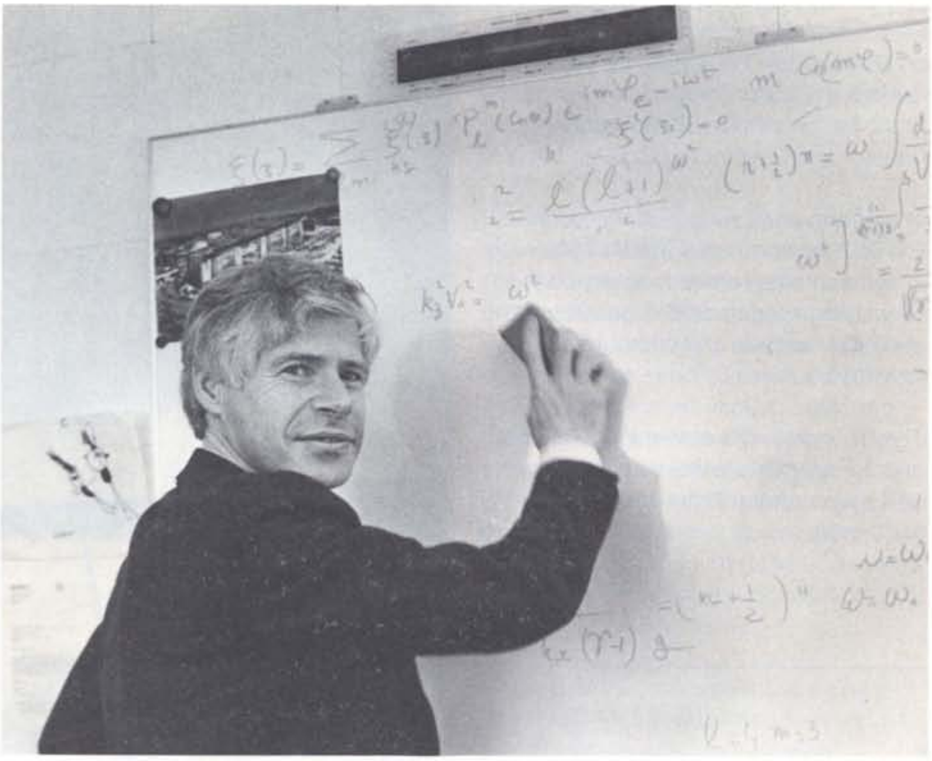
In brief

Nomination of ESA's New Director of Scientific Programmes

At the ESA Council meeting of 19 January the appointment of Mr. Roger Bonnet to the post of Director of Scientific Programmes was unanimously approved, with effect from 1 May 1983.

Mr. Bonnet, who is French and 45 years of age, is a member of CNRS (Centre National de la Recherche Scientifique) where he has held the post of Director of Research since 1977. He was appointed to his present position as Director of the Laboratoire de Physique Stellaire et Planétaire in 1969. He is a prominent member of numerous scientific societies, including IAU (International Astronomical Union) and COSPAR (Committee for Space Research), chairing a number of committees and sub-committees.

Since the start of space activities in Europe Mr. Bonnet has had close links with the scientific activities of the Agency, and was Chairman of ESA's Space Science Advisory Committee from 1978 to 1980.



Council Chairman and Vice-Chairmen Visit ESTEC

On 7 January, Prof. Hubert Curien, Chairman of the ESA Council, and Dr. Harry Atkinson and Mr. Henrik Grage, Vice-Chairmen of Council, made a tour of the ESA facilities at Noordwijk. After being welcomed to ESTEC by Mr. Erik Quistgaard, the ESA Director General, and a presentation on the activities of the Technical Directorate and ESTEC's work by Prof. Massimo Trella, ESA's Technical Director and Director of the ESTEC Establishment, the Council officials were shown the Laboratories of Product Assurance Division, the Battery Test Centre, the ESTEC Test Floor, and the EMC Laboratory.

Visit to ESTEC by Party led by Denmark's Minister of Education

Mr. Bertel Haarder, Denmark's Minister of Education, Mr. Bjoern Brynskov, Permanent Undersecretary of the Ministry of Education, Prof. Phil Flemming Woldbye, Director of the Danish Research Administration, and Mr. Christian F. Rovsing, Chairman of Christian Rovsing International AS, were among a group of Danish visitors to ESTEC on Friday 7 January.

The guests were welcomed to the Establishment, and given presentations on ESA and ESTEC activities, by Mr. Erik Quistgaard, ESA's Director General, and Prof. Massimo Trella, ESA's Technical Director and Director of ESTEC.

The visiting party subsequently toured ESTEC's environmental test facilities, integration area (where they viewed the Exosat engineering model), satellite-checkout facilities, and computer installations.

They rounded off their visit to ESTEC with an informal get-together with the Danish ESA and contract staff working at the Centre.

German Federal Minister Visits ESOC

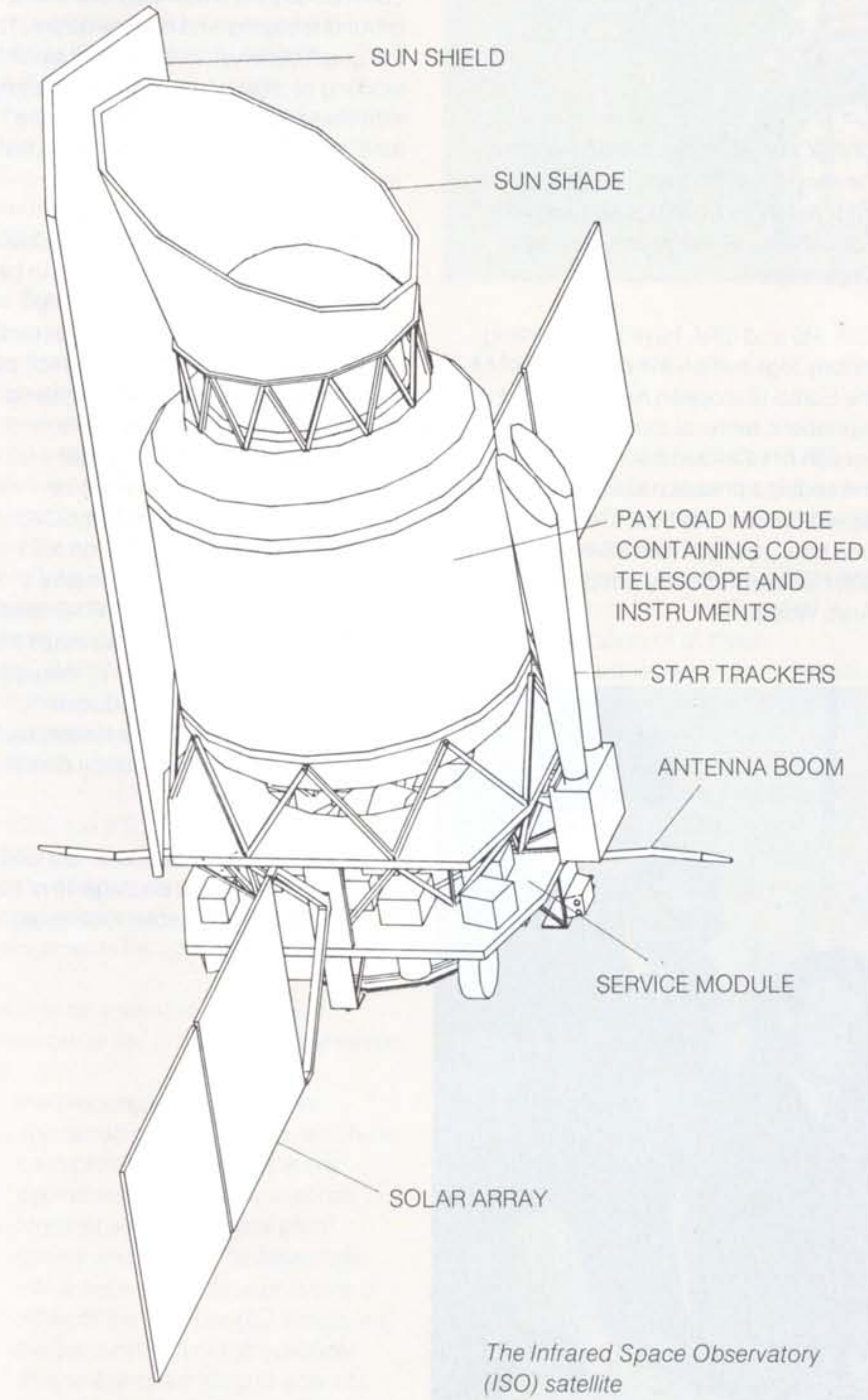
Dr. Heinz Riesenhuber, the German Federal Minister for Research and Technology, accompanied by Mr. Gerhard Pfeffermann, Member of the Bundestag and Mr. Bernard Salzer, Member of the European Parliament, visited ESOC in Darmstadt, on 7 February. They were welcomed by Mr. Erik Quistgaard, ESA's Director General, and Dr. Reinold Steiner, Director of ESOC.

The Federal Minister and his party were given a detailed account of current programmes, in particular operations, monitoring and control of OTS, Marecs-A and Meteosat-2, and an extensive tour of the Centre.

After the visit, the Federal Ministry for

Research and Technology issued the following press statement:

'The Federal Ministry for Research and Technology's 1983 budget includes 770 million Deutschmarks for promoting space research and space engineering – that is, 11% of the total budget amount. That is a very substantial share. I want to use it to consolidate and enhance the sound position held by German space research and technology' said Dr. Heinz Riesenhuber, Federal Minister for Research and Technology, today at the European Space Agency's Operations Control Centre – ESOC – at Darmstadt. Dr. Riesenhuber stressed the European dimension of space research, and made the point that Germany's contribution to ESA takes up about half the country's budget for promoting research. In providing scientific experiments on ESA space missions, too, the Federal Republic was strengthening European cooperation in this field.'



The Infrared Space Observatory (ISO) satellite

ISO Chosen as ESA's New Scientific Project

The Agency's Science Programme Committee (SPC) agreed, on 29/30 March, to the Director General's proposal to undertake a new scientific project in infrared astronomy.

For most of the infrared and submillimetre wavelength range, astronomical observations cannot be made from the ground because of absorption and emission by the Earth's atmosphere. The purpose of the new ISO satellite is to provide astronomers with an observing facility in space which will allow observations to be made at these wavelengths with very high sensitivity. This sensitivity will be similar to that currently obtainable with modern radio and optical telescopes, for which the atmosphere is far less of a limiting factor.

Of the many possible scientific areas in which ISO will have an important impact, that of extragalactic astronomy is expected to be one of particular importance. Detailed observations of selected galaxies, especially involving spectroscopy of the nearer and brighter ones, will be very informative. With those galaxies containing large amounts of dust, the infrared measurements can probe into regions that are completely obscured from visible observation. Extending this out to the most distant galaxies might enable a new distance scale for the Universe to be established using the emission of infrared bright galaxies.

Star formation takes place within large clouds of gas and dust, and so is visually obscured. Infrared observations with ISO will be able to probe into these regions and so allow this process to be studied in detail, as well as the astrophysical mechanisms that initially trigger star formation. Spectroscopic analysis of the infrared radiation emitted by various regions throughout our own galaxy and other nearby galaxies will enable their chemical compositions to be determined and compared. Within the solar system, studies of the giant planets, asteroids and comets will benefit enormously from the high sensitivity of ISO and the range of measurements obtainable with the infrared instruments.

The observatory nature of ISO requires that it should have an operational lifetime of at least 18 months, and should offer the whole sky for observation a number of times. Studies have shown that the lifetime will be achieved with generous margins. This time scale is also appropriate for observing a wide range of variable infrared objects, and gives a good chance to study a number of exceptional and periodic objects such as novae and comets.

ISO consists essentially of a 60 cm diameter telescope, with a range of infrared instrumentation. To provide the working temperature for the infrared detectors, the whole assembly is cooled to about −260°C by mounting it inside a cryostat cooled with liquid helium and liquid hydrogen. The operational lifetime of ISO is set by the lifetime of these cryogens.

ISO is planned as an infrared observatory facility available to the whole community. Operation of the spacecraft and pointing of the telescope will be maintained nearly continuously via a telemetry link with a ground receiving and control centre. To the guest observer, it will be very much like working at a ground-based observatory with on-line displays, even though the satellite is in orbit thousands of kilometres away.

The infrared instrumentation on ISO will enable selected regions of the sky to be examined in detail and with very high sensitivity. This examination will primarily involve spectroscopic analysis which can lead to the identification of the material from which the object or region is composed and the local physical conditions. Polarimetry will also be important. The development of ISO to provide this detailed information is very timely, following the successful launch and operation of the IRAS satellite. With the production of the sky maps that IRAS is making at a number of infrared wavelengths and the subsequent astrophysical analysis, an excellent basis will be established for efficiently directing the ISO observations.

A more detailed description of ISO and its mission can be found on page 19 of ESA Bulletin No. 32 (November 1982 issue).

Collaboration between ESA-IRS and IERA Continues

Within the framework of continued collaboration between ESA-IRS (ESA's Information Retrieval Service) and IERA (l'Institut d'Etudes et de Recherche pour l'Arabisation, Morocco), Mr. Erik Quistgaard, ESA's Director General, visited the Moroccan stand at the 'Expo langues' exhibition at the Grand Palais in Paris on 31 January.

Mr. Quistgaard was welcomed by Prof. Lakhdar-Ghazal, IERA's Director, who described the LEXAR (Arab Lexemes) project, the first Euro-Arab lexographical data bank. The project was sponsored and funded by His Majesty Hassan II, with UNESCO/UNDP aid (United Nations Development Programme), and has been adopted by ALECSO (Arab League Educational, Cultural and Scientific Organisation).

ESA-IRS and IERA have been working closely together on the development of the Eurab (European Arab) terminal, a bi-alphabetic terminal that uses a modified version of ESA-Quest software. 'Codar-U', the coded alphabet used by the terminal, based on Prof. Lakhdar's 'one character, one form' concept (see ESA Bulletin No. 30), has been officially adopted by the Arab World.

New European Contribution to the World Meteorological Satellite System Agreed

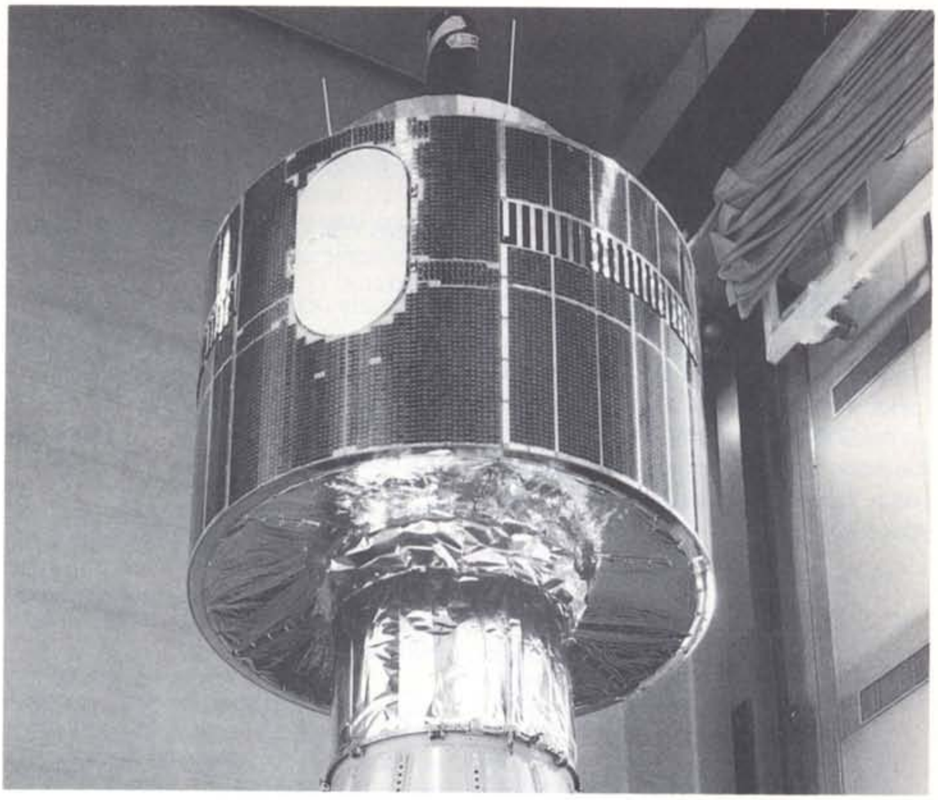
The second session of the Intergovernmental Conference on an operational European Meteorological Programme, held at ESA Headquarters in Paris from 21 to 23 March 1983 and attended by Delegations from 17 European countries (the 11 ESA Member States, plus Austria, Finland, Greece, Norway, Portugal and Turkey), reached agreement on a new 12-year operational programme. This programme will benefit European meteorological organisations, enabling them to embark on joint activities making use of space technologies applicable to meteorological research and weather forecasting and will also ensure the distribution of meteorological data to African and Middle-East countries.

The Conference approved a Convention setting up a small international organisation, to be known as EUMETSAT, which will provide the cooperative framework to enable Europe to carry out the operational programme. The primary objective of EUMETSAT is to establish, maintain and exploit European systems of operational meteorological satellites, taking into account, as far as possible, the recommendations of the World Meteorological Organisation (WMO). The EUMETSAT Convention will be submitted for signature to the Conference of Plenipotentiaries to be held in Geneva in the second half of May 1983.

Pending the entry into force of the EUMETSAT Convention, and in order not to delay the programme, it will be carried out per interim under the terms of ESA's arrangements for optional programmes.

ESA is to be entrusted, within the framework of the operational programme, with:

- the procurement of three new spacecraft (M0-1, 2 and 3), which will be improved versions of the pre-operational Meteosat spacecraft, together with a complete set of spares which could be assembled into a flight unit in case of failure of either of the MO-1 or MO-2 missions
- the procurement of the European Ariane launchers for and activities associated with the launch of all three flight units during May 1987, August 1988 and November 1990
- the continued exploitation of the pre-operational Meteosat system from the end of the current funding arrangement in November 1983 until the launch of MO-1 in May 1987
- the exploitation of all three operational spacecraft from mid-May 1987 until the end of the programme in November 1995.



The Meteosat-2 spacecraft

The overall cost of the programme, due to get underway in June 1983 under an ESA management team, is projected to be 400 MAU (1 AU = ± $ US 1 at 1983 exchange rates) at current price levels.

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 77 and using the Order-Form on page 78.

ESA Journal

The following papers have been published in ESA Journal Vol. 7, No. 1 (March 1983):

THE ERS-1 PROGRAMME OF THE EUROPEAN SPACE AGENCY
HASKELL A

ATTITUDE PERTURBATIONS OF THE GIOTTO SPACECRAFT IN THE DUST CLOUD OF COMET HALLEY
COUPE GM, DEAN RM & LAINE R

CHARACTERISATION OF THE 50-70 GHz BAND FOR SPACE COMMUNICATIONS
DAMOSSO E, STOLA L & BRUSSAARD G

DYNAMIC QUALIFICATION OF SPACECRAFT BY MEANS OF MODAL SYNTHESIS: PART 2
BERTRAM A & CONRAD P

LARGE-SIGNAL DYNAMIC-STABILITY ANALYSIS OF SYNCHRONISED CURRENT-CONTROLLED MODULATORS: APPLICATION TO SINE-WAVE HIGH-POWER INVERTERS
CAPEL A ET AL.

EVALUATION STATISTIQUE DE LA COUVERTURE AU SOL D'UN SATELLITE ET DE LA VISIBILITE STATION
FLANDRIN JC & FERRANTE JG

Special Publications

ESA SP-181 // 250 PAGES
SOLAR ENERGY '82: RESOURCES, TECHNOLOGIES & POTENTIAL – PAPERS PRESENTED AT THE SUMMER SCHOOL HELD AT IGLS, 28 JULY – 6 AUGUST 1982 (NOV 1982)
BURKE WR (ED)

ESA SP-192 // 99 PAGES
GALACTIC AND EXTRAGALACTIC INFRARED SPECTROSCOPY – PROC 16TH ESLAB SYMPOSIUM, TOLEDO, SPAIN (OCT 1982)
KESSLER MF, PHILLIPS JP & GUYENNE TD (COMPILERS)

ESA SP-194 // 180 PAGES
RADAR CALIBRATION – PROCEEDINGS OF EARSEL WORKSHOP, ALPBACH, AUSTRIA, 6–10 DECEMBER 1982 (FEB 1983)
ROLFE EJ & BATTRICK B (EDS)

Procedures, Standards & Specifications

ESA PSS-01-711 ISSUE 1//18 PAGES
PRODUCT ASSURANCE REQUIREMENTS FOR MICRO VCM APPARATUS AND ASSOCIATED EQUIPMENT (OCT 1982)
PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-704 ISSUE 1 // 21 PAGES
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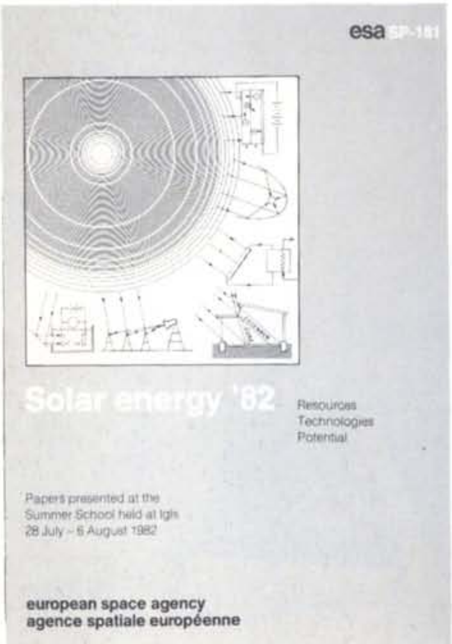

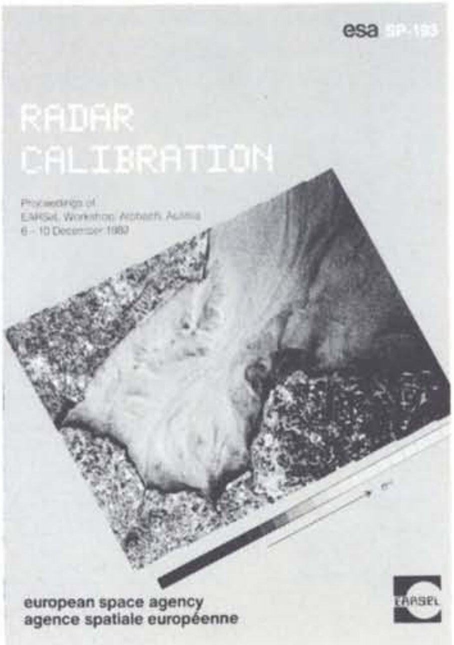

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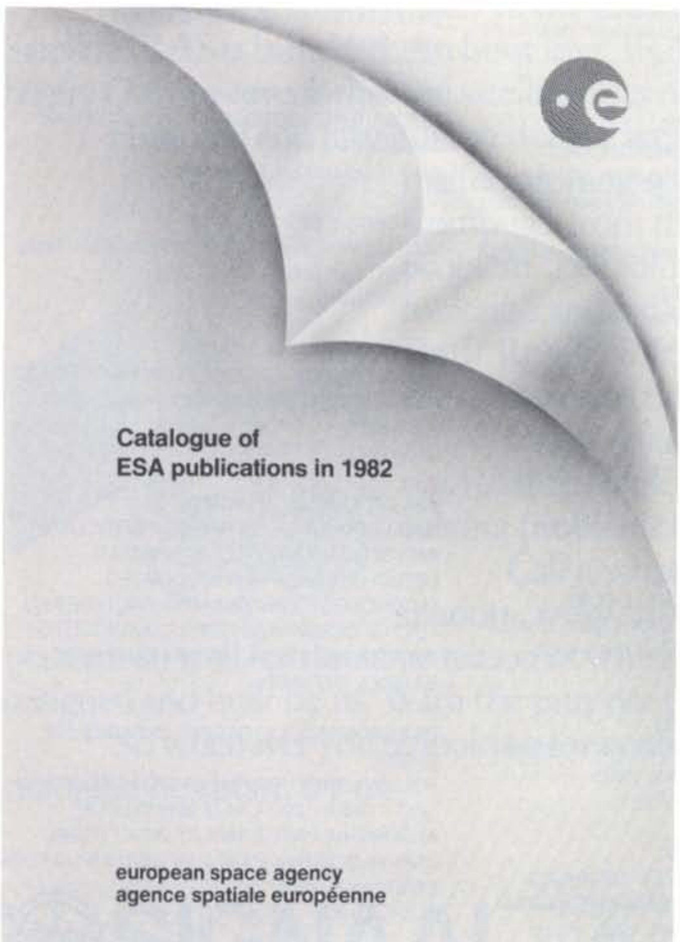

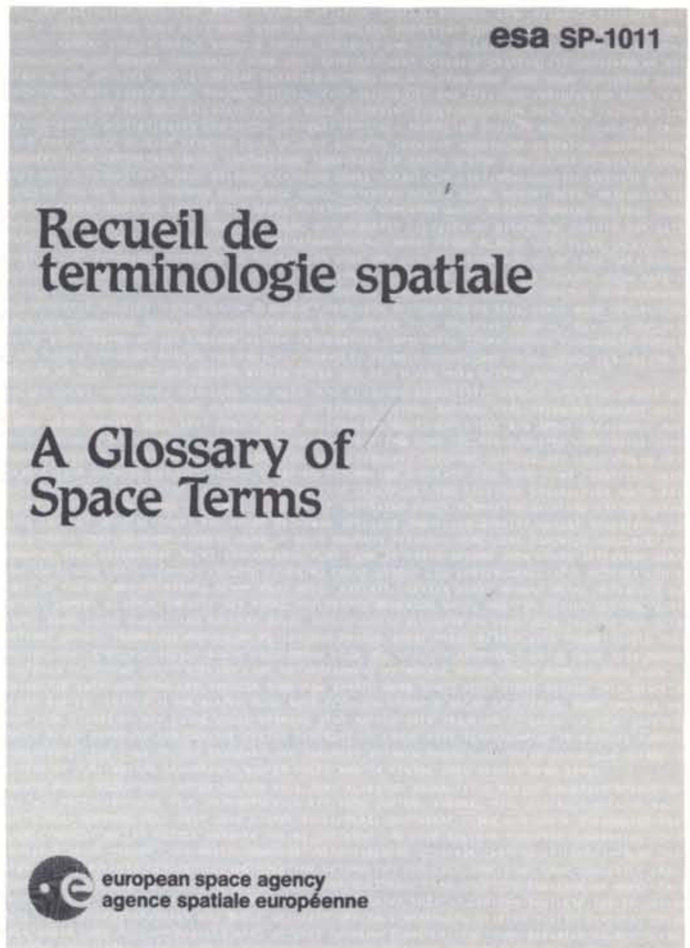

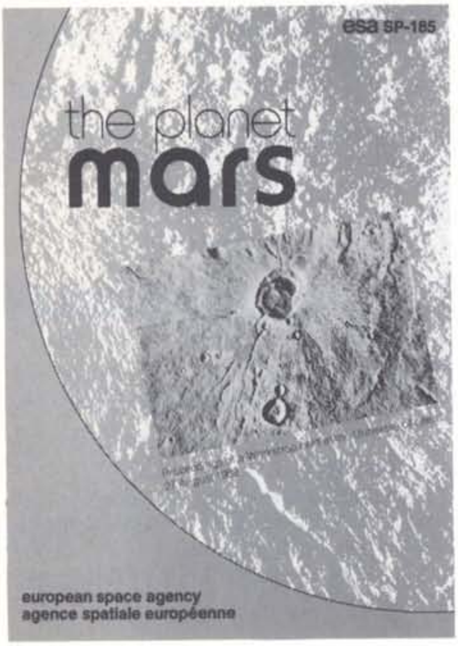

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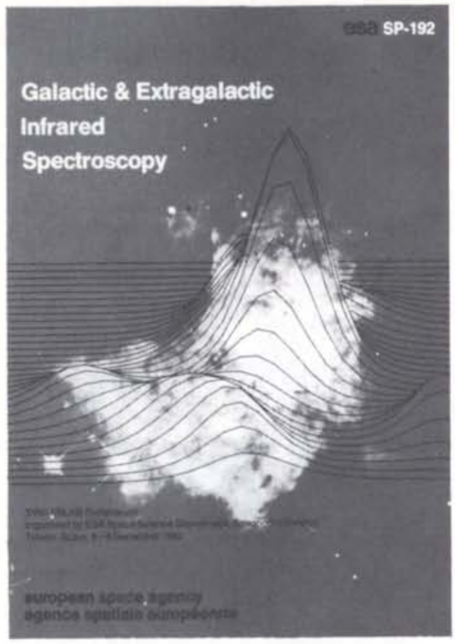

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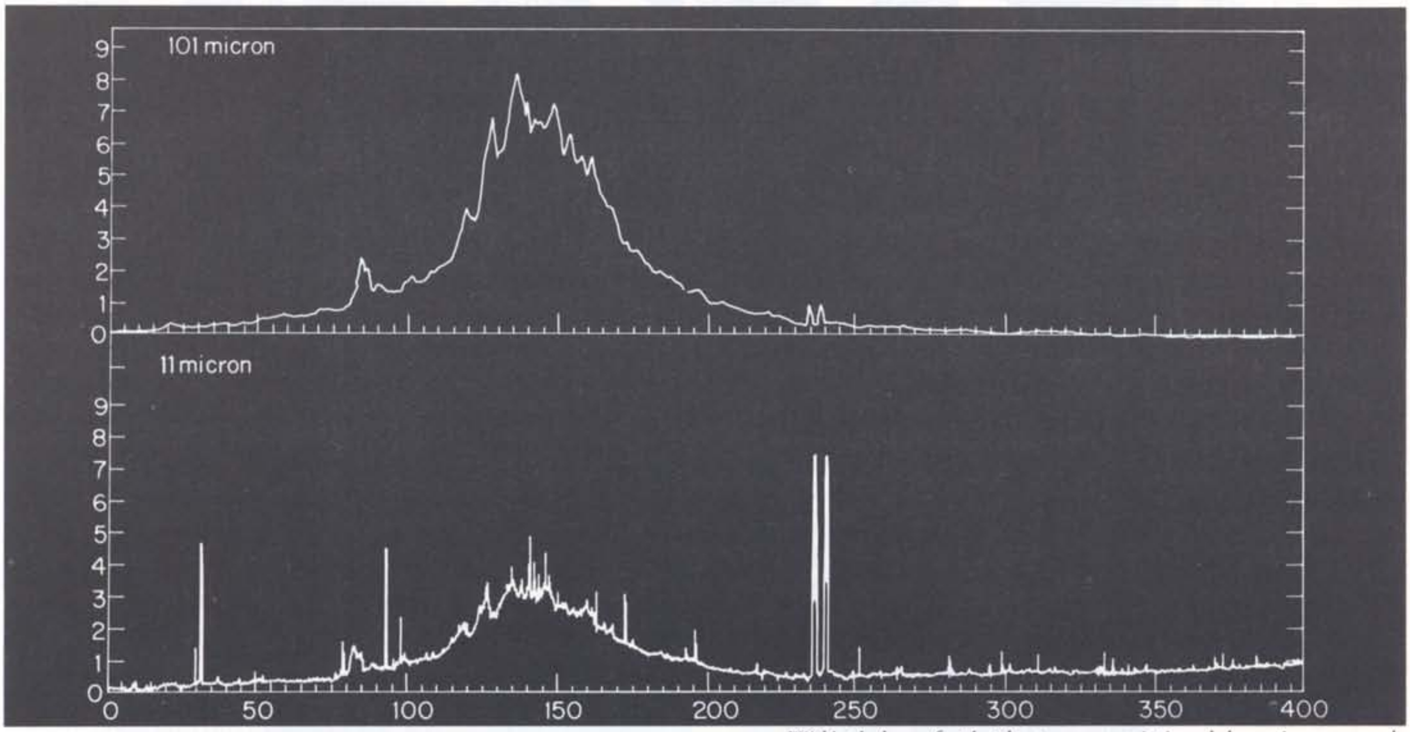

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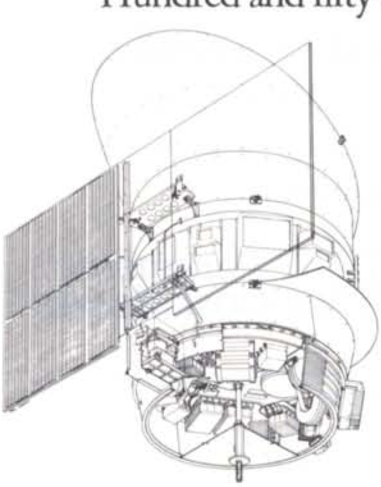

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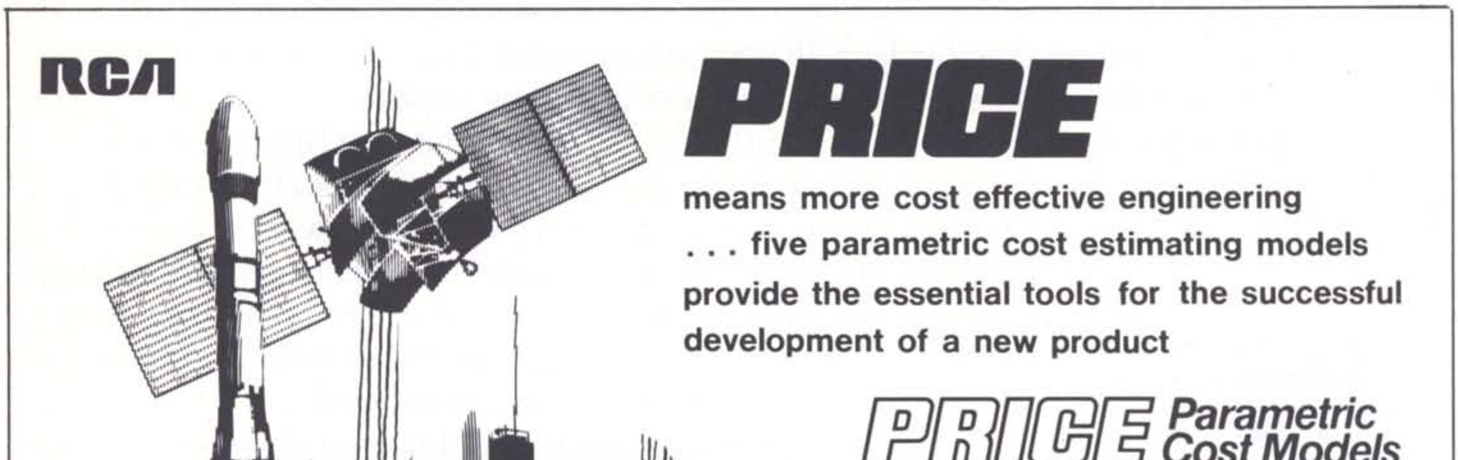
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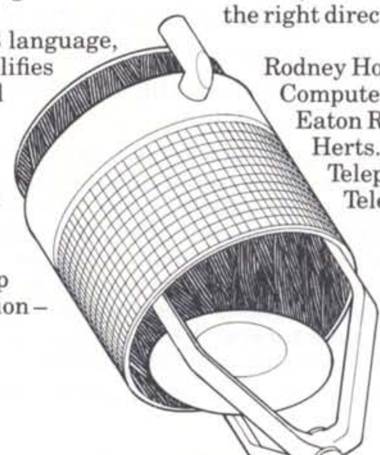

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