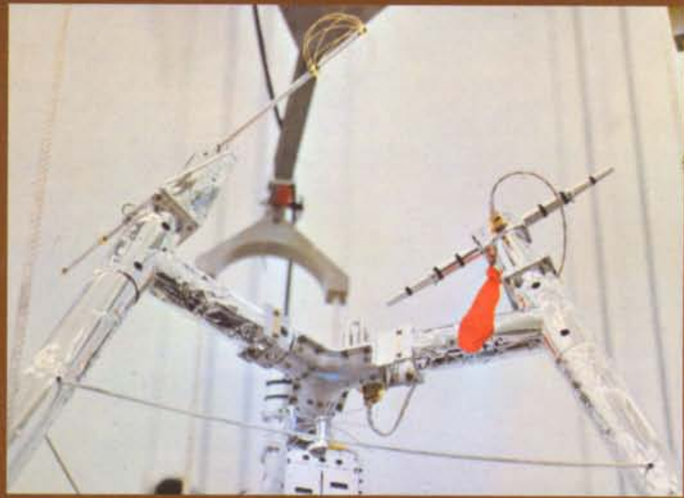
esa bulletin



International
Sun-Earth Explorer
(ISEE) Spacecraft Operational

european space agency
agence spatiale européenne

no. 12
february 1978

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

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific and Meteorological Satellite Programmes; the Director of Communication Satellite Programmes; the Director of the Spacelab Programme; the Technical Inspector; the Director of ESTEC and the Director of ESOC.

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.

THE SPACE DOCUMENTATION SERVICE (ESRIN), Frascati, Italy.

Chairman of the Council: Dr. W. Finke (Germany).

Director General: Mr. R. Gibson.

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

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

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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

Le Directoire de l'Agence est composé du Directeur général, du Directeur des Programmes futurs et des Plans, du Directeur de l'Administration, du Directeur des Programmes de satellites scientifiques et météorologique, du Directeur des Programmes de satellites de communications, du Directeur du Programme Spacelab, de l'Inspecteur technique, du Directeur de l'ESTEC et du Directeur de l'ESOC.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

LE SERVICE DE DOCUMENTATION SPATIALE (ESRIN), Frascati, Italie.

Président du Conseil: Dr. W. Finke (Allemagne).

Directeur général: M. R. Gibson.

esa bulletin

No. 12 February/Février 1978

The ESA Bulletin is published by the European Space Agency. Individual articles may be reprinted provided that the credit line reads 'Reprinted from the ESA Bulletin' plus date of issue. Signed articles reprinted must bear the author's name.

Le Bulletin ESA est une publication éditée par l'Agence Spatiale Européenne. Les articles peuvent être reproduits à condition d'être accompagnés de la mention 'Reproduit du Bulletin ESA' en précisant la date du numéro. Les articles signés ne pourront être reproduits qu'avec la signature de leur auteur.

Editorial Office/Bureau de la rédaction
ESA Scientific and Technical
Publications Branch
ESTEC, Noordwijk
Netherlands.

Editors/Rédacteurs
B. Battrick
T.D. Guyenne

Assistant Editor & Advertising/Rédacteur adjoint chargé des annonces
S. Vermeer

Circulation Office/Bureau de distribution
ESA Space Documentation Service
8-10 rue Mario Nikis
75738 Paris 15, France

Printer/Imprimeur
ESTEC Reproduction Services 773677

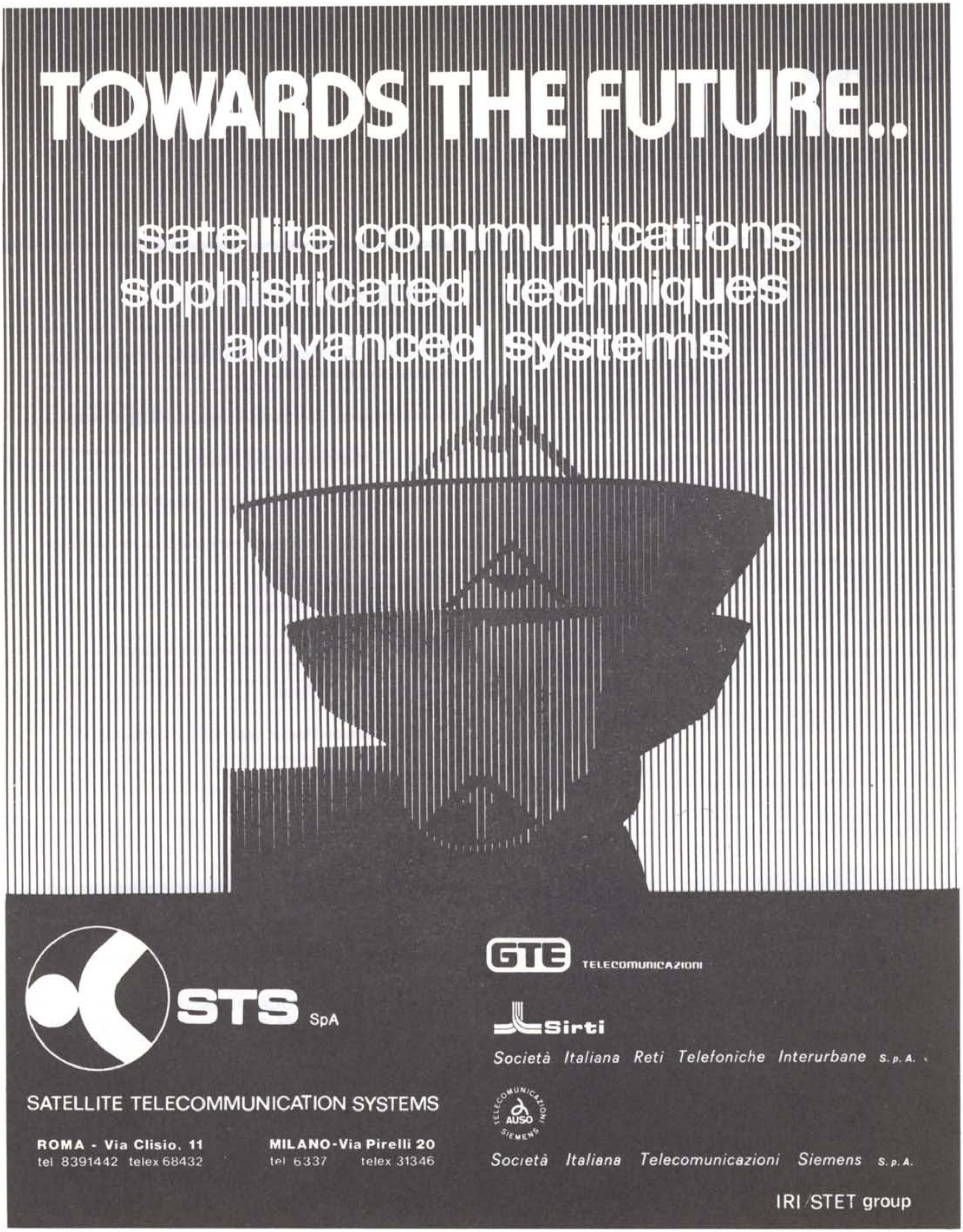
esa
european space agency
agence spatiale européenne

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

CONTENTS/SOMMAIRE

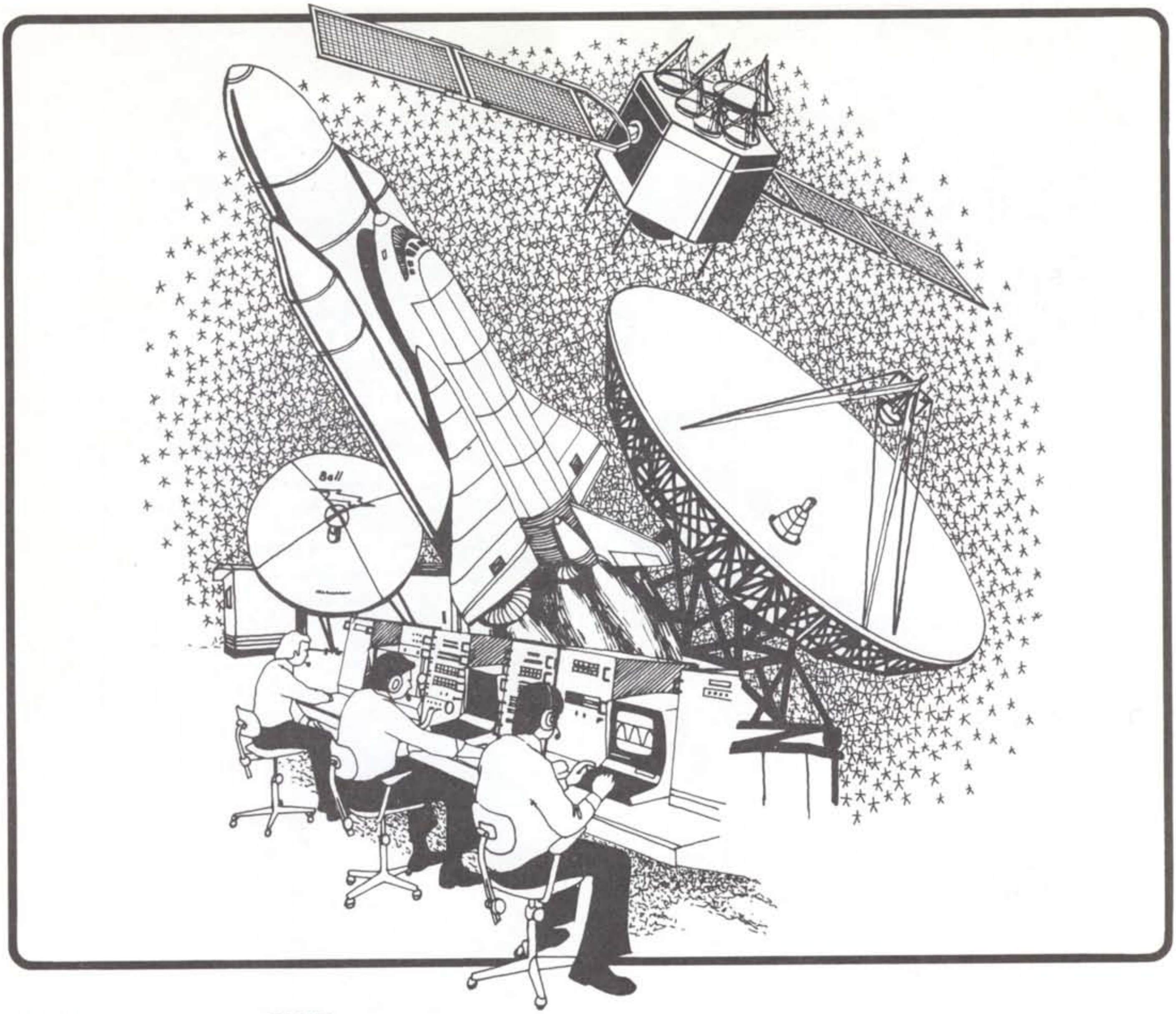
PHOTOGRAPHS/PHOTOGRAPHIES:
NASA (cover, page 8, 9, 23, 34); 'Photo SEP' (page 37); Meteosat (page 63); and ESTEC Photographic Services.

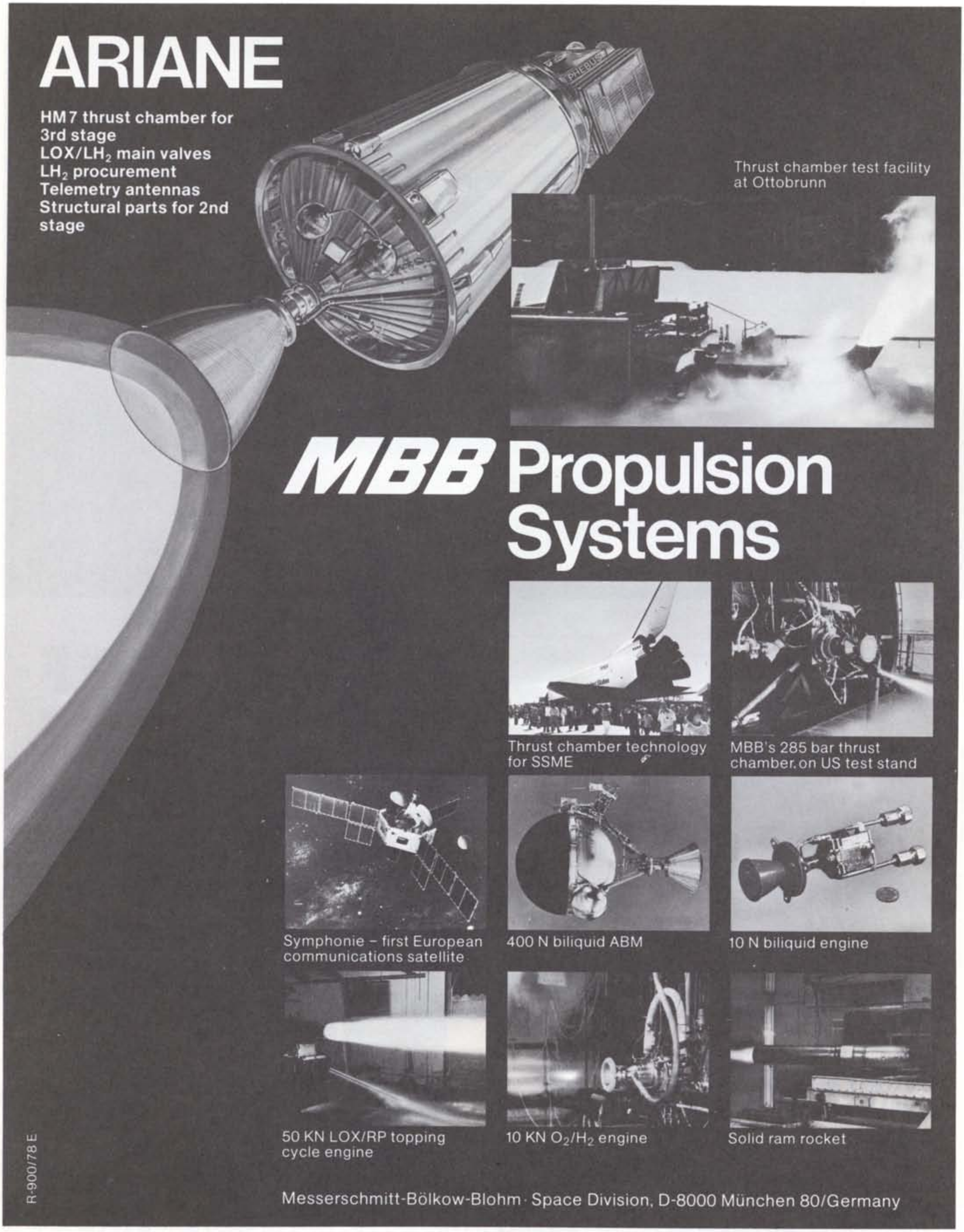
COVER/COUVERTURE:
Preparations for the launch of ISEE-A and B from Cape Canaveral
Préparatifs du lancement d'ISEE-A et B à Cap Canaveral


TOWARDS THE FUTURE..
satellite communications
sophisticated techniques
advanced systems
STS SpA
SATELLITE TELECOMMUNICATION SYSTEMS
ROMA - Via Clisio, 11
tel 8391442 telex 68432
MILANO-Via Pirelli 20
tel 6337 telex 31346
GTE TELECOMUNICAZIONI
Sirti
Società Italiana Reti Telefoniche Interurbane S.p.A.
TELECOMUNICAZIONI AUSO SIEMENS
Società Italiana Telecomunicazioni Siemens S.p.A.
IRI/STET group

Advertisers index

For all information contact:
Simon Vermeer, Advertising Manager, ESA Bulletin, c/o ESTEC, Noordwijk, the Netherlands


Bell


ARIANE
HM 7 thrust chamber for 3rd stage
LOX/LH2 main valves
LH2 procurement
Telemetry antennas
Structural parts for 2nd stage
Thrust chamber test facility at Ottobrunn
MBB Propulsion Systems
Thrust chamber technology for SSME
MBB's 285 bar thrust chamber on US test stand
Symphonie – first European communications satellite
400 N biliquid ABM
10 N biliquid engine
50 KN LOX/RP topping cycle engine
10 KN O2/H2 engine
Solid ram rocket
R-900/78 E
Messerschmitt-Bölkow-Blohm · Space Division, D-8000 München 80/Germany

International Co-operation in Major Manned Space Projects after the Shuttle

Presentation by Mr. Roy Gibson, Director General of the European Space Agency, on the Occasion of the 20th Session of the United Nations Committee on the Peaceful Uses of Outer Space, in Vienna

I am greatly honoured by the invitation to speak to you. Let me at the outset confess that I am also a little intimidated by the title of my talk; many of you might well think it would have been more appropriate for the speaker to have come from one of the two great national space agencies which have already achieved so much in manned space projects, rather than from the European Space Agency which still has to prove itself in this field. We would thereby have had an authoritative account of what is in store for us all in the coming years. I sympathise with this point of view.

My excuse for having accepted the invitation is that in the presence of this particularly distinguished international audience I want to address the subject from a different angle – to examine with you the anatomy of international co-operation in large space projects and to relate this to the sort of project we can envisage developing over the next few years.

What I am to say is directed at manned projects, but in my view the thesis is equally valid for all projects. The presence of man in the system of course introduces additional complexity, and expense to the project itself, but it does not complicate the nature of the international co-operation as our Soviet and American friends have shown with the Apollo-Soyuz link-up. There might be complications in an expensive international manned space project where only one lonely astronaut had to be chosen – but I prefer to think of this as purely academic and we need not torture ourselves with looking for a solution.

BASIC REQUIREMENTS

With that last remark I have unwittingly started to develop my theme, for fundamental to my approach to such international co-operation is that it must be based on a large measure of satisfaction of national needs, wishes and hopes. An English playwright once wrote:

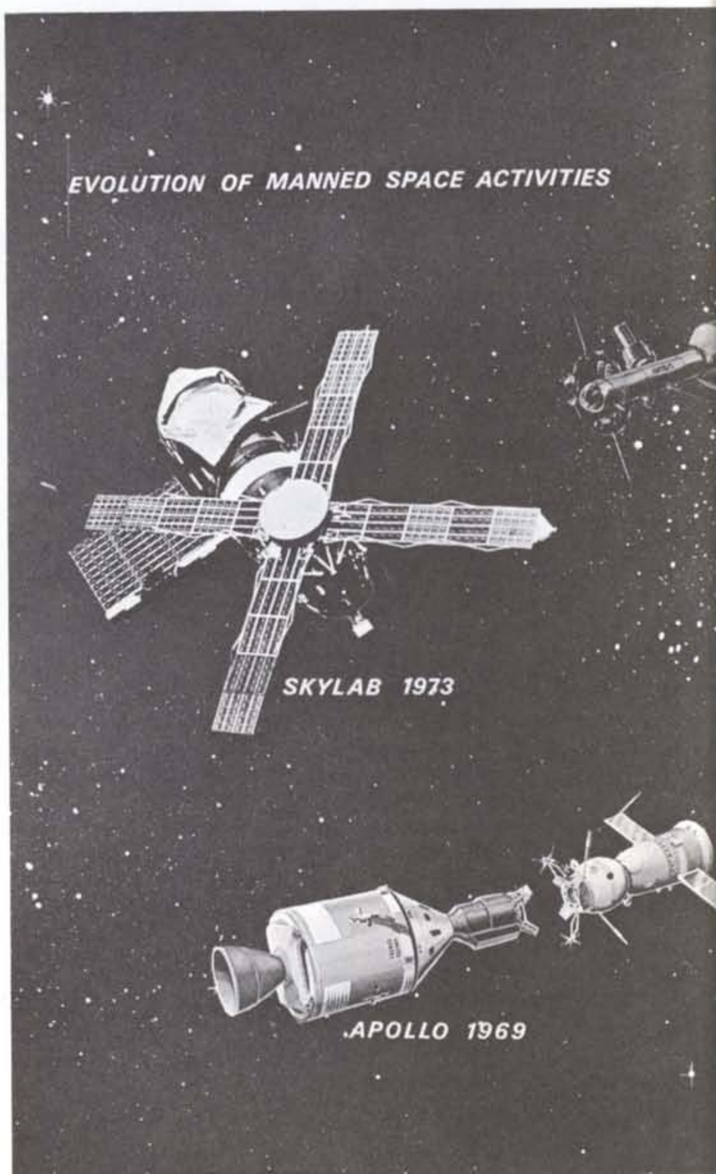
'silence is unnatural to man,
he starts life with a cry and ends it in silence'

We might, without cynicism, paraphrase this to read:

'co-operation is unnatural to man,
he starts and ends life alone'.

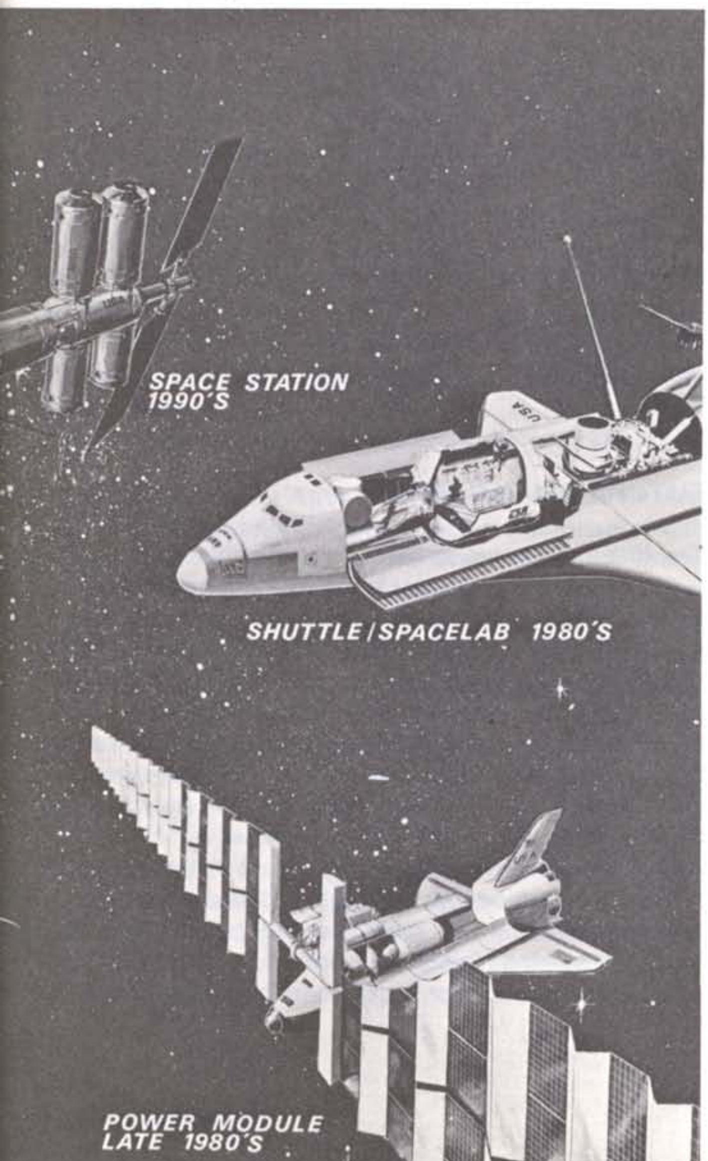
Far be it from me, however, to exaggerate the difficulties of international co-operation. I simply want to emphasise that its success depends entirely on defining a project that caters for the self-interest of all concerned sufficiently to overcome the initial inertia.

The second rule, if I may be so pretentious, is that the



interfaces between the various national contributions must be designed realistically. What may at first seem to be a disproportionate amount of effort must be spent in specifying who should do what, and how the pieces will fit together. If this is left to be done during the course of the development phase, it can only lead to friction between the partners and damage the programme. When this happens it is a victory for the ever-present isolationists.

Thirdly, and this comes naturally from a careful definition of the project, the price – literally speaking – of the international co-operation must be known to all at the start. It is virtually inevitable for a multinational project to cost more in total than one undertaken by a single nation which itself has all the necessary technology. But it is important for all concerned to know the additional price they are paying and what advantages they are getting for it.



To be complete I must add my conviction that nowadays it is unthinkable that a large space project should be wholly motivated by considerations of prestige. There must be a useful and explainable end-product. Hard-headedly, this is necessary in order to obtain the necessary finance, but one should surely add in this age of dawning realisation that man's resources are not unlimited, there is a strong moral obligation on space planners honestly to expose the direct and indirect benefits to mankind of the project they propose. I apologise in space circles for being so down to earth, but it is because I am so passionately in favour of international co-operation that I dare, so to say, look it straight between the eyes.

CURRENT SYSTEMS

Against this background, let us look at where we can go from here. My basic hypothesis is that the next international manned space project will be, and should be, developed from what is available. We cannot stop our planners from planning or our visionaries from stimulating us with the fruits of their dreaming – we certainly would not want to inhibit them. Nonetheless, in my opinion the immediate future has to make the fullest use of existing systems or those nearing completion – to exploit the experience gained from them rather than to encourage the start of an entirely new line of development. This means the Space Transportation System (STS) so far as the US is concerned, and the corresponding developments in the Soviet Union. Europe, as many of you who contribute to the budget of the European Space Agency well know, contributes a key element – Spacelab – to NASA's STS, and in so doing Europe has demonstrated (to the tune of 500 million dollars) its great interest in, and its commitment to, manned space activities. Those who are already familiar with the Spacelab project will, I hope, forgive me if I take a few minutes to describe it, for I believe it has an important part to play in future developments.

Mr. Roy Gibson, Director General of ESA.

The space laboratory consists of two parts, the pressurised module and the unpressurised pallet. The module allows scientists and technicians to work and carry out experiments in space in an earth-type shirt-sleeve environment. Various services and laboratory-type support equipment are available to enable a variety of missions to be accomplished. The unpressurised pallet can be used for carrying large items of space-proofed equipment which may be manipulated from the module or from earth. The modular design of Spacelab allows different configurations to be assembled, using a short module or a long module together with an appropriate number of pallets. This flexibility is extremely important for its use in future systems.

Besides attracting the user community of the traditional space disciplines, Spacelab provides favourable conditions for new disciplines, in particular for:

- Life Sciences, to study life processes under space conditions, and
- Material Sciences, to investigate physical and chemical processes.

The potential of those disciplines to contribute a new understanding of life processes and to produce new materials and pharmaceutical products for the benefit of mankind has already been demonstrated during previous manned space missions. The STS with Spacelab now makes this possible on a regular routine basis.

I should now like to spend a few moments looking at the utilisation of the STS and the Spacelab in the years immediately following its entry into service in 1980. This utilisation has, in effect, already been initiated. Experiments from many nations have been selected and are under development for the first Spacelab flight, which will take place in the second half of 1980. Contributions from ESA Member States comprise, inter alia, experiments to measure the composition of the earth's atmosphere, to determine solar radiation with high accuracy, to photograph the earth's surface and to remotely sense it by microwaves, to investigate the influence of space conditions on life effects and in particular on man, and to produce new materials which can only be developed in a near-gravitationless environment.

Planning and preparation of further missions is under way both in the US and in Europe. The necessary investments to support efficiently a large European user community are being made by ESA, which has established a small group, known as SPICE, for this purpose at the Federal Republic of Germany's Aerospace Centre near Cologne. We have made a number of programme suggestions to ESA Member States and they will shortly decide on the extent of their Spacelab utilisation programme over the coming years. It is evident that both through the Agency and through national programmes several hundreds of millions of dollars will be expended in the 1980's. (It should be noted here that although ESA is well on the way to completing the development of its heavy launcher – Ariane – there will certainly be ESA missions in the future which will use the Shuttle other than in the Spacelab mode).

FUTURE DEVELOPMENT

The first logical step to extend the capability of the STS will be to aim at an increase in the mission durations, which are limited to 7-30 days with the system now under development. To provide the system and its payload with the additional electrical power required for longer durations, one could equip it with solar arrays. The next step could be to leave these solar arrays in orbit, assembled together with other necessary technical support systems, to become a power module to which the Shuttle/Spacelab, Soyuz/Salyut space vehicles could dock – a sort of out-of-this-world caravan camping site. A further step in this evolution might be to leave a Spacelab, suitably modified, in orbit together with the power module, making thereby a rudimentary STS-derived space station. Further extensions could be aimed at increasing the capabilities with respect to the number of crew and the number of laboratories, and to providing facilities necessary to handle, construct and even fabricate large structures in space.

This would lead to the space-platform concept presently under study by NASA. I should like to recall here that the US/ESA Member State intergovernmental agreement which gave birth to the STS/Spacelab co-operation, makes it clear that this was not considered as a one-shot operation, but rather as a first important step in a continuing co-operation; a co-operation, I should like to add, that was never intended to be exclusive. It was therefore greatly welcomed in Europe when NASA offered to keep ESA informed of the progress of its space-platform studies and it is a pleasure for me here to pay tribute to NASA's co-operative spirit in this – and indeed other – domains.

For our part, the European Space Agency is examining what studies it could fund or undertake in-house that would be complementary to NASA's studies. It seems clear that the main thrust of our effort ought to be aimed at the extension of Spacelab to fit it as an element in the evolution of the STS programme towards permanently manned space platforms. Efficient use could thus be made of the ESA/European expertise gained through Spacelab development and costly duplications in starting new development of similar systems could be avoided.

The European Space Agency is presently systematically analysing the possible Spacelab-related hardware and technology contributions for the construction of space platforms and will recommend to its Council those which can be identified as the most suitable for exploiting the potential developed by Europe, mainly as a result of the Spacelab programme. Other non-Spacelab-related European contributions to a manned space-platform programme, which contains a large variety of different elements, may well also be in the common interest, and these are also under study.

The availability of a manned space platform opens challenging possibilities for the exploration and use of outer space for peaceful purposes. The scientific, technical and social objectives of such a programme will need to be studied carefully. In this respect, we in the space business would be wise to remember the experience gained by our Indian friends in organising their stimulating SITE programme – the satellite educational television experiment using NASA's ATS-6 satellite. They quickly found that the technical problems were much easier to overcome than the social problems, and a tremendous amount of unseen effort was devoted to the latter. A similar effort to predict and understand the impact on society of future space developments is going to be needed.

The potential evolution of the STS outlined so far may indeed be already realised in the 1980's. How manned space activities will develop beyond that period can only be the subject for speculation; ingenious – and convincing – ideas are not lacking. It seems to me certain, however, that for some decades to come there will be a concentrated effort to contribute to the solutions of two of mankind's major problems, namely the protection and control of the environment, and the development of energy sources. By measuring, observing and continuously monitoring the earth and its environment and by applying new methods and higher accuracy, favourable conditions may be provided for the control of environmental parameters and the conservation of earth resources. The possibility to construct and assemble large structures in space may also be a key for harnessing solar power as a contribution to the solution of the energy shortage. I predict a swing towards consolidation and exploitation of existing development.

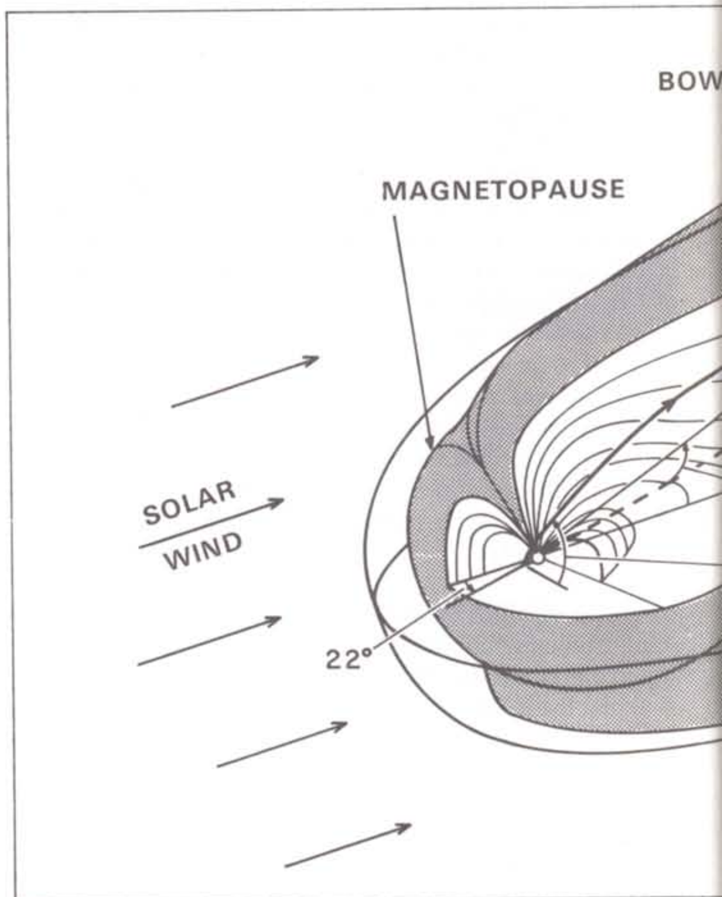
CONCLUSION

Returning, by way of conclusion, to the immediate future, we must see in the recent agreement between the USSR Academy of Sciences and NASA on co-operation in the area of manned space flight, an encouraging step towards an international space platform with a multilateral participation. We in Europe noted with satisfaction that the agreement specifically leaves the door open to multilateral co-operation, and my Agency looks forward with real pleasure to making its contribution. Multinational co-operation in large space programmes is certainly not easy, but this is surely the way in which history – thank God – is pushing us. May we all live to see its fruits! □

The International Sun-Earth Explorer (ISEE) Mission

A.C. Durney, Space Science Department of ESA, ESTEC, Noordwijk, The Netherlands

This large project has been mounted with the intention of solving many of the scientific mysteries that still remain in the near-earth space environment or 'magnetosphere'. The approximate positions of the magnetosphere's main features are known, but their natures are not necessarily understood (Fig. 1). The ISEE project has the novel ability to identify and to measure the speed of movement of these various features, and by so doing will be the first mission able to watch in detail how the magnetosphere reacts to solar changes.



WHY STUDY THE MAGNETOSPHERE?

The reasons for the study are many. We want to establish the exact interactions between particles and electric and magnetic waves in space, under conditions that cannot be reproduced in a laboratory. We want to know how auroral particles are accelerated, as this is a persistent mystery. We want to discover why about 10% of all solar particles manage to leak through the magnetospheric boundary – the magnetopause – that separates the earth's magnetic field from that of interplanetary space. We want to understand the complicated processes that occur in the magnetospheric 'tail', which extends for thousands of kilometres behind the earth (on the side away from the sun) like a comet's tail, the mechanisms that are at work in the space between the bow shock and the magnetopause, and many other interesting effects that relate to the magnetosphere. We also need to understand the magnetosphere as a whole because it is not unique; Jupiter and Mercury have magnetospheres too, and some exotic astrophysical objects (pulsars) may also possess them. Greater knowledge of our own magnetosphere will undoubtedly help us to understand these others more readily.

The magnetosphere is also important for life on earth, for it protects us from harmful radiation from interplanetary space. The ozone in the upper atmosphere, for example, shields the earth from extreme ultraviolet and x-rays, and there is already concern about how man's activities may affect that ozone content and hence life as we know it. Similarly, man's activities can be detected far out into space. Long power lines carrying megawatts of electricity produce waves that can be measured well out into the magnetosphere. It is known that magnetospheric storms can cause damage to power lines; could there be an equivalent effect in the opposite direction? Atomic bombs exploded at high altitudes have filled the inside of the magnetosphere with radiation that has stayed there for many years, another way of polluting the earth's environment. Recently, evidence has been mounting that short-term (days) disturbances on the sun affect our weather. Since these disturbances also cause large perturbations in the magnetosphere, there may well be a link between magnetospheric processes and the weather. The energy involved in such processes is much smaller than that

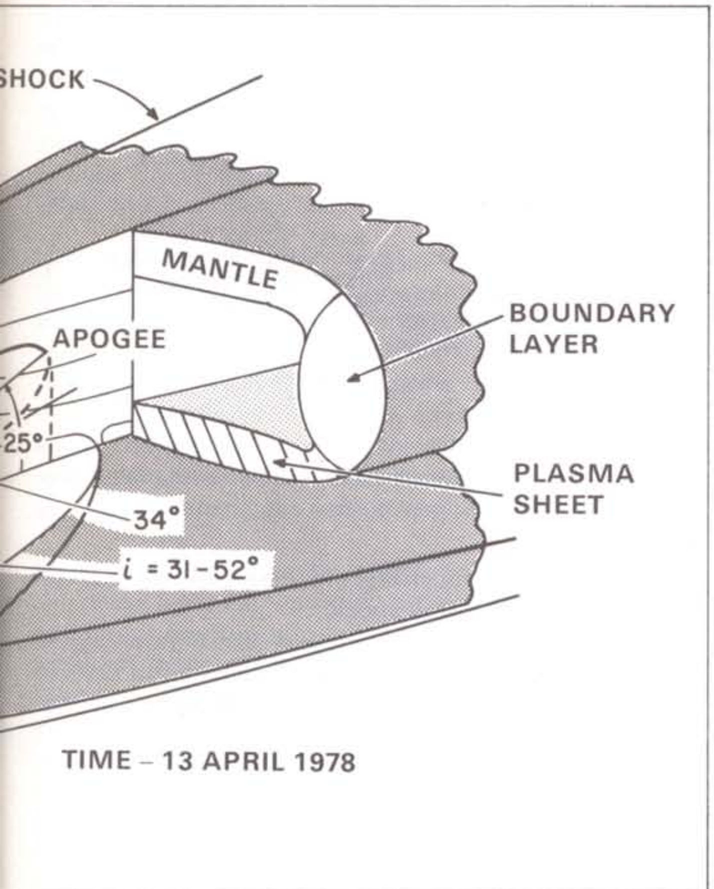


Figure 1 – Three-dimensional schematic of the earth's magnetosphere, showing the main features and the orbit of ISEE-A and B as it will be on 13 April 1978. The main features are places where there is a sharp boundary between different types of magnetic fields and/or particles. The most important of these are the 'magnetopause', which is the boundary between the interplanetary magnetic field and that of the earth, and the 'bow-shock', which is where the solar-wind particles (coming from the sun) first start to change direction because of the presence of the magnetosphere.

TABLE 1
ISEE Spacecraft Parameters

	A	B	C
Structure	Modified IMP	New	Modified IMP
Spin rate, rpm	19.7	19.8	19.75
Mass, kg	340	157	469
Payload mass, kg	89.0	27.7	97 (incl. ant.)
Payload power, W	76	27	57
No. of experiments	13	8	12
Data rate, bps:			
high	16 384	8 192	2 048
low	4 096	2 048	1 024, 512, 64
Spin-axis alignment	Perpendicular to the ecliptic plane		

contained in the weather system, so that any link would have to be a delicate trigger effect.

To be able to assess the role of such effects in space, we need more exact measurements of the structure and movement of the magnetosphere than we have at present, and the ISEE mission should be able to provide these.

THE SPACECRAFT

The ISEE mission relies on three spacecraft, each of which has been designed for a three-year lifetime (Table 1). It is a joint project with NASA, which is responsible for the ISEE-A and ISEE-C spacecraft. ISEE-B has been supplied by ESA and is a new design, purpose-built for the mission.

ISEE-A and ISEE-B, which circulate in the magnetosphere to measure its perturbations, were launched as a stacked pair on a single Thor-Delta 2914, at 13.53 GMT on 22 October 1977, into the same highly elliptic orbit, with an apogee of 22.64 earth radii (138 000 km altitude) and a perigee of 287 km. The third spacecraft, ISEE-C, will be launched on 24 July 1978 and will be placed at a point 235 earth radii (1 500 000 km) from earth, on the line between the earth and the sun, where the gravitational forces of the two and centrifugal force balance. This point of equilibrium, called a libration or Lagrangian point, is shown in Figure 2. In this position, ISEE-C will be able to observe solar particles that 'boil' off from the sun as they stream past in the so-called 'solar wind' to impinge later on the magnetosphere. It is thought that variations in this wind give rise to many of the disturbances that occur in the magnetosphere. ISEE-C will detect the 'input conditions' for the disturbances to be monitored and measured by ISEE-A and ISEE-B.

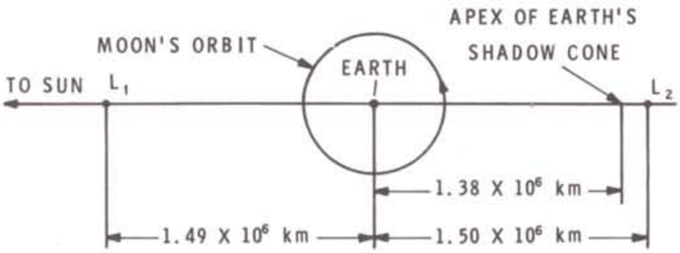


Figure 2 – Schematic of the libration points that lie near the earth on the earth-sun line. ISEE-C will be placed at L_1.

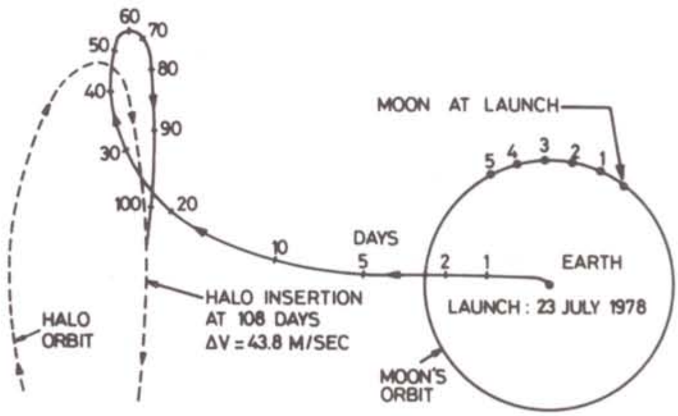


Figure 3 – The transfer orbit that will be used for injecting ISEE-C into its halo orbit.

SPATIAL AND TEMPORAL AMBIGUITIES

The near-earth environment is not static: almost all of the features that can be observed are constantly moving, swirling, contracting and expanding at speeds that often far exceed those of the spacecraft. Because of these movements, when a single spacecraft measures some change it is difficult to decide whether it was a real change in local conditions or was caused by a feature sweeping past. In addition, when a moving phenomenon is observed, its speed, and in many cases its direction of motion, cannot be ascertained.

This problem has beset single-spacecraft measurements since the first scientific satellite was launched and it is one of the main reasons why very many magnetospheric phenomena are still unexplained. Features are known to exist, but their nature is not understood. By following each other around the same orbit a known and controllable distance apart, ISEE-A and B will be able to determine whether a feature is static or in motion (and with what velocity). For the first time, it will be possible to separate and measure spatial and temporal variations in an organised manner, a manner that is expected to lead to the detailed understanding of the earth's environment that we lack at present.

SCIENCE AND THE ORBIT

The scientific aims of the ISEE mission shaped the orbit for the A and B spacecraft through three main demands:

1. The spacecraft must make a maximum number of crossings of the bow shock.
2. The axis of the orbit should allow bow-shock crossings to be made early in the mission to reduce the amount of bow-shock information lost in the event of early failure of a unit.
3. Crossings of the plasma sheet must be made.

To these scientific criteria were added a number of technical constraints:

4. The orbit must be stable enough to sustain a three-year lifetime.
5. The maximum eclipse time must be less than 6 h to prevent the spacecraft becoming too cold when not sunlit (during 'eclipses' when passing through the earth's shadow).
6. The solar aspect angle at injection should be between 70° and 160° to prevent the sun from overheating the spacecraft during launch.

The number of bow-shock crossings depends on the height of apogee. With a higher apogee, the orbit will intersect the bow shock for a longer period each year, tending to increase the number of crossings. But a higher apogee also means that the time the spacecraft takes to travel around the orbit will also increase, thus tending to reduce the number of crossings. The combination of these two effects creates a slow variation in the number of bow-shock crossings with apogee height, with a maximum for an altitude of 23 earth radii (140 000 km altitude). This was the figure chosen by the investigators to satisfy condition 1. Combining it with the total mass of the two spacecraft and the performance of the launcher gave a perigee of 280 m, which was just acceptable (a lower perigee would make the orbit susceptible to air drag in the atmosphere, probably resulting in early re-entry).

Given this shape of orbit, it was difficult to find a launch time that would satisfy scientific conditions 2 and 3 whilst still giving the spacecraft a three-year lifetime and an eclipse time of less than 6 h. The calculation of these launch 'windows' is a highly complex business, involving many orbital parameters such as air drag, the fact that the earth is not exactly spherical, the gravitational pull of the moon, the pressure of solar radiation on the spacecraft (an appreciable effect), the earth's magnetic field, and so on.

Many hours of computer calculation were needed to determine a launch window that met all the conditions and it was eventually found that a stable orbit could be achieved if the spacecraft were launched on any day between 13 October and 5 November within a few minutes of 14.00 h GMT. Unfortunately, stability also demanded that the angle between the orbital plane and the earth's equatorial plane be increased on each successive day which meant that for a launch on or after 28 October the fixed directional antenna on ISEE-B would no longer point towards the earth and telemetry signals would not be received satisfactorily from high altitudes. The two spacecraft were, in fact, ready for launch on 13 October, but some problems with the launch vehicle delayed lift-off until 22 October, only five days before the closing of the window.

ISEE-C falls into a different orbital category, the scientific requirements here being:

1. that it should be positioned between the sun and earth where it can observe the passing solar-wind conditions that subsequently affect the magnetosphere, and
2. that it must be far enough away from the earth not to observe waves and/or particles generated by or reflected from the magnetosphere.

The chief problem in satisfying these demands was that

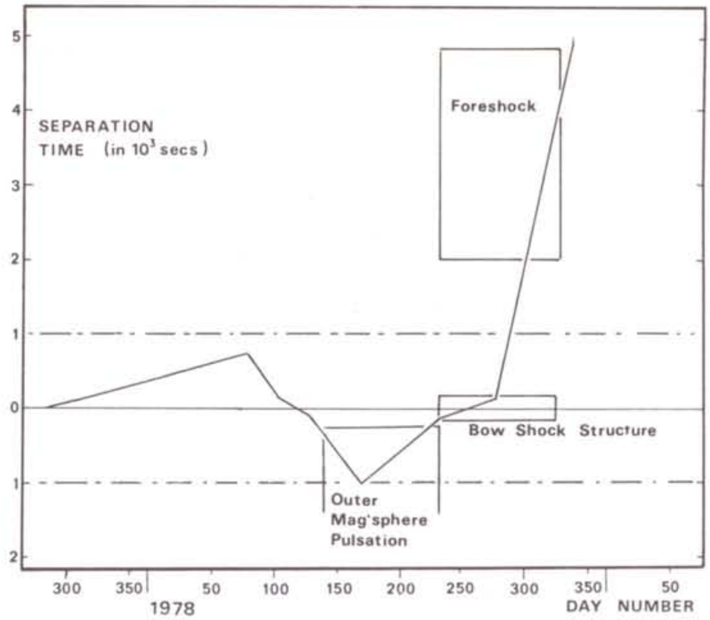


Figure 4 – The separation strategy adopted by the ISEE Science Working Team for the period up to the end of 1978. Separation time is used because it is more constant around an orbit than distance, which varies very considerably. Some areas are shown where significant measurements will be made.

the spacecraft would have needed a prohibitively heavy propulsion system to keep it on station, had not the clever solution of placing it at the Lagrangian point been adopted. As mentioned earlier, this point where the various interplanetary forces balance lies on the earth-sun line and is sufficiently far from the earth to satisfy condition (2). Although the equilibrium at this point is unstable, the amount of propulsion necessary to keep ISEE-C there is relatively small.

The second problem for ISEE-C was that the sun is an intense radio source and if the spacecraft were placed directly in front of it at the exact Lagrangian point the telemetry signals would be swamped. This difficulty has been overcome by making the spacecraft gyrate around the sun (as seen from the earth) in a so-called 'halo' orbit, the plane of which is to be adjusted from time to time to keep it normal to the earth-sun line.

ISEE-C will be launched as soon after ISEE-A and B as possible, namely in July 1978. The position of the moon is important for this launch as its attitude as seen from the spacecraft will be used to assess the trajectory correction that will probably be necessary as the spacecraft approaches the Lagrangian point. Figure 3 shows how ISEE-C will be put into its halo orbit, the launch window being 2 days per lunar month.

TABLE 2

The ISEE-A and ISEE-B Experiments

Instrument Title	Principal Investigator
Electrons and protons (A and B) Protons, 5 eV to 40 keV; electrons, 5 eV to 20 keV (high time resolution)	K.A. Anderson
Low-energy protons and electrons (A and B) 1 eV to 50 keV in 63 bands with 16% resolution and large solid angle	L.A. Frank
Plasma waves (A and B) Magnetic field: 10 Hz to 100 kHz (three axes, 16 channels; one axis only on B) Electric field: 10 Hz to 10 kHz (three axes, 12 channels). Sweep frequency spectrum analysis of electric field signals: 10 kHz to 200 kHz (128 steps)	D.A. Gurnett
Flux-gate magnetometer (A and B) $\pm 256\,\gamma$, ± 8192 (command); frequency response, 0–10 Hz	C.T. Russell
Fast plasma (A) Protons: 5 eV to 40 keV; electrons: 5 eV to 20 keV (high time resolution)	S.J. Bame
Plasma density (A) Resonance experiment on A, 0 to 350 kHz. Phase-related waves at 683 kHz and 272.5 MHz	C.C. Harvey
Very-low-frequency wave propagation (A) Reception from Siple transmitter	R.A. Helliwell
Direct-current electric field (A), 0.1 to 3200 Hz, nine steps	J.P. Heppner
Low-energy cosmic rays (A) Solar-wind iron: suprathermal, multiply charged ions ($Z \leq Q \leq 26$): 5 to 50 keV/nucleon; 0.05 to 20 MeV/nucleon; 0.05 to 6 MeV/nucleon; 5 keV/Q to 20 MeV/nucleon	D. Hovestadt
Energetic electrons (A) Protons, 25 keV to 2 MeV (8 channels); electrons, 25 keV to 1 MeV (8 channels) (B) Protons, 25 keV to 2 MeV (4 and 16 channels); electrons, 25 keV to 2 MeV (4 and 16 channels) Time-of-flight composition and angular scanning on A	D.J. Williams
Quasi-static electric fields (A), 0 to 5 mV/m; 0 to 12 Hz	F.S. Mozer
Fast electrons (A) 7 to 500 eV; 10 to 2000 eV; 105 to 7050 eV 7% FWHM resolution; 0.5 s time resolution	K.W. Ogilvie
Ion composition (A) 0 to 40 keV/Q; 1 to 138 atomic mass units and plasma density	R.D. Sharp
Solar-wind ion measurements (B) Ions, 50 eV/Q to 25 keV/Q; electrons, 35 eV to 7 keV	G. Moreno
Fast plasma (B) Ions, 50 eV to 40 keV; electrons, 5 eV to 20 keV	G. Paschmann

SEPARATION STRATEGY

The separation between ISEE-A and B can be varied from 50 to 5000 km to make it appropriate to the scale of the feature being studied. A gas (freon 14) propulsion system on ISEE-B is used for this purpose, because ISEE-B has lower inertias and is more nimble than ISEE-A. In practice, ISEE-B is given a 'kick' so that it drifts away from or towards the other spacecraft. The 'kick' takes the form of a series of small gas impulses synchronised with spacecraft rotation. The size of the 'kick', and thus the drift rate, can be adjusted by varying the number of impulses, which are given at perigee to maximise their effect and conserve gas. As the spacecraft is travelling too fast at perigee to receive commands, the number of impulses to be given must be loaded into a memory higher up in the orbit.

The separation strategy selected by the investigators for the first part of the mission (Fig. 4) is very cautious and intended to explore the capabilities of the system while still giving good science. It will be reviewed in mid-1978, when a bolder 12 month plan will be adopted based on the experience of the early months. Two recalibration periods are planned, next April/May and next August, when the A and B spacecraft will approach and pass each other. The second recalibration period is timed to coincide with the arrival of ISEE-C on station, so that correspondence between the instruments on all three spacecraft can be checked.

THE PAYLOAD

More than 100 investigators from 33 different institutes are involved in this heavily instrumented mission. Most of the magnetospheric scientific community are represented and the investigator list contains many well-respected names. After the initial choice of instruments, the

TABLE 3

The ISEE-C Experiments

Instrument Title	Principal Investigator
X-rays and electrons x-rays, 8 to 72 keV; electrons, 2 to 1000 keV	K.A. Anderson
Solar-wind plasma Ions, 150 eV to 7 keV, 4.2% FWHM; electrons, 5 eV to 2.5 keV, 10% FWHM Three-dimensional distribution function	S.J. Bame
High-energy cosmic rays Species H through Fe (resolution, 0.15 atomic mass unit, $1<Z<26$)	H.H. Heckman
Low-energy cosmic rays Particle composition; up to 20 MeV/nucleon	D. Hovestadt
Energetic protons Protons, 30 keV to 1.4 MeV; alpha-particles, 1.4 to 6 MeV	R.J. Hynds
Cosmic-ray electrons and nuclei Electrons, 5 to 400 MeV (DES); protons, 36 to 13 000 MeV (DES); 13 GeV (IES) Elements separated: helium-sulphur, 60 to 13 000 MeV/nucleon (DES); >13 GeV/nucleon (IES)	P. Meyer
Plasma composition 470 eV/Q to 10.5 keV/Q: M/Q 1.4 to 6.5; 3% FWHM resolution	K.W. Ogilvie
Plasma waves Magnetic field: 8 channels, 60-dB range, 20 Hz to 1 kHz Electric field: 16 channels, 80-dB range, 20 Hz to 100 kHz (continuous, no switching)	F.L. Scarf
Radio mapping Three-dimensional tracing of paths of type III bursts in band from 20 kHz to 3 MHz	J.L. Steinberg
Helium vector magnetometer Eight ranges (± 4, ± 14, ± 42, ± 640, ± 4000, $\pm 22\,000$, and $\pm 140\,000\,\gamma$); Frequency response 0 to 3 Hz with three bands (0.1 to 1, 1 to 3, and 3 to 10 Hz) for measurements of fluctuations parallel to the spacecraft spin axis	E.J. Smith
High-energy cosmic rays Ranges: $Z=3$ to 28 (Li to Ni); $A=6$ to 64 (^{6}Li to ^{64}Ni); energy=2 to 200 MeV/nucleon Mass resolution: Li, 0.065 to 0.83 proton masses; Fe, 0.18 to 0.22 proton masses	E.C. Stone
Medium-energy cosmic rays Nuclei, $Z=1$, 0.5 to 4 MeV/nucleon (SPA) and 4 to 500 MeV/nucleon (MPA); $2\leqslant Z\leqslant 26$, 0.5 to 500 MeV/nucleon (MPA) Electrons, 0.7 to 0.2 and 0.3 to 12 MeV Isotopes, $Z=1$ and 2, 4 to 80 MeV/nucleon; $3\leqslant Z\leqslant 7$, 8 to 120 MeV/nucleon; $8\leqslant Z\leqslant 16$, 10 to 200 MeV/nucleon	T. von Rosenvinge
Ground-based solar studies Solar spectral observations	J.W. Wilcox

investigators of the chosen experiments were formed into a Scientific Working Team, with a mandate to make the mission cohesive, to fill any gaps, and generally to 'round off the corners' (Tables 2 & 3). The instruments have cost an average of 1 million dollars each, which gives a measure of their sophistication and complexity.

In order to use spacecraft separation to differentiate effectively between movements and intensity changes, the ISEE-A and B payloads have been carefully matched. ISEE-A carries 13 instruments, eight of which are similar or complementary to the eight carried on the smaller B spacecraft; some are identical.

The instruments on A and B can be divided roughly into three groups. First, there are those intended to measure both static and fluctuating electric and magnetic fields. The measurement of electric fields is a relatively new and important development in spacecraft technology, while magnetic-field measurements are important as a reference for all other observations since the various parts of the magnetosphere can be recognised by their magnetic signatures.

The second group of instruments measures particles. Such instruments are quite commonplace on satellites, but they do not generally form such a close-knit group as those on ISEE. Proton and electron measurements start at energies of 1 eV and extend all the way up to 2 000 000 eV for protons and 250 000 eV for electrons. Two different techniques are necessary to cover this wide range, and so two instruments measure the low energies and two the high energies. One pair of instruments concentrates on measuring the distribution of energies accurately, the other on measuring intensity changes with time. In addition, one instrument on each spacecraft is specially designed to make comprehensive measurements of solar-wind particles.

The third group are active instruments which transmit radio waves. Their purpose is to measure electron densities around the spacecraft. This is the only investigation in which there is contact between the two spacecraft in space, all other measurements being transmitted to the ground separately from each platform. Operation of these active experiments has to be time-shared with the field experiments, which are completely saturated during active transmissions. ISEE-A, being larger, contains more instruments than ISEE-B and the extra instruments have been chosen so that together they can measure very accurately the effect that magnetic and electric waves have on particle movements, and vice-versa. Finally, ISEE-A carries an instrument which will measure the energies and intensities of very high-energy ions (cosmic rays) for special comparison with some investigations on ISEE-C.

ISEE-C carries a similar package of wave and particle experiments for its measurements of the solar wind. It also carries a group of newly developed, highly sophisticated instruments which will make the first measurements of all the separate high-energy isotopes up to iron produced by the sun and other stars. These are important measurements in their own right.

ANALYSIS OF THE DATA

The purpose of any spacecraft is to gather data and their analysis forms the most important part of any mission. For ISEE, the crucial factor for mission success is inter-comparison of the data after or even before it has been digested by the separate experiment groups. Special 'pool' tapes carrying compressed results from most of the mission's experiments will be produced for ISEE-A/B and C and distributed to each investigator. They will form an index to which an investigator can refer when searching for interesting events to correlate with his own data. He can subsequently contact the appropriate principal investigator for accurate, high-resolution data.

In addition to comparison and correlation of data inside the Project, ISEE results must be compared with outside observations. This is especially important at present with the intensive collaboration between ground-based, balloon, rocket and satellite investigators in the programme

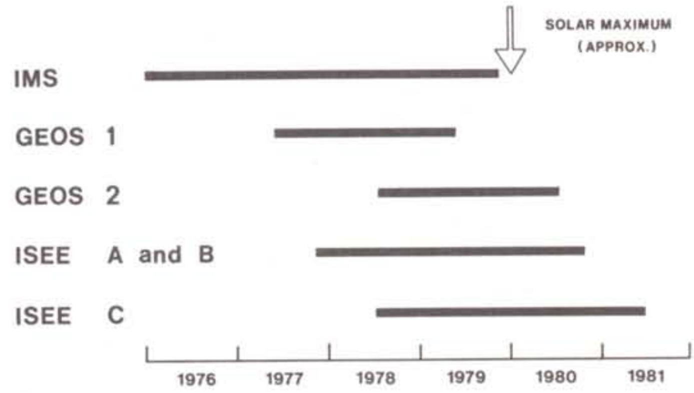


Figure 5 – Lifetime of the ISEE spacecraft in relation to those of the two Geos platforms and the duration of the International Magnetospheric Study.

that constitutes the 'International Magnetospheric Study' (IMS). ISEE-B and Geos, the time scales of which are shown in Figure 5 in relation to the duration of the IMS, form the major part of Europe's contribution to this Study.

The ISEE data pool tapes will be made available to any member of the IMS programme. Aside from this, a programme of ISEE workshops is being set up which will include collaborative meetings with Geos investigators and other members of the IMS. These could prove especially fruitful as Geos carries a similar experiment payload to ISEE-A and B and some investigators have instruments on both missions.

OPERATION OF THE SPACECRAFT IN ORBIT

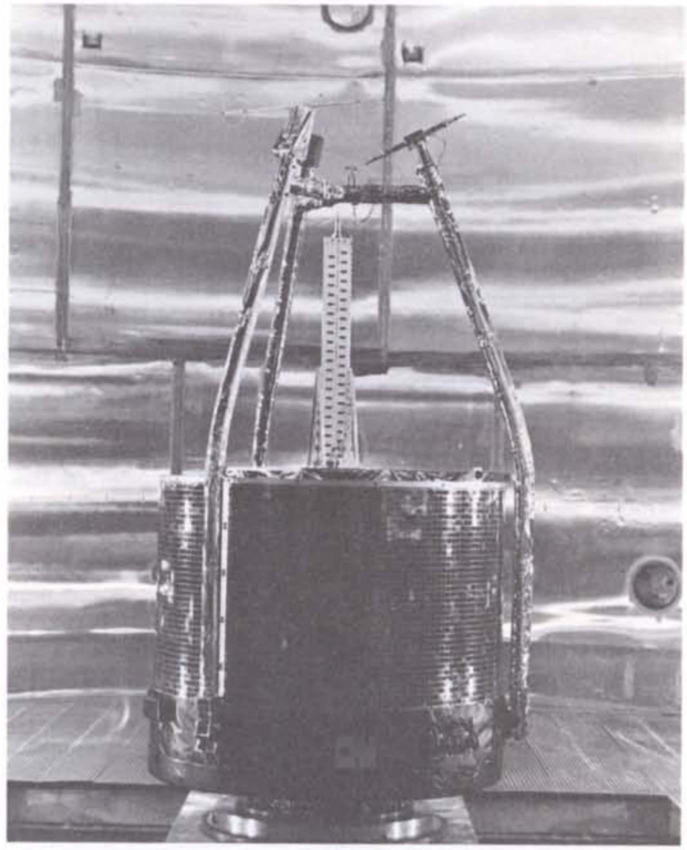
At the time of writing, the switch-on of the spacecraft has barely been completed and no significant scientific data are available. Nevertheless, electric-wave movements have already been identified, ion-cyclotron resonances have been observed in unexpected places, and the magnetosphere has been found to be in a very compressed stage. There is general satisfaction with the data and excitement about the prospects. All experiments on ISEE-B are working well, and everything seems set for a highly exciting and successful mission. □

ISEE B – A Minimum-Model Project

D. Eaton, ISEE-B Project Manager, ESA

Space is an area in which the cost of failure is extremely high, whether it is measured in financial, temporal or scientific terms. Accordingly, the traditional approach to satellite design and development has always tended to be extremely conservative, utilising full redundancy of units within the spacecraft and a multiplicity of specialised development models, each undergoing specific tests, in order to ensure that when launched the satellite would have the maximum probability of success.

In recent years, however, there has been a measure of rethinking of the basic philosophy. This has been occasioned partly by the need for financial economy in individual space projects but also, and predominantly, because of the improvements in European design and development techniques in spacecraft subsystems and systems over the years. Accordingly, it was decided for the International Sun-Earth Explorer (ISEE) project to try out a technique by which a reduced number of subsystem assemblies would be manufactured and maximum use made of each satellite model.



THE ISEE PROJECT

ISEE has been a co-operative project with NASA, the first of its kind, in which three satellites (A, B and C) take part. A and B, the former a NASA and the latter an ESA satellite, have been placed in a highly elliptical orbit, whilst ISEE-C, also from NASA, will be launched into a heliocentric orbit in July 1978. The scientific mission of ISEE is described in the preceding article.

For both NASA and ESA, ISEE had to be a low-cost, time-constrained programme and the Goddard Space Flight Center team selected to carry out the NASA responsibilities had much experience in minimum-model work, having worked on the IMP series of satellites. ISEE therefore became an obvious choice for trying out this approach.

THE 'GOOD ENOUGH' PHILOSOPHY

Before discussing the model philosophy per se, another very important element of the ISEE low-cost approach should be pointed out. This was to take, so far as possible, elements created for other projects and to use them with minimum modification. This frequently meant that the unit was not ideally matched to ISEE requirements or that the technology employed was not the latest available. However, provided that the performance was adequate for ISEE, it was considered that these restrictions were amply compensated for by the lack of new development needed and the existence of already qualified units. This was an extremely important factor in the minimum-model programme.

TABLE 1

Conventional versus ISEE Model Approach

	MODELS	SUBSYSTEMS/EXPERIMENTS
CONVENTIONAL	THERMAL } VIBRATION }	THERMAL/MASS DUMMIES
	ENGINEERING	FUNCTIONAL NONFLIGHT UNITS
	PROTOTYPE	QUALIFICATION UNITS
	FLIGHT SATELLITE	FLIGHT UNITS
		FLIGHT SPARES
ISEE-B	STRUCTURAL/INTEGRATION	{ MASS DUMMIES FUNCTIONAL/QUALIFICATION/FLIGHT SPARES
	FLIGHT SATELLITE	FLIGHT UNITS

THE ISEE MODEL PHILOSOPHY

The differences between the ISEE model philosophy and that used hitherto in ESA can best be appreciated by examination of Table 1, which compares the standard approach with that employed for ISEE. It can be seen that there is a substantial reduction in the number of models compared with the more conventional programme.

In the traditional approach, a simplified model of the satellite is made which exhibits the correct thermal properties and contains dummy units of the correct mass which generate the same quantity of heat as the real units will do in orbit. This assembly is tested in a thermal vacuum chamber to complete the design of the thermal subsystem and to predict the in-orbit temperatures of various parts of the satellite. The thermal model can also act on occasion as the vibration model of the spacecraft to prove satellite strength and stiffness, although a new model using the same thermal/mass dummies has frequently been manufactured. The final development satellite would be an engineering model into which integrated functionally operative units of nonflight quality have been integrated, and this can be used to prove compatibilities, electromagnetic cleanliness, and system-level operation. This is also the model upon which the checkout and operational software would be developed.

Following the conclusion of the development phase, a prototype spacecraft of flight quality hardware would be integrated and used for qualification testing of the complete system in terms of vibration, thermal vacuum, and functional performance. Then the flight-unit spacecraft would also be built, integrated and, following more limited testing, launched. Usually a number of dedicated flight-spare subsystems would also be manufactured,

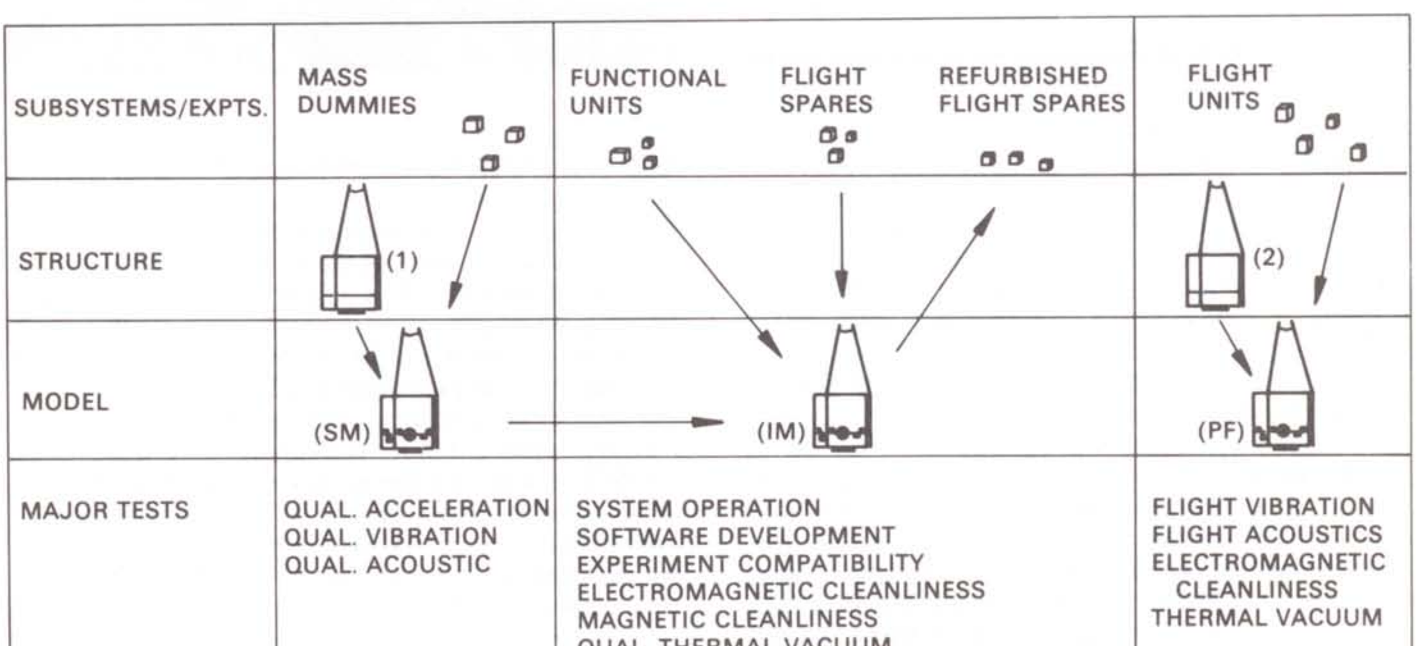


Figure 1 – ISEE-B model utilisation.

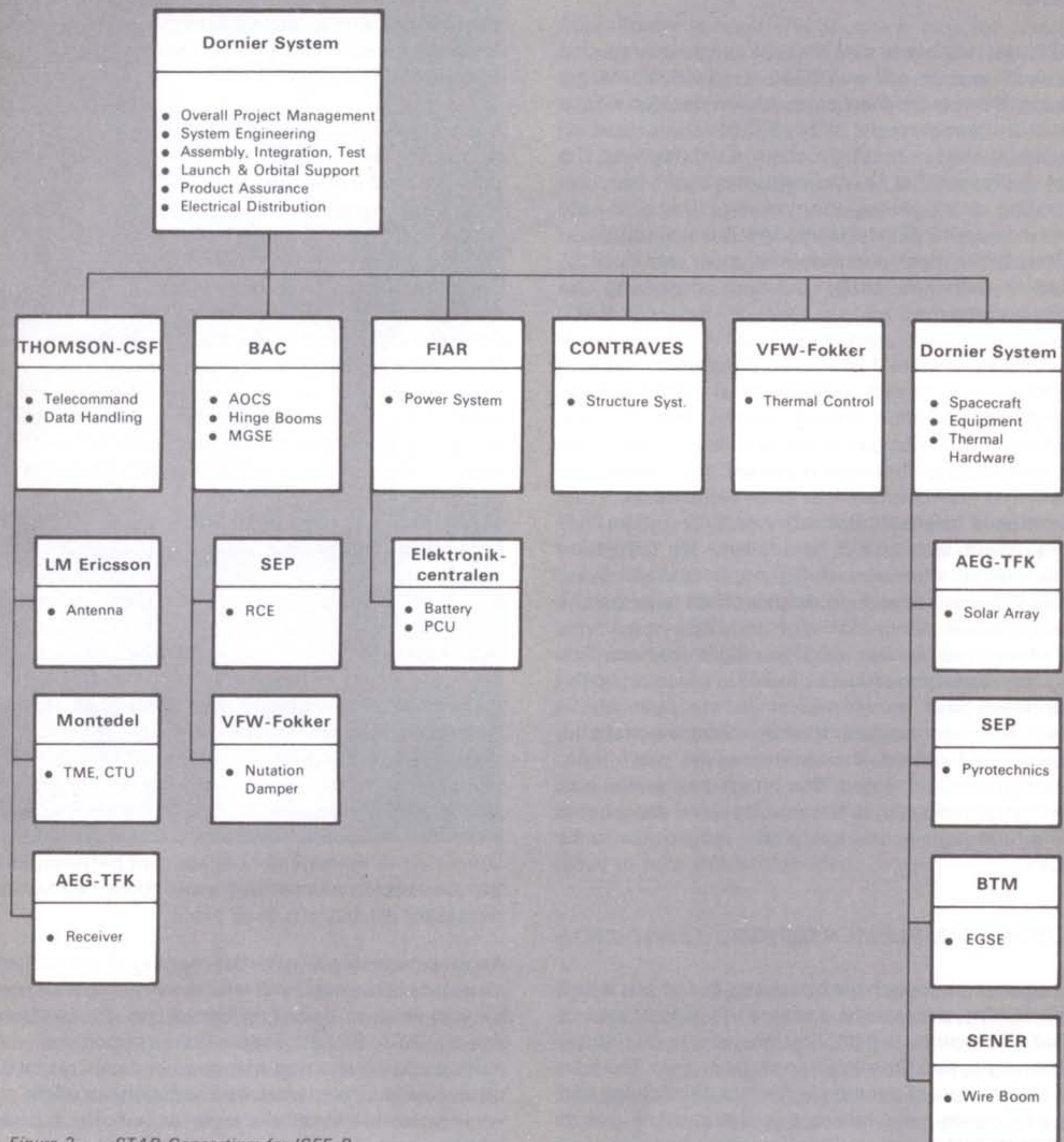


Figure 2 – STAR Consortium for ISEE-B.

although occasionally units from the prototype would be refurbished.

For ISEE, the number of satellite structures was reduced to two and maximum use was made of individual units by employing them more than once. It was decided not to construct a thermal model at all, but to rely instead on computation and to build a certain flexibility into the thermal design so that fine adjustments could be made after testing of the integration model. This not only reduced the number of satellite models, but also simplified considerably the mass dummies and, most significantly, removed an extremely costly and time-consuming test from the programme.

As illustrated in Figure 1, the ISEE programme reduced the number of hardware models to a minimum. The structural model, after having carried out the test programme indicated, was converted to an integration model by replacing the mass dummies with electrically functioning units. In some cases these were the units that had been used to qualify the subsystems; in others they were the flight spares and, particularly for redundant units, they were sometimes nonflight-quality engineering units. Following successful completion of tests on the integration model, the qualification and flight-spare units were refurbished to be used as flight spares. This refurbishment was sometimes as minor as touching up the thermal finish and sometimes, as in the case of the receiver, as major as an almost complete rebuild. Meanwhile the flight satellite – known as the 'protoflight' – was integrated and tested. The integration model was also re-integrated so that it could be used for trouble shooting, although in the event this proved not to be necessary.

PHILOSOPHY IMPLEMENTATION

To enunciate a philosophy is one thing, but to put it into practice is not necessarily so easy. It was therefore essential to consider the implications of the minimum-model concept upon the evolution of the project. The first, and most vital, consequence was the lack of flexibility and inability to repeat tests inherent in the multiple use of units, and lack of a conventional integrated engineering model. Accordingly, considerable attention was given to defining each experiment adequately in interface engineering terms prior to the start of spacecraft hardware manufacture. Once defined, wherever possible the experimenters avoided changes to their design which could reflect upon the spacecraft.

A very careful planning of all integration and test activities at system level was evolved which broke down all activities over a two-year period into half-day units. This was refined many times with the subsystem engineers to ensure that the sequence of events was correct and that the time allocated to each was 'realistic but not generous'. Once the planning had been established, as a matter of management policy no re-issues were permitted in the event of a slippage of work occurring. In this way the onus for recovery was placed squarely upon the area in which the problem had arisen and the 'waterfall' effect of unrealistic times for late programme events avoided. Key dates here were the delivery dates for subsystems and experiments and considerable pressure was exercised by the Prime Contractor (Fig. 2) and ESA at management level to ensure that these dates were kept or, if this was not possible, the delays minimised.

A further area of concern was that of engineering changes. Here the basic approach was 'Unless it is essential – don't change'. In particular, all 'nice to have' changes, aimed at perfecting performance, were firmly suppressed and although this sometimes led to hurt feelings on the part of some specialists, there is no doubt that time scale and cost both benefitted. On the other hand, once a change seemed essential, emphasis was placed on rapid decision making. Most change decisions were made within 48 hours of a costed proposal being submitted. A management agreement between ESA and the Contractor meant that work continued whilst any necessary discussions took place.

An essential ingredient in the running of the project, and especially in the rapid and effective change decisions, was the very close co-operation between the Prime Contractor and the ESA Project Team. This co-operation, and the mutual confidence that it engendered, was so close that on occasion it was remarked somewhat ruefully that 'it was impossible to tell the supplier from the customer'.

Finally, as an essential part of the increased technological

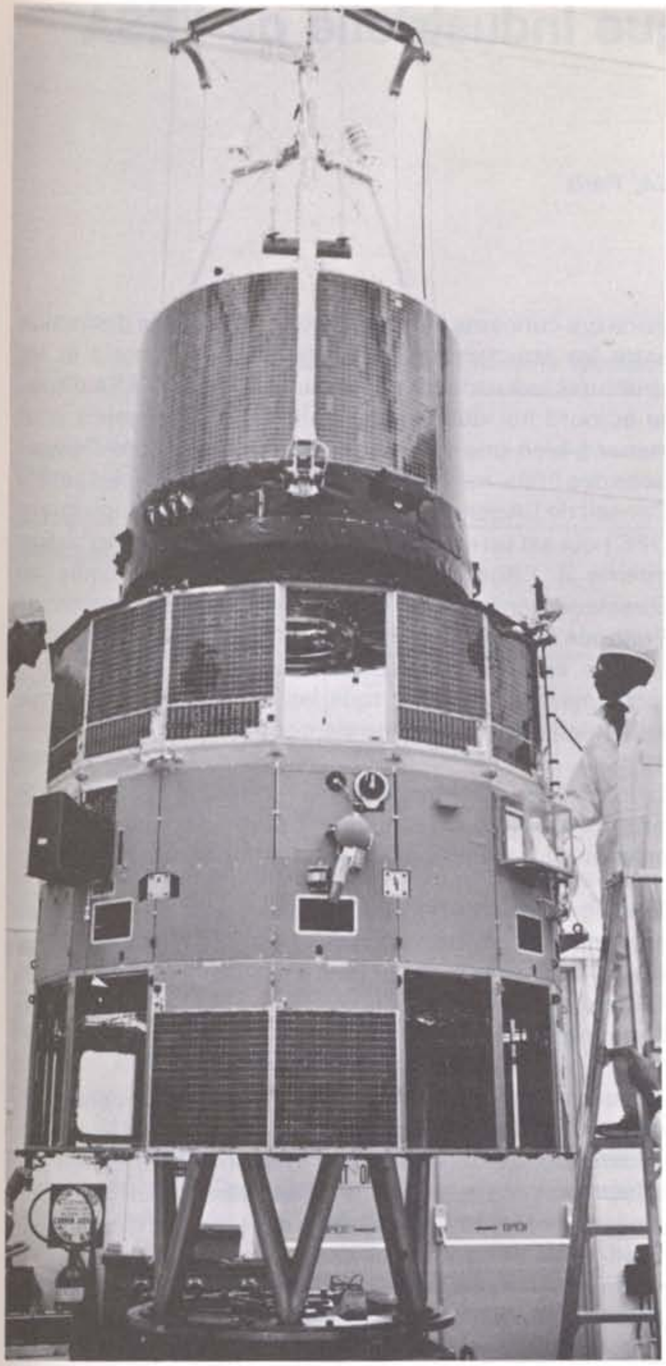


Figure 3– Mating of ISEE-A and B at Eastern Test Range, California.

risk inherent in such a programme, engineering judgement was at a premium. It was manifestly impossible to repeat tests after every change, and sometimes interesting lines of enquiry had to be stopped because they were judged not relevant to the main issue of preparing the satellite adequately on time and within cost. In such areas as product assurance and test-level determination therefore, individual judgements had frequently to be made rather than following the textbook.

THE NEXT STEPS

Superficially at least, the approach must be considered entirely successful. ISEE-B was launched, together with the NASA-integrated ISEE-A (Fig. 3), on 22 October, after a launcher-induced delay of 9 days. The satellite became fully operational with all experiments working on 2 November, only one day later than the target date set four and a half years ago when the project was started. Approximately one month later, ISEE-B is still in good health and relaying scientific data back to earth. Furthermore, the project has been completed within the cost envelope approved by the Member States, whilst the STAR Consortium looks certain to benefit under the incentive scheme for both schedule and performance.

However, there is still the possibility that the good result was achieved largely by good fortune rather than by use of the concepts and approaches described. During the next weeks, therefore, it is intended to hold a detailed review of the project to evaluate whether the various ideas and decisions made were genuinely justified or whether, in retrospect, they introduced too much technical risk, but happened to work on this occasion. On the other hand, it is interesting to note that at no time during the project did we have to utilise a flight-spare unit on the protoflight spacecraft, and that NASA's Goddard Space Flight Center for the ISEE-A satellite reduced the model philosophy to its ultimate by having no equivalent of our integration model and by manufacturing no flight-spare units. Their philosophy was that, should the occasion arise, they would consider relying on the built-in redundancy of the spacecraft and launching if necessary with one part dead. We might consider whether ESA is ready to take this further step.

ACKNOWLEDGEMENT

Based on our experience to date, one thing is certain – the success we have had so far would not have been possible without the assistance the ISEE team has had from the experimenters, the prime and subcontractors and our colleagues in ESA. The co-operation of all of them in this attempt to find a new approach to cost reduction has been much appreciated. □

Quelques aspects de la Politique Industrielle de l'ESA

J. Palaciös, Chef du Département de Politique industrielle, ESA, Paris

L'une des missions de l'Agence Spatiale Européenne est d'élaborer et d'appliquer une politique industrielle appropriée à la réalisation de ses programmes. La Convention de l'Agence définit de façon précise les quatre objectifs principaux à atteindre et qui peuvent se résumer comme suit:

- **répondre aux besoins des programmes spatiaux européens de manière économiquement efficiente,**
- **améliorer la compétitivité de l'industrie européenne dans le monde,**
- **garantir une participation équitable de l'industrie de tous les Etats-membres, et**
- **bénéficier des avantages de l'appel à la concurrence.**

Un examen détaillé de ces objectifs conduit à se poser un certain nombre de questions: Ces objectifs ont-ils tous la même importance? et, dans la négative, quel est l'ordre de priorité qui doit être établi? D'autre part, les deux derniers objectifs sont-ils de vrais objectifs ou correspondent-ils plutôt à certaines contraintes ou conditions que l'Agence doit respecter lors de la passation de ses contrats?

Ces objectifs sont mentionnés dans la Convention dans une séquence qui correspond à une indication de leur importance relative et cette sorte de classement devrait toujours être présente à l'esprit de tous ceux qui sont impliqués dans l'analyse d'un problème particulier de politique industrielle de façon à ce que leur décision ne soit pas motivée par des objectifs 'secondaires' au détriment des objectifs d'une importance supérieure.

Deux conditions principales sont nécessaires pour être en mesure d'atteindre les objectifs mentionnés ci-dessus: d'une part, l'existence des structures nécessaires pour la définition et la mise en oeuvre d'une certaine politique industrielle et, d'autre part, la disponibilité de moyens financiers suffisants ou, autrement dit, un niveau 'minimum' des programmes de l'Agence.

En ce qui concerne les *structures*, il faut faire la distinction entre les structures internes de fonctionnement et les structures industrielles externes à l'Agence. L'ESA dispose aujourd'hui des structures internes nécessaires pour mener à bien une telle politique. Au niveau des Délégations des Etats-membres, les organes responsables sont le Conseil de l'Agence et le Comité de Politique Industrielle (IPC) qui est un comité subsidiaire du Conseil. Au niveau interne à l'Agence, cette responsabilité incombe au Directeur général qui dispose du Groupe Interne de Politique Industrielle (GIPI) et du Comité d'Adjudication comme comités de soutien chargés de formuler des recommandations pour tous les aspects de la politique industrielle et l'attribution de contrats.

Le problème des structures de l'industrie spatiale européenne présente un intérêt très particulier qui mérite un examen plus détaillé dans le paragraphe suivant.

En ce qui concerne la seconde condition, c'est-à-dire un certain niveau de *moyens financiers*, il faut s'attendre à ce que l'importance et le volume des programmes de l'Agence soient tels qu'ils rendront possible de continuer à atteindre ces objectifs.

Il serait illusoire de croire que, si les deux conditions mentionnées étaient respectées, la définition et la mise en oeuvre d'une bonne politique industrielle pourraient être effectuées sans grandes difficultés. Dans le but de préciser davantage le type de difficultés qui peuvent être rencontrées, nous présentons ci-dessous une brève analyse de quelques-uns des problèmes principaux qui sont liés à la politique industrielle de l'Agence.

STRUCTURES INDUSTRIELLES

La nécessité de disposer de groupes industriels capables d'assumer la responsabilité totale de la réalisation des grands projets de l'ESRO (prédécesseur de l'ESA) apparut vers les années 1965-66 et eut pour origine deux faits fondamentaux:

- le besoin d'assurer une distribution de contrats équitable parmi les industries appartenant aux divers Etats-membres de l'Organisation;
- la nécessité d'utiliser la relativement faible compéten-

TABLEAU 1

Consortia de l'Industrie spatiale européenne pendant la période ESRO

	MESH	STAR	COSMOS
France	MATRA	THOMSON-CSF SEP	SNIAS
Allemagne	ERNO	DORNIER	MBB SIEMENS
Royaume-Uni	HSD	BAC	MARCONI-SDS
Italie	FIAT	CGE-FIAR MONTEDEL-LABEN	SELENIA
Autres pays	SAAB-SCANIA	FOKKER L.M. ERICSSON	ETCA

ce à l'échelle européenne dans un domaine nouveau de façon à éviter une duplication excessive dans le développement de nouvelles compétences parmi les firmes européennes.

Formation des Consortia

A partir de 1966, l'industrie européenne se mit à constituer des groupes industriels susceptibles de répondre aux besoins de l'Organisation pour la réalisation des projets de satellites. Cette initiative a été fortement encouragée par l'Organisation qui voyait là un moyen efficace de répondre aux besoins mentionnés ci-dessus.

Pendant quelques années, on put constater une évolution de la constitution de ces groupes, certaines compagnies passant d'un groupe à un autre. Cette évolution eut comme origine la nécessité d'équilibrer les compétences à l'intérieur de chacun des groupes dans le but d'éviter des duplications, et pour répondre au souci des industriels de constituer des 'consortia' le mieux adaptés aux besoins des projets de l'ESRO. Finalement, les trois groupes MESH, COSMOS et STAR furent constitués de façon stable à partir de 1972. Le Tableau 1 indique les firmes européennes qui participent à chacun de ces trois groupes industriels dans le cadre des programmes ESRO.

Outre qu'elle facilite la répartition géographique des contrats, aspect qui sera examiné plus tard, cette structuration de l'industrie européenne présente, ou du moins présentait, de nombreux avantages parmi lesquels une meilleure coopération européenne dans une technologie très avancée (ce qui permettait une participation de l'industrie des pays à faible contribution), l'occasion pour les firmes de s'habituer à travailler ensemble pour la réalisation des grands projets, une rapidité de réaction du groupe vis-à-vis de tout nouveau besoin de l'Organisation grâce à une structuration permanente, une augmentation des possibilités de l'industrie européenne de s'attaquer aux marchés non européens et, enfin, un certain support de l'industrie ainsi groupée vis-à-vis des gouvernements responsables du choix des décisions dans le domaine spatial.

Surcapacité et rigidité

Peut-on en conclure que la structuration actuelle de l'industrie spatiale représente la solution optimale? Malheureusement non car, à côté des avantages mentionnés, il est juste de souligner les inconvénients et les limitations qu'elle entraîne.

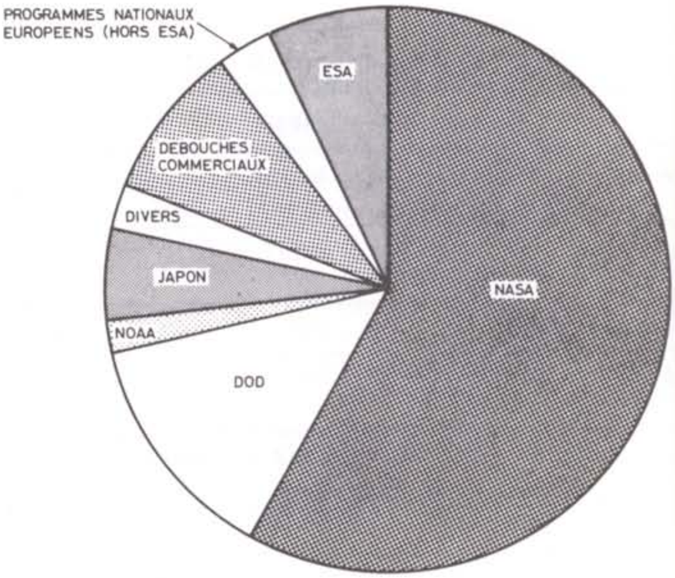
Le premier désavantage est la création de fait d'une surcapacité européenne dans le secteur spatial comme conséquence de l'aspiration logique des différentes firmes appartenant au même groupe d'obtenir la responsabilité de 'contractant principal'. Dans certains cas, cette responsabilité a été attribuée à l'intérieur du groupe soit par rotation, soit en tenant compte des caractéristiques et de la participation des Etats-membres au programme en question. Le résultat est un nombre trop élevé (huit à dix) de contractants principaux possibles. En outre, ces contractants principaux éventuels cherchent souvent, dans les cas où ils n'ont pas obtenu cette responsabilité, à démarrer des activités nouvelles, ce qui provoque une duplication des compétences même au sein du groupe. Enfin, la tendance de chacun des groupes à devenir tout à fait indépendants en ce qui concerne le développement des sous-systèmes ne fait qu'aggraver ce phénomène de surcapacité.

Un autre inconvénient qui découle de ce qui précède est la difficulté qu'a l'Agence d'assurer une charge de travail suffisante pour permettre aux industries de maintenir en activité des équipes minimales nécessaires à la poursuite des activités futures. L'approbation des programmes de l'Agence par 'package deals' a conduit à des 'pointes' de charges de travail et à la croissance peut-être trop rapide des équipes nécessaires dont la survie est difficile à assurer. Une étude détaillée de la charge de travail des principales industries européennes est en cours et ses résultats devraient permettre une certaine quantification du problème.

Enfin, on doit mentionner aussi que la relative rigidité des structures industrielles actuelles interdit parfois l'utilisation des compétences d'une firme qui se trouve en dehors d'un groupe et cela, en dépit du fait que les compétences ont pu être développées grâce au financement de l'Agence. Toute évolution qui permettrait une meilleure utilisation de ces compétences industrielles ne peut être qu'encouragée.

Il est facile de comprendre que certains de ces désavantages peuvent conduire à un accroissement 'artificiel' du coût d'un projet, phénomène qu'il faut manifestement éviter.

Evolution des structures
Les considérations ci-dessus font apparaître le besoin d'une évolution des structures industrielles actuelles. En fait, depuis la création de l'Agence, une certaine évolution s'est déjà effectuée soit comme conséquence des recommandations faites à l'industrie à l'occasion des appels d'offres, soit à l'initiative des industries elles-mêmes qui sont certainement très sensibles à ce type de problèmes et qui, conscientes des limitations actuelles, cherchent des



DOD: Département américain de la Défense.
NOAA: Agence américaine d'études océanographiques et atmosphériques.

Figure 1 – Débouches industriels offerts par l'espace pour la période 1976–1980 (Total= 21600 millions de dollars).

solutions nouvelles afin d'augmenter leurs chances.

Il serait prétentieux de se risquer à faire des pronostics sur le résultat final de cette évolution. A la question qui est très souvent posée: faut-il un, deux ou trois consortia? on ne peut répondre uniquement par un chiffre mais, en tout état de cause, il est nécessaire d'aboutir à une structure industrielle spatiale européenne qui permettrait un nombre limité de contractants principaux éventuels, une plus grande flexibilité dans la sélection des firmes responsables des sous-systèmes, une meilleure utilisation des compétences développées dans les firmes avec le support de l'Agence, et la réalisation des projets à des prix compétitifs sur le marché mondial. D'autre part, une structuration plus souple et en même temps plus rationnelle de l'industrie spatiale faciliterait la mise en oeuvre d'une politique technologique de l'Agence qui est en cours d'élaboration dans ses lignes essentielles, et dont les aspects principaux sont traités dans un autre article de ce même Bulletin.

Quelques progrès déjà réalisés dans ce sens ne nous empêchent néanmoins pas de mesurer le long chemin qu'il reste à parcourir pour arriver, en coopération avec les industries, à des résultats plus satisfaisants.

IMPORTANCE DU MARCHE ESA POUR L'INDUSTRIE EUROPEENNE

Comme il a déjà été mentionné, l'une des conditions nécessaires pour mener à bien une politique industrielle est de disposer de moyens budgétaires suffisants, ce qui veut dire en d'autres termes un certain niveau de programmes dont la responsabilité de réalisation incombe à l'Agence.

Il est opportun à ce stade de fournir quelques chiffres permettant au lecteur de se faire une opinion sur l'importance du marché ESA pour l'industrie spatiale européenne. Signalons aussi qu'il n'y a pas en Europe d'industrie spécifiquement spatiale alors qu'il existe une industrie aéronautique, automobile, etc. En fait, l'effort spatial européen provient des secteurs spatiaux qui existent à l'intérieur des firmes ayant une activité plus étendue, en particulier les firmes aéronautiques et électroniques.

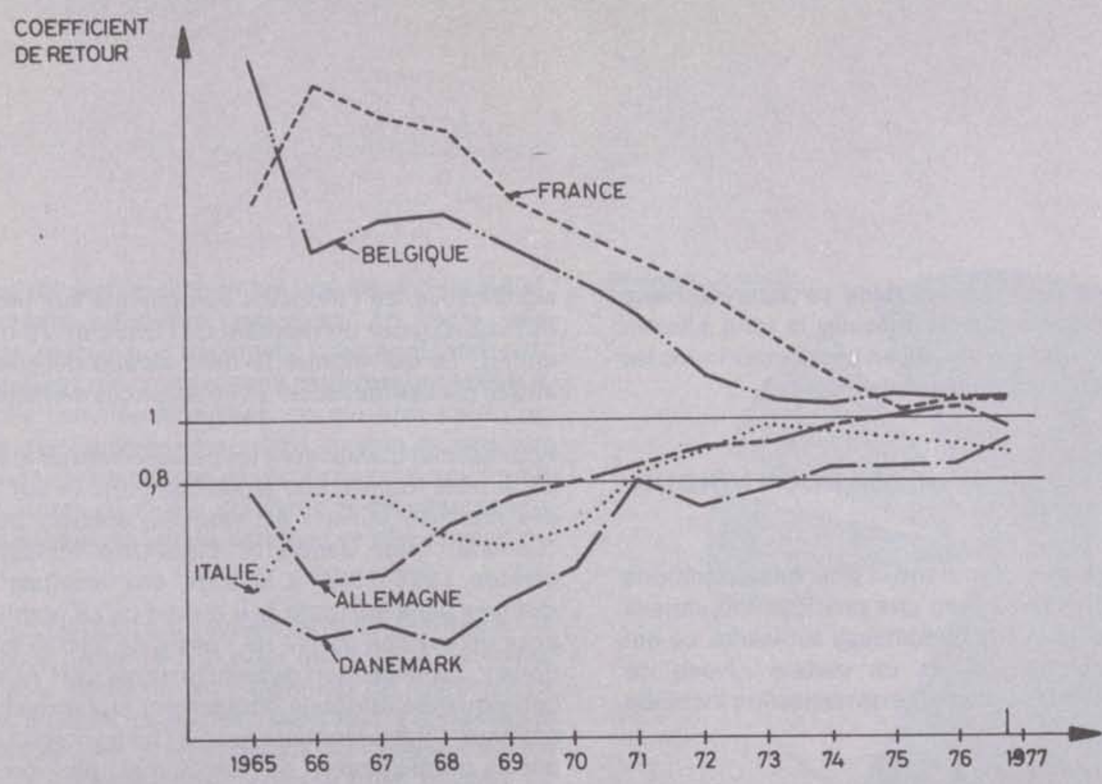
Malgré cela, l'importance de la participation de ces industries peut être mesurée si on tient compte du fait que, jusqu'à la fin de 1977, l'Agence a lancé plus de 1200 appels d'offres et placé parmi ces industries plus de 6500 contrats. Le montant global qui correspond à ces contrats est supérieur à 1800 millions de dollars et 200 firmes industrielles environ ont participé ou participent à l'effort spatial européen. Les effectifs de ces firmes affectés au secteur spatial représentent plus de 10000 personnes. D'autre part, l'industrie a reçu, dans le cadre des programmes ELDO (Organisation européenne pour la mise en point et la construction des lanceurs d'engins spatiaux), environ 800 millions de dollars. Ces chiffres témoignent de l'importance des programmes de l'Organisation qui ont conduit jusqu'à présent, comme on le sait, aux lancements réussis de 11 satellites. En outre, et indépendamment des travaux réalisés pour l'industrie européenne dans le cadre de programmes nationaux financés par quelques-uns des Etats-membres de l'Agence, il convient de mentionner la participation, très significative, de l'industrie européenne aux programmes INTELSAT pour un montant de l'ordre de 70 millions de dollars, ce qui montre le haut niveau de compétitivité atteint par ces industries au cours de ces dernières années.

Pour estimer quelles sont les perspectives de marché pour les années futures, une étude comparative sur le volume des marchés ouverts à l'industrie spatiale occidentale (Canada, Inde, Japon et Etats-Unis inclus) pour la période 1976–1980 a conduit aux résultats qui sont résumés dans la Figure 1. Il ressort de ce graphique que, pour un marché global de l'ordre de 21600 millions de dollars, 7% seulement seraient financés par l'Agence et en conséquence attribués directement aux industries européennes. Ce pourcentage pourrait bien entendu être accru par la participation de ces firmes aux programmes nationaux ainsi qu'à une partie du marché commercial; néanmoins, il semble raisonnable de supposer que le seuil des 2000 millions de dollars pourra difficilement être dépassé pendant la période considérée si on raisonne au niveau de prix constant. Ce résultat ne fait que renforcer la nécessité de maintenir le niveau de l'effort spatial européen au moins à sa valeur actuelle si on veut que le degré de compétitivité déjà acquis à l'échelle mondiale par l'industrie spatiale européenne continue à s'accroître au cours des années futures.

JUSTE RETOUR

L'obligation faite à l'Agence de répartir ses contrats entre les différents Etats-membres apparaît:
- pour l'ESRO, dans la Convention et dans le Règlement Financier qui prévoit que 'l'Organisation répartit ses commandes de matériels et ses contrats industriels aussi équitablement que possible entre les Etats-membres, compte tenu des considérations scientifiques, technologiques, économiques et géographiques';
- pour l'Agence, dans la Convention et son Annexe V qui traite de la politique industrielle et, en particulier, édicte les règles régissant la répartition géographique des contrats et définit le coefficient de retour d'un Etat-membre.

Cette obligation que l'Agence s'est ainsi imposée, cette contrainte communément admise sous le vocable de



Figures 2 & 3 – Evolution du coefficient de retour.

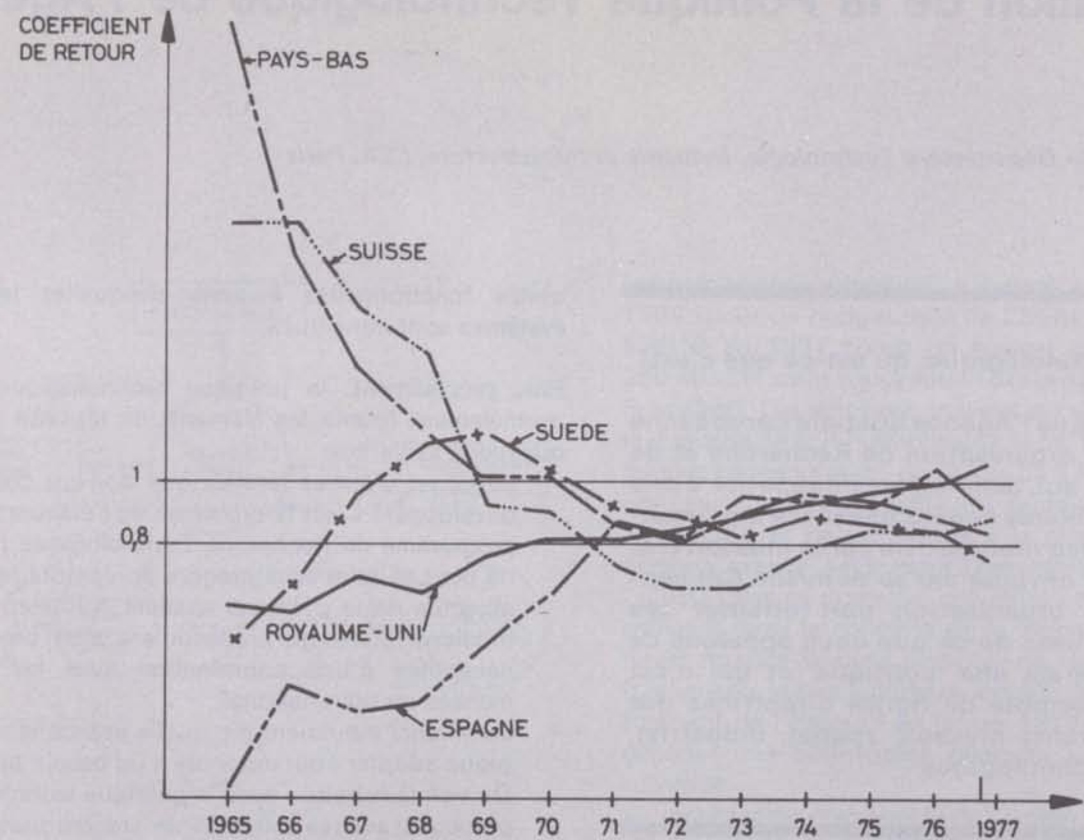
'juste retour', traduit le désir des Etats-membres de voir l'Exécutif réinvestir dans leur industrie à proportion des contributions qu'ils ont versées.

Cette notion de juste retour qui, à l'origine, ne recouvrait que des aspects financiers s'est peu à peu affinée pour tenir compte non seulement du montant des travaux confiés mais également de l'intérêt technologique, si bien qu'à présent le juste retour comporte, en plus d'un aspect quantitatif, un aspect qualitatif important.

Par ailleurs, avec la venue des programmes facultatifs tels que Télécom, Marots, Spacelab, Ariane, etc., pour lesquels les pourcentages de participation des Etats-membres peuvent différer de beaucoup les uns des autres, la règle du juste retour a été invoquée au niveau de chaque programme et les Arrangements conclus pour la conduite de ces programmes comportent généralement une clause selon laquelle, pour l'exécution des travaux, la préférence est donnée aux participants et ensuite aux autres Etats-membres.

Ainsi, peu à peu, cette notion de juste retour s'est élargie pour couvrir les programmes facultatifs et s'est affinée pour caractériser les tâches confiées en fonction de leurs attraits technologiques.

Au cours des premières années d'existence de l'Organisation, la répartition des travaux de façon équitable était une condition très difficile à remplir. Outre les difficultés découlant de l'obligation de faire appel à la concurrence et de la nécessité de mener à bien les programmes de l'Organisation, les écarts entre les Etats-membres au niveau de la technologie spatiale étaient trop importants, ce qui constituait une difficulté supplémentaire. En fait, pour certains pays, cette technologie était inexistante et on voit mal comment le principe consistant à faire participer les industries de chaque Etat-membre aux programmes de l'ESRO pouvait être respecté. Plus tard, la venue de programmes facultatifs a fait apparaître, comme il a été indiqué antérieurement, des limitations supplémentaires et, dans de nombreux cas, l'Agence a été obligée de prendre des décisions qui manifestement ne pouvaient pas contribuer simultanément à permettre d'atteindre les objectifs d'efficacité fixés et à développer la compétitivité en respectant les contraintes du juste retour imposées par la Convention. C'est à cause de ce caractère parfois conflictuel entre les objectifs recherchés que l'Agence analyse très en détail, et cas par cas, chaque marché avant son attribution en vue de trouver le meilleur compromis possible entre les différents aspects à considérer. Les résultats obtenus sont indiqués dans les Figures 2 et 3 qui représentent l'évolution du coefficient



de retour géographique pour les différents Etats-membres de 1963 à 1977. On constate que ce n'est que vers les années 1971-1972 qu'un certain équilibre a pu être atteint et que le seuil de 0,7 fixé par le Conseil de l'ESRO a été sensiblement dépassé par tous les pays. La situatic à la fin de 1977 peut être considérée comme asse satisfaisante, à quelques exceptions près qui font l'objet d'une attention toute particulière de la part des services responsables de l'Agence.

Ce redressement a pu s'opérer sans que la qualité des travaux en soit affectée et au prix certes d'un supplément de dépenses pour l'ESRO mais d'un volume assez modeste à notre avis. Il faut reconnaître à cette occasion l'aide remarquable que l'industrie européenne a fournie à l'Organisation en cherchant une coopération internationale maximale pour la réalisation des grands projets.

CONCLUSIONS

On a essayé dans cet article de fournir une information très succincte sur les objectifs et les moyens de la Politique Industrielle de l'ESA en examinant par ailleurs quelques-uns des problèmes s'y rapportant et en indiquant les résultats obtenus.

La mise en application d'une politique industrielle cohérente et rationnelle est une tâche complexe et de longue haleine en raison du nombre assez élevé de considérations parfois contradictoires qu'il ne faut jamais perdre de vue. Si on examine néanmoins à nouveau les objectifs définis dans la Convention, malgré les limites et les difficultés mentionnées, on peut affirmer que:

- les programmes spatiaux européens ont été réalisés de façon efficace, comme le montre le lancement réussi de 11 satellites de l'Organisation et cela s'est accompli avec la participation des industriels de tous les Etats-membres de l'Agence;
- les industries spatiales européennes ont atteint un niveau de compétitivité reconnu à l'échelle mondiale et leur participation aux programmes spatiaux extra-européens en témoigne.

Bien sûr, on ne saurait se contenter de ces résultats et on a largement conscience de l'effort qu'il reste encore à faire, en particulier pour résoudre les problèmes posés par certains pays dont le retour industriel est faible ou est en train de s'affaiblir mais, dans l'ensemble, il n'est pas utopique de penser que les moyens nécessaires sont disponibles et que les résultats, moyennant une étroite collaboration indispensable avec les Délégations et les Industries, ne pourront manquer de s'améliorer. □

L'élaboration de la Politique Technologique de l'Agence

R. Fraysse, Chef du Département Technologie, Industrie et Infrastructure, ESA, Paris

La Politique Technologique: qu'est-ce que c'est?

Nul ne conteste que l'Agence Spatiale Européenne soit une grande organisation de Recherche et de Développement qui, dans le domaine spatial, a pris au cours des dernières années une place importante même au niveau mondial. De par la mission très large qui lui est dévolue par sa nouvelle Convention, une telle organisation doit orienter ses activités sur la base de ce que nous appelons de façon très générale une 'politique' et qui n'est autre qu'un ensemble de lignes directrices des actions à différents niveaux: spatial, industriel, technique et technologique.

La *politique spatiale* vise à regrouper les objectifs généraux au niveau européen dans le domaine spatial (par exemple: indépendance en matière de satellites d'applications et donc de lanceurs), et à définir les relations de l'Agence avec les autres organisations nationales et internationales (par exemple: le rôle de l'ESA dans la gestion des systèmes opérationnels d'applications).

La *politique industrielle* vise à orienter l'action de l'Agence dans le développement des capacités et des structures industrielles de ses Etats-membres.

La *politique technique*, se situant au niveau du développement des systèmes (projets de satellites), concerne les méthodes de gestion, les plans de développement, d'intégration et d'essais, les investissements sol etc. Une composante importante de cette politique technique a commencé de recevoir une attention particulière au sein de l'Exécutif: le degré de standardisation souhaitable des satellites et de leurs sous-systèmes.

Enfin la *politique technologique* englobe l'ensemble des orientations à donner au programme de Recherche et Développement (R&D) au niveau des technologies, c'est-à-dire des éléments constitutifs des systèmes spatiaux, depuis les composants élémentaires jusqu'aux unités fonctionnelles à partir desquelles les sous-systèmes sont constitués.

Plus précisément, la politique technologique devrait normalement fournir les éléments de réponse aux trois questions suivantes:

- *quoi?* en d'autres termes, que doit-on chercher et développer? C'est le problème de l'élaboration d'un programme de Recherche Technologique (RT), qui ne peut se faire sans prendre en compte les grands objectifs de la politique spatiale européenne et les missions futures qui en découlent, aussi bien que les nécessités d'une coordination avec les activités menées au plan national;
- *comment?* autrement dit, quelle approche technologique adopter pour répondre à un besoin technique? On voit là la liaison avec la politique technique et en particulier avec sa composante 'standardisation' pour laquelle une action systématique vient d'être entreprise;
- *où?* dans quelles firmes, dans quels Etats-membres telle ou telle action de R&D doit-elle être exécutée? La liaison est évidente avec la politique industrielle de l'Agence dont les objectifs principaux doivent être également pris en compte.

Outre les interactions ci-dessus avec d'autres composantes essentielles de la politique d'ensemble de l'Agence (voir Figure 1), on doit également noter que l'élaboration d'une politique de RT est rendue très complexe du fait de l'énorme variété des problèmes à considérer: la technologie des satellites (sans parler des lanceurs, et sans même descendre au niveau des composants) est classiquement découpée en une dizaine de secteurs, chacun de ces secteurs pouvant lui-même comporter de nombreux éléments fonctionnels dont il convient de maîtriser la technologie, après avoir fait un choix pour chaque fonction à assurer parmi les diverses solutions techniques possibles. Pour donner un exemple, le projet de programme à moyen terme de RT en cours de définition ne comporte pas moins de 120 propositions d'actions de recherche.

Enfin, la définition de la politique technologique d'une organisation telle que l'ESA doit tenir compte d'un *environnement complexe:* les Etats-membres ont en effet des motivations différentes vis-à-vis de ce problème; leurs

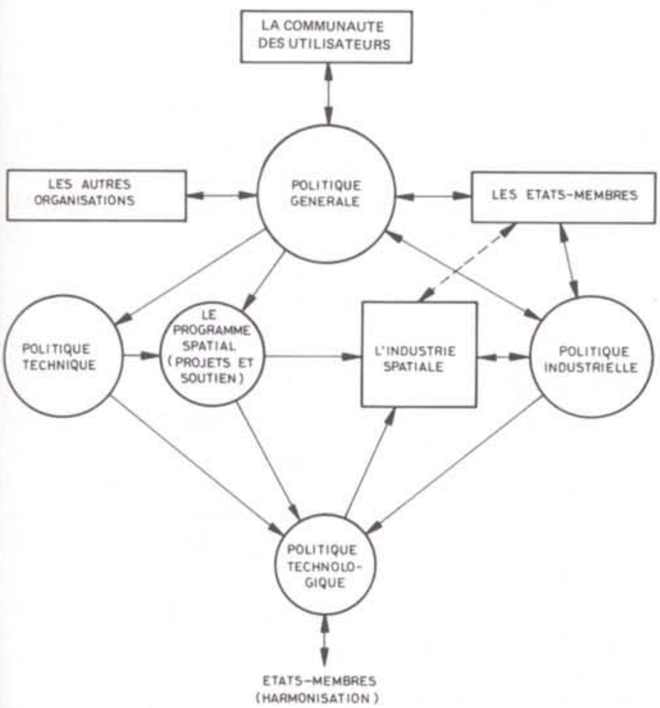


Figure 1

potentiels industriels spatiaux sont extrêmement variés; certains gèrent des programmes nationaux et d'autres non.

Il n'est donc pas surprenant que l'élaboration d'une telle politique, dans le cadre des contraintes imposées par les multiples interfaces ci-dessus, soit un processus extrêmement long et dont la durée se mesure en années. Le rappel historique ci-après illustre ce point.

UN PEU D'HISTOIRE

Le financement consacré aux contrats extérieurs pour ce qu'on a appelé d'abord 'recherche appliquée' puis 'recherche technologique' a évolué entre 1,4 MUC en 1969 (pour un budget total de l'ESRO* de 60 MUC) et 5 MUC en 1977 (pour un budget total de l'ESA de 250 MUC** après soustraction des programmes Ariane et Spacelab). Les réflexions initiales sur une politique dans le domaine de la RT remontent à la fin 1973 (alors que le budget correspondant, de l'ordre de 3 MUC, représentait une part non négligeable du budget total d'environ 100 MUC), et faisaient suite à la prise de position de certains 'grands' pays visant à remettre en cause le rôle de l'ESRO dans ce domaine; ces réflexions, par ailleurs, se situaient dans le contexte de la longue gestation de la future Agence Spatiale Européenne, et en particulier des fondements de sa politique industrielle. Un document émanant de l'Exécutif en février 1974 essayait alors de dégager une philosophie générale sur les problèmes suivants:

- conception d'ensemble de l'action technologique en Europe et rôle particulier de l'ESRO;
- politique de l'ESRO vis-à-vis des programmes nationaux: harmonisation des programmes européens de recherche technologique et coordination des activités correspondantes;
- exécution du programme ESRO dans l'industrie, et en particulier 'promotion technologique' des 'petits' pays.

Mais le débat qui s'est instauré en 1974 au sein du JPPC ('Comité commun des Programmes et de la Politique générale', prédécesseur du 'Comité' de la Politique industrielle') sur la base de ce document est resté sans conclusions: le Comité a 'pris note et invité le Secrétariat à poursuivre ses études...'. Peut-être la raison de cet insuccès résidait-elle dans la difficulté de confronter des idées générales, sans que les interlocuteurs puissent clairement discerner les conséquences pratiques de leur mise en application au niveau des activités de recherche dans les divers secteurs.

Sans perdre de vue les lignes directrices générales de son action, l'Exécutif a alors décidé de mettre en oeuvre en 1976 une nouvelle approche fondée sur une concertation permanente et approfondie avec les représentants des Etats-membres, en orientant *le dialogue sur des problèmes techniques ou industriels concrets*. C'est ainsi qu'une étude systématique des activités de technologie spatiale, secteur par secteur, a été entreprise, chaque

* ESRO: Organisation européenne de Recherche spatiale, prédécesseur de l'ESA.
** MUC: millions d'unités de compte. (1 UC=5,2 FF ou 1,1 US $ au taux de conversion de 1977).

secteur donnant lieu à un 'dossier' détaillé, qui définit non seulement les activités qui pourront effectivement être financées dans le cadre de l'Agence, mais aussi l'ensemble de celles qu'il serait désirable de poursuivre au niveau européen, et qui présente toutes les informations disponibles sur les activités ou intentions nationales et sur les compétences industrielles dans les différents domaines. Ces dossiers sont discutés au cours de Tables Rondes réunissant les experts techniques et les représentants des Délégations des Etats-membres et soumis ensuite au Comité de la Politique industrielle (IPC), accompagnés éventuellement de propositions de l'Exécutif concernant la politique industrielle à suivre ou la coordination souhaitable avec des activités nationales. Actuellement vingt dossiers de recherche technologique ont déjà été établis et soumis à discussions, et neuf autres sont en préparation.

Cette approche pragmatique, qui consistait à bâtir l'édifice pierre par pierre, a été bien accueillie, mais à peine les premières fondations étaient-elles mises en place que certaines des Délégations ont exprimé le désir – tout à fait légitime – de connaître les plans de l'architecte. Tout en reconnaissant l'effort considérable d'analyse et de dialogue fait par l'Exécutif, elles ont souligné la difficulté pour elles de prendre position sur telle ou telle mesure de politique industrielle ou sur telle ou telle proposition de programme sans disposer d'une vue d'ensemble des orientations de l'Exécutif.

UNE PREMIERE TENTATIVE DE SYNTHESE

L'étape suivante a donc consisté dans la préparation, au début 1977, d'un document sur la '*Politique Technologique de l'ESA: Essai de synthèse sur les orientations à moyen terme de la Recherche Technologique*'. Ce document discuté par l'IPC en mai 1977, a reçu un accueil favorable de la part de l'ensemble du Comité, mais comme on le verra plus loin, le travail est loin d'être achevé. Toutefois la construction de l'édifice continue sur des bases plus solides.

Rappelons rapidement le contenu de cet essai de synthèse et en particulier les éléments relativement sûrs sur la base desquels l'élaboration d'une politique technologique peut se poursuivre:

Objectifs généraux
Les programmes de technologie spatiale de l'Agence visent à assurer en temps opportun la disponibilité des techniques et des technologies nécessaires aux activités spatiales futures. Par ailleurs, ces programmes ont un rôle essentiel à jouer en matière de politique industrielle en favorisant la rationalisation des potentiels de compétence et la participation effective et équitable des industries de tous les Etats-membres aux activités spatiales européennes.

Rôle de l'Agence
Le rôle de l'Agence est double:
- d'une part, élaboration d'une politique technologique, sous ses aspects techniques et industriels, en concertation avec les Etats-membres, visant à une 'harmonisation' des efforts nationaux et de ceux de l'Agence, mais en tenant compte des différences de statuts entre les Etats;
- d'autre part, définition et mise en oeuvre de son propre programme de technologie.

Exécution des programmes/Politique industrielle
La politique industrielle de l'Agence doit viser à la recherche d'un équilibre raisonnable entre la rationalisation de l'industrie, le maintien de la compétition, et le 'juste retour' industriel.

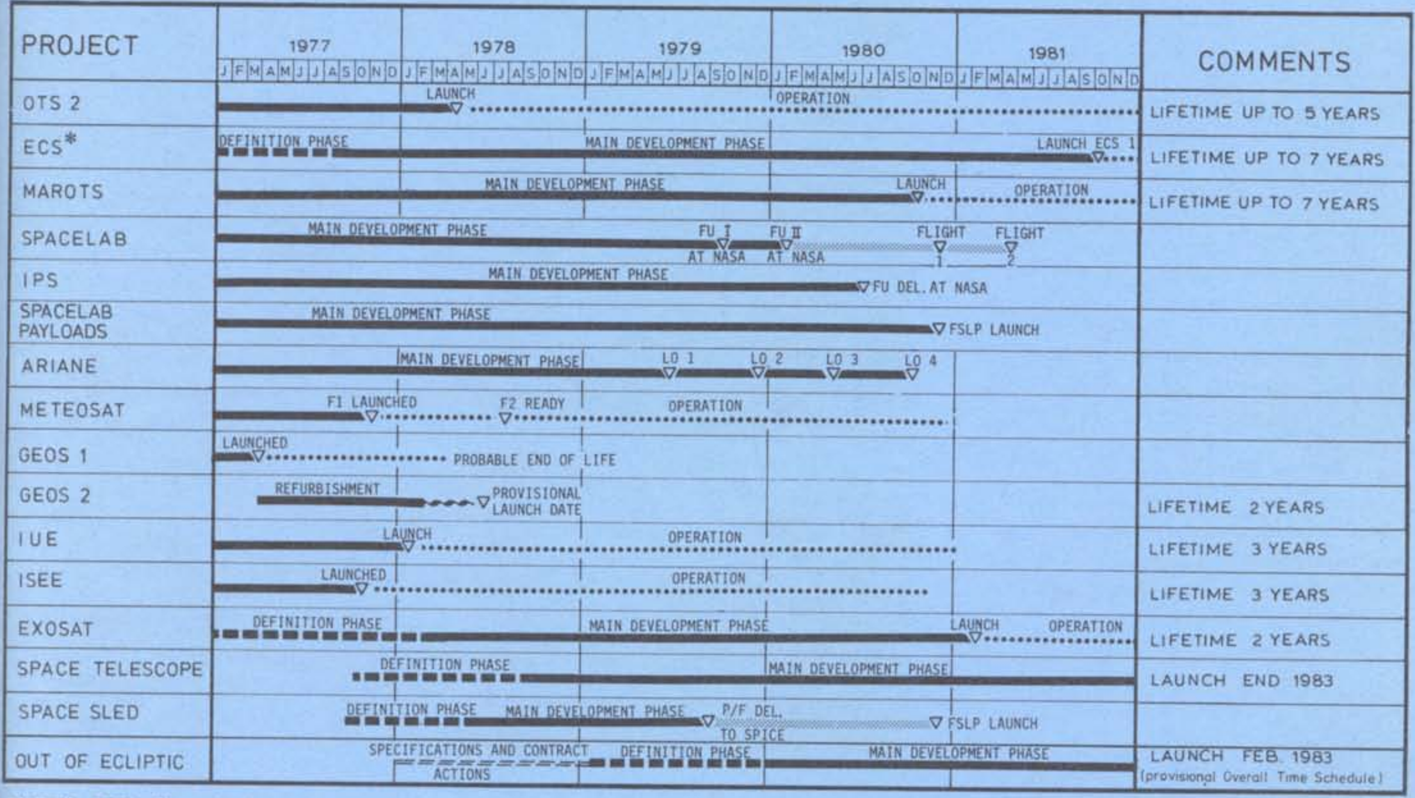
En conséquence et sous réserve de mesures particulières visant à prendre en compte la diversité des contributions des Etats-membres et de leurs structures et compétences industrielles en matière de technologie spatiale, l'orientation générale doit être fondée sur une *politique de spécialisation industrielle sélective* (en ce qui concerne les secteurs) et suffisamment souple pour ne pas contrecarrer le dynamisme des firmes.

Enfin, la mise ou le maintien en condition des industries de certains Etats-membres nécessite, par dérogation à la politique générale ci-dessus, un support délibéré de l'Agence, au moins à court et moyen terme, sous la forme *d'actions de promotion technologique* échappant au principe de la compétition (– de telles actions ont été définies en faveur de la Suisse, l'Espagne et la Belgique dont le retour industriel en matière de recherche technolo-

(Suite page 43)

Projects under Development
Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (END DECEMBER 1977)



*NOTE: ECS still awaits formal approval

OTS-2

Preparations for the launch of OTS-2 in April 1978 are continuing on schedule with the major test programme now set for January and February 1978. Shipment to the range is scheduled for mid-March 1978.

The investigation of the Failure Review Board into the OTS-1 launcher explosion continues, with no final report having yet been released. However, as a result of the recovery operations a considerable amount of hardware was retrieved, including major portions of the main launch vehicle and the five ground-lit solid strap-on motors. Examinations revealed that one of the solid motors was the source of the failure and that the main launch vehicle behaved normally. Further investigations and analyses of the solid-motor characteristics, including the propellant, are in progress. NASA is proposing to manufacture new solid motors in time for the next launch.

ECS

The preliminary phase of the ECS Main Development Phase (C/D) which commenced in August 1977 was extended to mid-January 1978 by the November Joint Communications Satellite Programme Board and further discussions will take place in December on the extension of the approval to the whole of Phase C/D as part of the new overall satellite communications programme.

MARITIME SATELLITE

The Joint Communications Programme Board has approved the modification from X to C-band

OTS-2

Les préparatifs en vue du lancement d'OTS 2 en avril 1978 se poursuivent conformément au calendrier, le principal programme d'essais étant maintenant fixé à janvier – février 1978. L'expédition du satellite à la base de lancement est prévue pour la mi-mars 1978.

Les travaux de la commission chargée de l'enquête sur l'explosion du lanceur d'OTS 1 se poursuivent et son rapport final n'a pas encore été rendu publique. Toutefois, les opérations de récupération ont permis de retrouver beaucoup d'équipements, y compris de grands fragments de la fusée principale et les cinq propulseurs à poudre accolés et allumés au sol. Des examens ont révélé que l'un de ces propulseurs était à l'origine de la défaillance et que le lanceur principal s'était comporté normalement. De nouvelles enquêtes et analyses des caractéristiques du propulseur à poudre, y compris l'ergol solide lui-même, sont en cours. La NASA propose de fabriquer de nouveaux propulseurs à poudre à temps pour le nouveau lancement.

ECS

L'étape préliminaire de la phase de réalisation (C/D) d'ECS, commencée en août 1977, a été prolongée jusqu'à la mi-janvier 1978 par le Conseil directeur commun des programmes de satellite de communications à sa réunion de novembre, et de nouvelles discussions auront lieu en décembre sur l'extension de cette approbation à la totalité de la phase C/D prévue, en tant qu'élément du nouveau programme d'ensemble dans le domaine des satellites de télécommunications.

Débris du lanceur d'OTS rassemblés dans le hangar de Cap Canaveral.

Fragments of the OTS launcher assembled on hangar floor at Cape Canaveral.

SATELLITE MARITIME

Le Conseil directeur commun des programmes de Communications a approuvé le changement des fréquences de la bande X à la bande C pour les liaisons station côtière-satellite sur tous les modèles de vol de Marots. Des soumissions pour une série de quatre véhicules spatiaux opérationnels ont été reçues de l'industrie et sont en cours d'évaluation mais la définition finale du programme révisé est encore à l'étude. En attendant, l'exécution des contrats déjà passés pour la charge utile et la plate-forme s'est poursuivie et le modèle d'identification de la charge utile a été livré au contractant responsable du satellite en vue de son intégration avec l'ex-modèle de qualification du module de service d'OTS pour des essais au niveau système. La fabrication des modèles de qualification et de vol des unités de la charge utile sur lesquelles le changement de fréquences n'a pas d'incidence, se poursuit. Enfin, la recette de la station sol de Villafranca est prévue pour décembre 1977.

frequency of shore-to-satellite links of all Marots flight models. Tenders for a series of four operational spacecraft have been received from industry and are being evaluated, but the final definition of the revised programme is still under discussion. Meanwhile, the existing payload and platform contracts have continued, with the engineering-model payload being delivered to the satellite prime contractor for integration with the former OTS service-module qualification model for system-level testing. The manufacturing of the qualification and flight-model payload units, unaffected by the frequency change, is progressing. Finally, acceptance of the Villafranca ground station is scheduled for December 1977.

SPACELAB

Spacelab Annual Review

The ESA Director General met with the NASA Administrator, Dr. Frosch on 7 October 1977 in Paris. The meeting was considered as the Annual Review of the Spacelab Programme provided for in the Spacelab Memorandum of Understanding, though the meeting was not restricted to Spacelab affairs. Some of the principal results of the meeting are as follows:

1. As a result of changes in the Space Shuttle's initial launch schedule December 1980 and April 1981 have become the agreed target launch dates for the two first Spacelab missions. Because of the increasing weight of the Tracking and Data Relay Satellite (TDRS), NASA has been forced to plan the two TDRS launches on individual Shuttle flights instead of conventional Atlas-Centaur launches.
2. NASA and ESA have agreed that the first contract award for the production of an additional Spacelab should take place in October 1978. The agreement represents an important step forward since the NASA commitment will help ESA and European industry to plan for the transition from development to production phase.
3. The two Agencies have agreed on a distribution of tasks concerning Spacelab operations and logistics support activities. Under the agreement, ESA will set up a maintenance depot in Europe for European-provided hardware and implement depot maintenance in Europe for the first two Spacelab flights. NASA has agreed to use the European capability thereafter.
4. Agreement has also been reached on the principles and procedures for transfer of Spacelab technical data between NASA and ESA and their contractors. European industry has been involved in the preparation of the agreement.
5. As far as long-term Spacelab improvements are concerned, the two Agencies have agreed to set up a joint group of 'imaginators' to establish a list of Spacelab mission requirements that can be accommodated with the present design and a list of those missions that require extension of the capability of the current design leading to possible further Spacelab developments.

Project progress

Electrical Systems Integration (ESI) is progressing on schedule and several subsystem interface tests have been successfully completed.

The Critical Design Reviews at co-contractor level have been completed or are close to completion, (except for the igloo). Corrective actions have been taken where required.

Set 1 of the Electrical Ground-Support Equipment (EGSE) was delivered on schedule and installation and preparations for acceptance testing are progressing according to plan.

The pallet and module acoustic tests have been successfully completed on schedule, despite an incident in which the module fell off its support structure and was slightly damaged.

An Orbiter/Spacelab interface meeting took place in November 1977, with NASA, ESA and contractors present. The purpose of the interface meeting was to resolve open issues mainly in the avionics, thermal and structural areas.

New delivery schedule

As a result of the new NASA Spacelab launch schedule, deliveries of hardware to NASA have now been agreed between ESA and the Spacelab Prime Contractor as follows:

- four Orbital Flight Test (OFT) pallets, in November 1978, February 1979, May 1979 and June 1979
- engineering model: long module plus two pallets, and one set of Ground Support Equipment (GSE) in June 1979
- flight unit to be delivered in two shipments in October 1979 and February 1980. The first delivery will include the long module plus one pallet, the second delivery the igloo plus three pallets and one set of GSE.

NASA has concurred with the delivery dates.

First Spacelab Payload (FSLP)

The budget for the FSLP project has been established at 12 MAU for the years 1977-1981 and the division of cost among the Member States agreed. Council is expected to officially approve the juridical declaration of the Member States participation at its December meeting.

Selection of European candidates for payload specialist on the first Spacelab mission is proceeding on schedule. After a series of interviews and tests (medical, psychological, scientific and general), six will be selected by the Agency at the end of 1977. These six will undergo further ESA and NASA tests between January and April 1978.

A similar process to choose the NASA payload specialist has been under way at NASA since September 1977.

ARIANE

The series of ten tests on four first-stage propulsion bays have just been completed, the final test lasting 30 s and making a total of 404.5 s in this configuration.

The series began in November 1976,

SPACELAB

Examen annuel du Programme

Le Directeur général de l'ESA a rencontré le Dr Frosch, Administrateur de la NASA, le 7 octobre 1977 à Paris. Cette réunion était censée constituer l'examen annuel du programme prévu dans le Mémorandum d'Accord Spacelab, bien qu'elle n'ait pas été limitée aux questions concernant ce seul programme. Parmi les principaux résultats de cette réunion, on peut citer les points suivants:

1. Suite à des modifications intervenues dans le calendrier initial de lancement de la Navette de la NASA, les dates-objectifs de lancement convenues pour les deux premières missions Spacelab sont maintenant décembre 1980 et avril 1981. En raison de l'accroissement de poids du satellite TDRS (satellite de poursuite et de relais de données), la NASA a été contrainte de prévoir, pour les deux lancements de TDRS, le recours à des vols de la Navette au lieu des lanceurs Atlas-Centaure classiques.

2. La NASA et l'ESA sont convenues que l'attribution du premier contrat pour la production d'un Spacelab supplémentaire aura lieu en octobre 1978. Cet accord représente un important pas en avant puisque cet engagement de la part de la NASA aidera l'Exécutif et l'industrie européenne à préparer la transition de la phase de développement à la phase de production.

3. Les deux Agences se sont mises d'accord sur une répartition des tâches pour les opérations Spacelab et les activités de soutien logistique. Il ressort de cet arrangement que, l'ESA créera en Europe une capacité de maintenance pour le matériel d'origine européenne et mettra en oeuvre ce type de maintenance pour les deux premiers vols du Spacelab. La NASA a accepté d'utiliser par la suite la capacité européenne.

4. Un accord est intervenu sur les principes et procédures concernant le transfert des données techniques du Spacelab entre la NASA et l'ESA et leurs contractants. L'industrie européenne a été associée à la préparation de l'accord.

5. En ce qui concerne les améliorations à long terme du Spacelab, les deux Agences sont convenues de créer un 'Groupe d'imagination' mixte chargé d'établir une liste des impératifs de mission qui peuvent être satisfaits avec la conception actuelle du Spacelab, et une liste des missions nécessitant une extension des possibilités de cette conception, ce qui pourra conduire à de nouveaux développements du Spacelab.

Avancement du projet

L'intégration des systèmes électriques (ESI) progresse conformément au calendrier. Plusieurs essais portant sur les interfaces des sous-systèmes ont été menés à bonne fin.

Les examens critiques de conception au niveau des co-contractants sont soit terminés soit sur le point de l'être, exception faite pour l'igloo. Des mesures correctives ont été arrêtées lorsqu'elles s'avéraient nécessaires.

Le premier jeu d'équipements électriques de soutien au sol (EGSE) a été livré comme prévu; sa mise en place et sa préparation en vue des essais de recette progressent conformément au plan.

Les essais acoustiques du porte-instruments et du module se sont terminés de façon satisfaisante dans les délais en dépit d'un incident survenu au module, qui est tombé de son support et a été légèrement endommagé.

Une réunion consacrée aux intefaces Orbiteur/Spacelab a eu lieu en novembre 1977 entre la NASA, l'ESA et les contractants. Cette réunion avait pour objet de mettre un point final à des questions demeurées en suspens principalement dans les secteurs de l'avionique, de la régulation thermique et des structures.

Nouveau calendrier de livraison

En raison du nouveau calendrier de lancement du Spacelab arrêté par la NASA, il a été convenu entre l'ESA et le contractant principal chargé de la réalisation du Spacelab que les matériels seraient livrés à la NASA comme suit:

- *quatre porte-instruments pour les essais en vol orbital (OFT), successivement en novembre 1978, février 1979, mai 1979 et juin 1979;*
- *un modèle d'identification comprenant un module long plus deux porte-instruments avec un jeu d'équipements de soutien au sol (GSE) en juin 1979;*
- *une unité de vol à livrer en deux lots, en octobre 1979 et février 1980 respectivement. Le premier lot comprendra le module long plus un porte-instruments, le second l'igloo plus trois porte-instruments et un jeu d'équipements de soutien au sol (GSE).*

La NASA a accepté ces dates de livraison.

Première charge utile du Spacelab (FSLP)

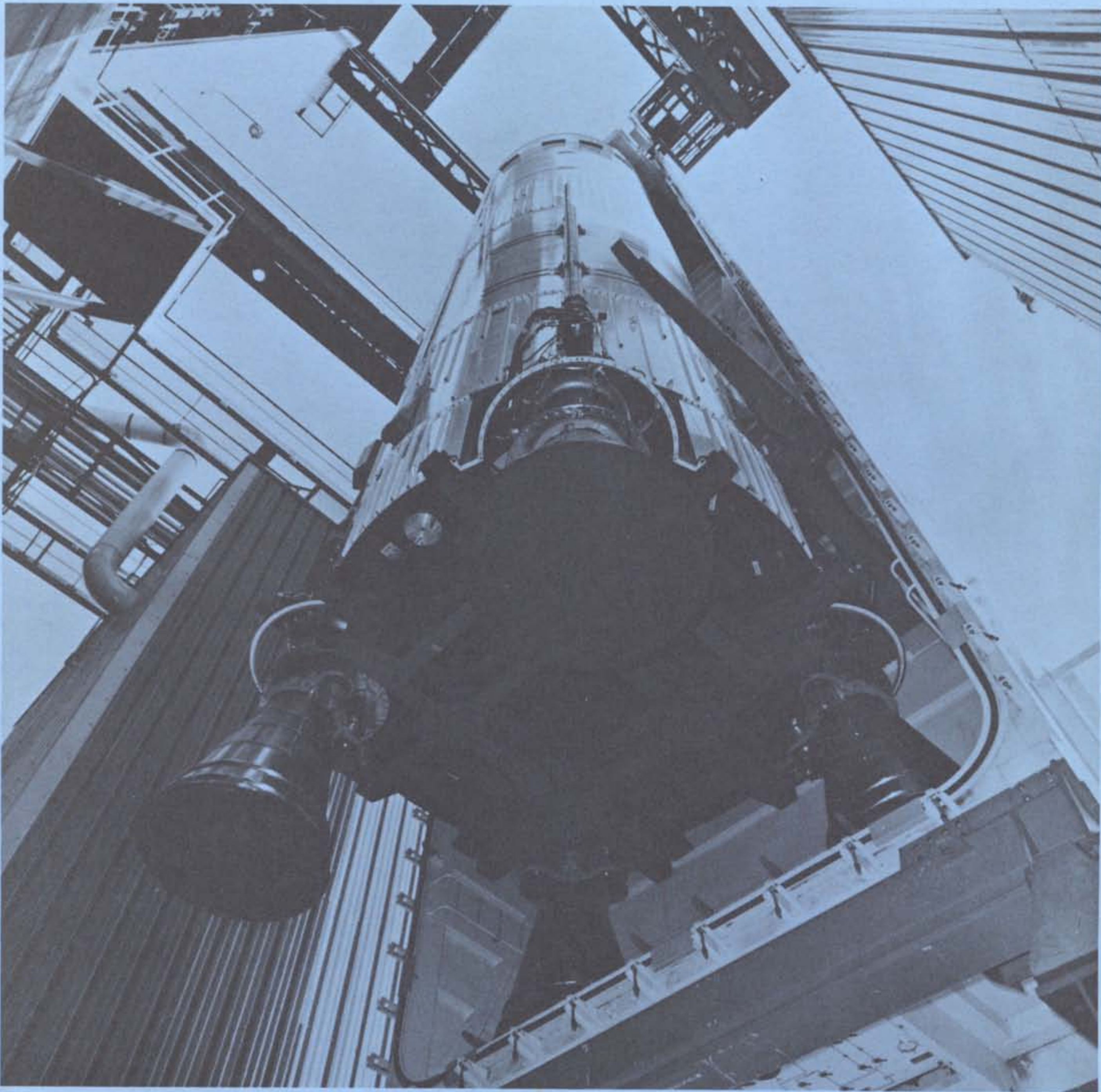
Le budget du projet FSLP a été fixé à 12 MUC pour les exercices 1977-1981 et la répartition des coûts entre les Etats-membres a été approuvée. On pense que le Conseil avalisera officiellement, à sa session de décembre, la déclaration juridique relative à la participation des Etats-membres.

La sélection des candidats européens aux fonctions de spécialiste charge utile pour la première mission se poursuit conformément au calendrier. Après une série d'interviews et de tests (aspects médicaux, psychologiques, scientifiques et généraux), six candidats seront présélectionnés par l'Agence fin 1977. Ces six candidats seront soumis à de nouveaux tests par l'ESA et la NASA entre janvier et avril 1978.

Une procédure analogue est en cours à la NASA depuis septembre 1977 pour la sélection du spécialiste charge utile de la NASA.

ARIANE

Un dernier essai de 30 s vient de clore la série de dix essais réalisés sur quatre baies de propulsion du premier étage, totalisant 404,5 s de fonctionnement dans cette configuration.



with the following main objectives:

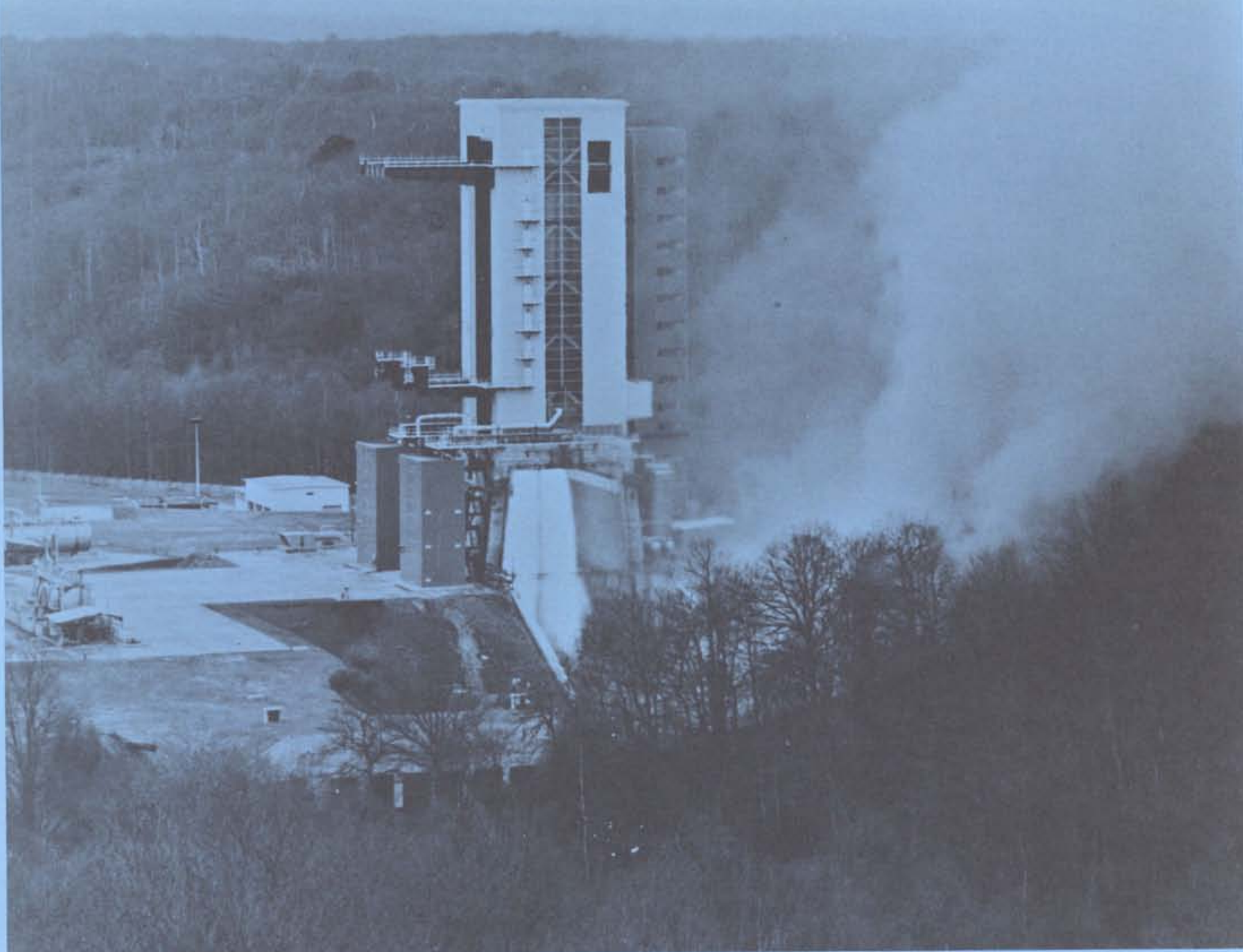
- investigation of the behaviour of the propulsion-bay in the dynamic and thermal environment created by the simultaneous functioning of the four engines
- optimisation of the transients affecting the tank-pressurisation system and the start-up/cut-off control system on start-up and shut-down of the four engines
- checking of the steady regime
- verification of the operation of the Pogo-correction systems and the nozzle actuators
- checking of the procedures for operating and qualifying the ground facilities prior to the stage tests.

During these tests, flight-standard equipment was progressively integrated, with the one exception of the two main nitrogen tetroxide and

Utilisation of lower part of transport container for elevation of Ariane 1st stage on test stand PF20.

Utilisation de la partie basse du conteneur de transport pour l'érection du 1er étage d'Ariane sur le banc d'essais PF20.

UDMH tanks, which were of the 'battleship' type in order to allow the pressurisation system to be adjusted. The capacity of the battleship tanks



Essai de baie de propulsion du 1er étage d'Ariane sur le banc d'essais PF20.

Ariane 1st stage propulsion-bay test on test stand PF20.

Commencée en novembre 1976, cette série d'essais avait pour objectifs essentiels:
- *étude du comportement de la baie de propulsion dans l'ambiance dynamique et thermique créée par le fonctionnement simultané des quatre moteurs;*
- *optimisation des transitoires au démarrage et à l'extinction des quatre moteurs, du système de pressurisation des réservoirs, du système de commande de démarrage et d'arrêt;*
- *vérification du régime stabilisé;*
- *vérification du fonctionnement des systèmes correcteurs Pogo, des vérins d'agitation des tuyères;*
- *vérification des procédures de mise en oeuvre et qualification des installations sol avant les essais d'étage.*

Ces essais ont été effectués en intégrant progressivement les équipements aux normes de vol, à la seule exception des deux réservoirs principaux de peroxyde d'azote et d'UDMH qui ont été remplacés par des réservoirs lourds de type banc pour permettre les réglages du système de pressurisation. Le volume de ces réservoirs lourds permettait un fonctionnement de 88 s environ, contre 145 s pour les réservoirs de vol.

Le problème majeur identifié dès le premier essai fut la rupture des étanchéités des circuits ergols, consécutive à l'ambiance dynamique induite à l'intérieur de la baie. L'ensemble des remèdes appliqués permirent de conduire les essais longue durée jusqu'à épuisement des ergols. Ces mêmes baies furent en outre mises à feu plusieurs fois consécutives pour permettre l'optimisation des réglages. Tous les objectifs ont été atteints de façon parfaitement satisfaisante, permettant ainsi l'introduction des réservoirs de vol dans la série d'essai d'étage complet.

Le transfert du premier étage du Site d'Intégration Lanceur aux Mureaux au Centre d'Essai à Vernon a été effectué par convoi exceptionnel dans un conteneur pressurisé de 21 m de long, 5 m de large et 6 m de hauteur.

Rappelons que quatre essais de mise au point du premier étage seront effectués de novembre 1977 à mai 1978, suivis de trois essais de qualification pendant la période de septembre 1978 à mars 1979.

allowed the engines to be run for some 88 s compared with 145 s with the flight-standard ones.

A major problem apparent during the first test was rupturing of the propellant-circuit seals, as a result of the dynamic environment induced inside the bay. A number of corrective measures enabled the long-duration tests to be conducted to propellant depletion. These same bays were also fired several times in succession in order to optimise the adjustments.

It was satisfactorily demonstrated that all the objectives had been achieved, and it was thus possible to introduce the flight-standard tanks for the series of tests on the complete stage.

The first stage was transferred from the Launcher Integration Site at Les Mureaux to the Vernon Test Centre in a pressurised container 21 m long, 5 m wide and 6 m high. It constituted an out-of-gauge load, for which special arrangements were necessary.

It might be recalled that the first stage is to undergo four series of development tests between November 1977 and May 1978, followed by three series of qualification tests between September 1978 and March 1979.

GEOS-2

The first Geos satellite was launched on 20 April 1977, but could not be placed in the correct orbit owing to a launcher malfunction.

In May, the Science Programme Committee (SPC) authorised the refurbishment of the reserve flight satellite, in order to permit a reflight on a Delta vehicle in the first half of 1978. The seven experiments on board are the same as those on Geos 1, but some minor hardware improvements have been made to four of them (without changing the spacecraft interfaces), based on the experience gained in orbit. The programme was formally approved by the SPC in November, and a tentative launch opportunity in June 1978 has been assigned by NASA. However, this date provides a wait-listed position only, and is unlikely to be confirmed before January 1978.

The refurbishment and re-integration of the satellite has proceeded smoothly, and thermal-vacuum tests have shown that performance is extremely close to that of the first Geos. A very comprehensive programme of improvement and test has been applied to the axial booms, and at the time of writing delivery for satellite boom-deployment testing is imminent.

IUE

NASA's current schedule for Delta launches foresees launch of IUE in January 1978.

In the past months, final testing of the spacecraft and scientific instrument has been carried out at Goddard Space Flight Center (GSFC). These tests included the successful deployment of the ESA-supplied solar-cell arrays.

The preparations for flight are proceeding according to a tight schedule which involves shipment of the complete spacecraft to Kennedy Space Center by 10 December.

The target date for operational readiness of ESA's IUE ground station is 1 January 1978. However, due to the delays experienced so far with the contract for station integration, intensive training and simulation activities will have to be continued during the first two weeks of January. The contractor responsible for station integration is expected to hand over all deliverables to ESA by the end of November 1977.

The progress achieved in the past months has been substantial:

- usage of the Sigma-9 computer system increased and its reliability was assured by the introduction of a second maintenance shift in April;
- several new releases of NASA software were delivered and successfully installed at Villafranca (Spain);
- the last communications facilities at the station became operational, providing a badly needed improvement, particularly with respect to close liaison between Villafranca and GSFC;
- the ESA Operations Engineer, Observatory Assistants and Spacecraft Controllers were instructed on the scientific instrument of IUE during a course held in October at GSFC;
- in September a 'dialogue' was established for the first time between the Sigma-9 computer at Villafranca and the IUE dynamic software simulator at GSFC (IBM 360 computer) via the 27.6 kbit/s data line. NASA's portable simulator was subsequently used with the IUE equipment at the station and the success of this simulation served to confirm the good progress achieved so far.

A meeting of European Users of IUE was held in Madrid in mid-September. More than 70 astronomers attended, the main aims being to sponsor collaboration among European astronomers and to familiarise existing and future users with the spacecraft, the scientific instrument and the ground observatory. The meeting included presentations by NASA, the UK Science Research Council and ESA project personnel, and a visit to the IUE ground station.

EXOSAT

Satellite

Since the Test Concept Review in July, efforts have been directed towards drawing, reviewing and approval of system/subsystem design specifications and plans/procedures for implementation of the development programme. Full readiness of all base material for the Critical Design Review early in December has not been achieved. In particular, design work for structure/thermal and attitude and

GEOS-2

Le premier satellite Geos a été lancé le 20 avril 1977 mais n'a pu être mis sur la bonne orbite en raison d'une défaillance du lanceur.

En mai, le Comité du programme scientifique a autorisé la remise en état du modèle de vol de réserve du satellite pour pouvoir procéder à un deuxième lancement sur véhicule Delta dans le courant du premier semestre 1978. Les sept expériences embarquées sont les mêmes que celles qui figuraient sur Geos 1 mais les enseignements tirés du premier satellite ont permis d'apporter quelques améliorations mineures au matériel de quatre expériences (sans pour autant modifier les interfaces avec le véhicule spatial). Le programme a été officiellement approuvé par le SPC en novembre et la NASA a provisoirement donné juin 1978 comme première possibilité de lancement. Toutefois, cette date n'est qu'une indication de rang sur la liste d'attente et il est vraisemblable qu'elle ne sera pas confirmée avant janvier 1978.

La remise en état et la ré-intégration du satellite se sont effectuées sans heurt et les essais de vide thermique ont montré que ses performances sont très voisines de celles du premier modèle de Geos. Un programme très complet d'améliorations et d'essais a été appliqué aux bras axiaux et, au moment où ce texte est rédigé, les essais de déploiment des bras du satellite sont imminents.

IUE

L'actuel calendrier de la NASA pour les lancements par fusées Delta prévoit le lancement d'IUE en janvier 1978.

Au cours des derniers mois, les essais définitifs du véhicule spatial et de l'instrumentation scientifique ont été effectués au Goddard Space Flight Center (GSFC). Au nombre de ces essais figurait le déploiement réussi des panneaux de cellules solaires fournis par l'Agence.

Les préparatifs du vol se déroulent conformément à un calendrier serré, qui prévoit l'envoi du véhicule spatial complet au Kennedy Space Center pour le 10 décembre.

La date-objectif à laquelle la station sol IUE de l'ESA doit être opérationnelle est celle du 1er janvier 1978. Toutefois, étant donné les retards rencontrés jusqu'ici à l'occasion du contrat relatif à l'intégration de la station, il faudra poursuivre pendant les deux premières semaines de janvier des activités intensives de formation du personnel et de simulation. On prévoit que le contractant chargé de l'intégration de la station livrera à l'ESA pour la fin de novembre 1977 tous les éléments prévus.

Au cours des derniers mois, des progrès notables ont été réalisés:

- *l'utilisation du système calcul Sigma 9 a été renforcée et sa fiabilité a été assurée par la mise sur pied en avril d'une deuxième équipe de maintenance;*
- *de nouveaux lots de logiciel NASA ont été livrés et installés avec succès à Villafranca (Espagne);*
- *les installations de télécommunications définitives de la station sont devenues opérationnelles, ce que l'on attendait avec impatience étant donné en particulier la nécessité d'assurer une liaison très étroite entre Villafranca et le GSFC;*
- *l'ingénieur ESA responsable des opérations, les assistants de l'Observatoire et les contrôleurs du véhicule spatial ont participé en octobre au GSFC à un cours de formation à l'instrumentation scientifique d'IUE;*
- *en septembre, un dialogue a été établi pour la première fois entre le calculateur Sigma 9 de Villafranca et le simulateur dynamique de logiciel d'IUE installé dans le calculateur IBM 360 du GSFC, via la liaison de données à 27,6 kbit/s. On a, par la suite, utilisé le simulateur portatif de la NASA pour tester l'équipement IUE à la station et les bons résultats de cette simulation ont confirmé les progrès réalisés.*

Une réunion des utilisateurs européens d'IUE s'est tenue à Madrid à la mi-septembre. Plus de 70 astronomes assistaient à cette réunion, dont l'objectif essentiel était de favoriser la collaboration entre astronomes européens et de familiariser les utilisateurs présents et futurs d'IUE avec le véhicule spatial, l'instrumentation scientifique et l'observatoire au sol. Au cours de la réunion des exposés ont été faits par des responsables du projet de la NASA, du Conseil britannique de la Recherche scientifique et de l'ESA; les participants ont en outre visité la station sol IUE qui les a beaucoup intéressés.

EXOSAT

Le satellite

Depuis l'examen de conception des essais qui a eu lieu en juillet, on s'est attaché à rédiger, réviser et approuver les spécifications conceptuelles aux niveaux système et sous-système ainsi que les plans et procédures pour la mise en oeuvre du programme de développement. Tous les éléments de base n'ont pu être intégralement prêts pour l'examen critique de la conception en début décembre. En ce qui concerne en particulier les aspects structure/thermique, la commande d'orientation et le contrôle d'orbite, la conception n'a pu être poussée à son point final. Malgré ces retards, le contractant prévoit que la phase B se terminera dans les délais prévus, en février 1978.

Le choix – à partir de trois options – d'un système d'orientation par jets d'hydrazine/propane s'est traduit sur le plan technique par certaines modifications intéressantes de la configuration des matériels – notamment un réservoir toroïdal pour le propane et des chambres combinées d'ébullition et de tranquillisation pour transformer le liquide en gaz. Les bilans de masse et de puissance sont préoccupants et devront retenir toute l'attention lors du prochain examen.

Le choix du quatrième étage du lanceur Ariane a fait l'objet d'une orbit control could not be finalised. In spite of the delays, the contractor foresees timely completion of Phase-B in February 1978.

Technically speaking, the selection of a hydrazine/propane reaction control system from three options studied has led to some interesting changes in hardware configuration – notably a toroidal storage tank for the propane and combined thermal boiler and plenum chambers for liquid/gas conversion. Trends in mass and power budgets are a matter for concern and merit full attention at the forthcoming review.

An internal trade-off study concerning the choice of the fourth stage for the Ariane launcher has been performed. As a result of the investigation, the Po 7 stage so far considered in the baseline configuration has been retained and the alternative (MOPU) dropped for the Exosat launch.

Payload
A series of Critical Design Reviews is currently being held with the payload-unit contractors, and the outcome so far is considered satisfactory.

An area of concern related to the Ariane-induced launcher environment, may be alleviated by a proposal to replace the random-vibration test on the flight spacecraft by an acoustic-noise test. This change, which is currently being studied, could lead to a relaxation in subsystem/unit test levels.

The long-beam x-ray testing of the LE telescope is currently taking place in Denver USA, as part of the Phase 1 payload-unit programme. The objective of this programme is to derive detailed designs for engineering-model payload units prior to giving the go-ahead for engineering-model production.

ESOC
The idea of using the DFVLR ground station at Weilheim for the operational support of Exosat has now to be dropped because of the agreed extension of the Helios mission.

Negotiations are currently being held with the German Authorities regarding the use of S-band frequencies from the Michelstadt ground station in the Odenwald. In the event that a satisfactory agreement can be reached, the current Geos facilities at Michelstadt will have to undergo some modification and the question of an operational conflict in later years needs to be resolved.

SPACE TELESCOPE

The ESA/NASA Memorandum of Understanding on the Space Telescope Project was signed on 7 October 1977.

Solar array
Following evaluation of the proposals from industry for the Space-Telescope solar array and negotiations with the tenderers for the flexible-type array on some interface modifications that had to be introduced after NASA had selected the Prime Contractor for the Telescope, a recommendation for contract award was made to the Industrial Policy Committee. The IPC, at its September meeting, approved the recommendation to award the contract to the British Aircraft Corporation (BAC), and at its October meeting endorsed the recommendation that the subcontract for a welded solar blanket be placed with AEG-Telefunken. Phase-B (Definition Phase) activities were formally initiated on 4 October 1977 and progress since then has been satisfactory.

Photon-detector assembly
Several alternative technical solutions for the Photon Detector Assembly (PDA) had been submitted by Industry in their tenders. Following a detailed analysis of both performance characteristics and development risks, a configuration based on a two-stage intensifier and an EBS camera tube (I^2-EBS configuration) was selected. The evaluation of the proposals for the PDA led to a recommendation to the IPC for contract award to BAC, which was approved by the IPC at its September meeting. Phase-B activities were formally initiated on 6 October 1977 and progress since the has been satisfactory.

Camera module
Following receipt of the camera-module proposals on 26 September 1977, evaluation has started with the aim of presenting a recommendation for contract award to the IPC in December 1977, so that the camera-module Phase-B can be initiated in early January 1978.

NASA activities
NASA had signed the prime contracts for the Space Telescope support-systems module and Optical Telescope Assembly by mid-October and in early November selected the NASA scientific instruments. These instruments, a wide-field camera, a faint-object spectrograph, a high-resolution spectrograph and a high-speed photometer will, together with ESA's Faint Object Camera, form the complete scientific instrument package to be flown during the first in-orbit operation of the Space Telescope. NASA also nominated the Science Working Group members who will provide the scientific inputs for the Telescope's design and development.

SPACE SLED

Progress by ERNO, the Prime Contractor, since the start of Phase-B activities at the end of September 1977 has been satisfactory. Major external interfaces with Spacelab and the experimenter-supplied hardware packages have been well defined and initial subsystem trade-offs have been made. The work accomplished represents the first iteration towards establishing subsystem concepts by January 1978, the planned end of the first part of Phase-B, called the 'Design Evaluation Phase'.

The results of the First Spacelab Payload Accommodation Study presented at the formal SPICE review meeting in early November revealed no major problems in physically accommodating the Sled facility or its experiment packages.

étude d'arbitrage intra-muros. A la suite de cette étude, l'Agence a retenu l'étage P07 envisagé jusqu'à ce jour comme configuration de référence et a écarté la solution de remplacement (MOPU) pour la mission Exosat/Ariane.

La charge utile

Une série d'examens critiques de conception se déroulent actuellement avec les contractants responsables de la charge utile. Les résultats de ces examens sont jugés jusqu'à présent satisfaisants.

L'environnement imposé par le lanceur Ariane suscite quelques préoccupations; une proposition tendant à remplacer les essais en vibrations aléatoires à effectuer sur le satellite de vol par des essais de bruit acoustique améliorera peut-être cet état de choses. Cette modification, qui est à l'examen, pourrait conduire à fixer des niveaux d'essais moins rigoureux pour les sous-systèmes et les unités.

L'essai sous long faisceau de rayons X du télescope faible énergie se déroule actuellement à Denver, Etats-Unis. Cette activité entre dans le cadre du programme de phase 1 de la charge utile qui a pour objet de définir des conceptions détaillées de charges utiles 'modèle d'identification' avant que ne soit donné le feu vert pour la production de ces modèles.

ESOC

L'extension de la mission Hélios ayant été approuvée, on ne peut plus retenir pour le soutien opérationnel d'Exosat la station sol DFVLR de Weilheim à titre de solution de rechange pour la configuration de référence.

Des négociations ont lieu actuellement avec les autorités allemandes au sujet de l'utilisation de fréquences de bande S à partir de la station sol de Michelstadt dans l'Odenwald. Si elles aboutissent, certaines modifications devront être apportées aux installations Geos actuelles dans cette station et l'on devra régler la question d'un risque de chevauchement des opérations dans les années à venir.

TELESCOPE SPATIAL

Le Mémorandum d'Accord entre l'ESA et la NASA concernant le projet de télescope spatial a été signé le 7 octobre 1977.

Réseau solaire

Après évaluation des propositions soumises par l'industrie pour le réseau solaire du télescope spatial et négociation avec les soumissionnaires ayant offert un réseau souple de certaines modifications qui avaient dû être apportées aux interfaces après le choix par la NASA des contractants principaux du télescope spatial, l'Exécutif a fait une recommandation à l'IPC pour l'attribution du contrat. A sa réunion de septembre, l'IPC a donné son agrément à la passation du contrat avec la British Aircraft Corporation (BAC) et à sa réunion d'octobre, il a entériné l'attribution à AEG-Telefunken du sous-contrat relatif à la nappe de photopiles à soudage électrique, conformément aux recommandations formulées. Les activités de phase B ont officiellement démarré le 4 octobre 1977 et se sont déroulées depuis lors de façon satisfaisante.

Détecteur de photons

Différentes solutions techniques avaient été proposées pour l'ensemble détecteur de photons (PDA) dans les offres soumises par l'industrie. Après analyse détaillée des caractéristiques de performances, d'une part, et des risques de développement, d'autre part, une configuration comportant un intensificateur à deux étages couplé à un tube analyseur EBS (dite configuration I^2-EBS) a été retenue. L'évaluation des soumissions relatives au PDA a abouti à une recommandation d'attribution du contrat à BAC, que l'IPC a approuvée à sa réunion de septembre. Les activités de phase B ont officiellement démarré le 6 octobre 1977 et se sont déroulées depuis lors de façon également satisfaisante.

Chambre

Après réception le 26 septembre 1977 des offres concernant la chambre, l'évaluation a démarré avec pour objectif une recommandation à l'IPC en décembre 1977 pour l'attribution du contrat, de façon que les activités de phase B relatives à la chambre puissent commencer début janvier 1978.

Activités de la NASA

La NASA a signé à la mi-octobre les contrats principaux relatifs au module systèmes de soutien et à l'ensemble télescope optique et elle a sélectionné début novembre les instruments scientifiques dont elle équipera le télescope spatial. Ces instruments – une chambre à grand champ, un spectrographe pour objets de faible luminosité, un spectrographe à haute résolution et un photomètre ultra-rapide – constitueront avec la chambre pour objets de faible luminosité de l'ESA l'intégralité de l'instrumentation scientifique du télescope spatial durant sa première période d'exploitation en orbite. La NASA a également désigné les membres du groupe de travail scientifique chargé du télescope spatial qui aura pour tâche d'apporter les données scientifiques nécessaires à la conception et au développement du télescope spatial.

TRAINEAU SPATIAL

Depuis le démarrage des activités de phase B fin septembre 1977, les travaux progressent chez ERNO, le contractant principal, de façon satisfaisante. Les principales interfaces externes avec le Spacelab et les lots de matériels fournis par les expérimentateurs sont bien définis et l'on a procédé aux premières études d'arbitrage au niveau sous-systèmes. Les travaux accomplis constituent la première itération devant permettre la mise au point des concepts des sous-systèmes pour janvier 1978, date à laquelle doit en principe prendre fin la première partie de la phase B, appelée phase d'évaluation de la conception.

Les résultats de l'étude de logeabilité de la première charge utile du Spacelab, présentés début novembre au cours de la réunion officielle d'examen du SPICE, n'ont révélé aucun problème majeur touchant l'installation matérielle du traîneau ou de ses blocks d'expériences.

(Suite de la page 32)

gique était extrêmement faible –), ou sous la forme d'un soutien des compétences industrielles déjà développées dans certains 'créneaux' technologiques dans les pays membres dépourvus d'un programme spatial national.

Le même document contenait également:
- un tour d'horizon assez large sur l'évolution des exigences techniques des missions futures dans les grands secteurs de la Science, des Télécommunications, et de l'Observation de la terre, ainsi qu'une analyse détaillée des grands axes autour desquels un programme de RT à moyen terme devrait être élaboré;
- et enfin quelques réflexions préliminaires sur les problèmes restant à étudier.

En effet, malgré l'effort considérable déjà fait, les lacunes dans l'édification d'une politique technologique de l'Agence sont encore importantes et méritent qu'on s'y attarde quelque peu, ne serait-ce que pour poser les problèmes.

LA PROCHAINE ETAPE

Il est clair que l'absence d'une politique technologique codifiée dans un Règlement dûment approuvé (à supposer qu'un tel document puisse un jour exister), n'est pas une raison pour arrêter l'effort de R&D, et il importe donc qu'un programme des actions de recherche à mener par l'Agence, *harmonisé avec les activités nationales*, soit établi et approuvé. Un premier *'Projet de programme à moyen terme de RT (1978–1980)'* a été préparé et distribué aux Délégations. Il couvre la totalité des activités de recherche que l'Exécutif considère nécessaires pour la préparation des programmes futurs de satellites en distinguant les actions de recherche qui sont proposées pour un financement ESA (dans le cadre d'un budget annuel évoluant de 6 à 7 MUC entre 1978 et 1980), de celles qui pourraient être financées et exécutées dans un cadre national. Il n'y a là rien de bien nouveau sur le plan de la philosophie, sauf que cette distribution des tâches au niveau européen devra être conjointement décidée avec chaque Etat-membre intéressé pour arriver à 'harmoniser' le maximum possible de l'ensemble du programme européen (ESA et Agences nationales). Que recouvre ce concept? En fait il s'agit simplement d'une coordination souple, sous l'égide de l'Agence, de la programmation des activités technologiques nationales dont les résultats seraient alors, en échange, utilisés par l'ESA au même titre que ceux de ses propres activités de recherche.

Bien entendu, pour qu'une activité financée au plan national puisse faire partie de ce programme harmonisé, un certain nombre de conditions seront à remplir: engagement de l'Etat-membre intéressé à poursuivre l'activité selon les phases convenues; participation de l'ESTEC (principal Centre de Recherche et de Technologie de l'Agence) à l'établissement des spécifications; visibilité de l'Agence sur le déroulement des travaux (par exemple, participation des spécialistes de l'ESTEC aux réunions d'avancement); disponibilité des résultats pour l'Agence (avec évidemment les réserves d'usage, concernant leur utilisation)... Autrement dit la gestion du contrat restera sous la responsabilité de l'organisme spatial national, mais en consultation avec l'ESA. Dans certains cas particuliers, ce concept simple d'harmonisation peut aussi être étendu à une véritable coopération entre l'Agence et un Etat-membre (financement conjoint) pour des actions de recherche importantes pour lesquelles aucune des deux parties ne dispose de la totalité des fonds nécessaires. Un énorme gaspillage des rares ressources financières disponibles en Europe devrait ainsi être évité par une utilisation plus rationnelle d'une partie au moins des financements nationaux, orientée vers la satisfaction des besoins techniques de l'ESA; par ailleurs une telle orientation ne peut être en général que bénéfique pour les Etats-membres concernés et leurs industries. Le processus de concertation ci-dessus a commencé en novembre 1977 par des discussions bilatérales avec les responsables des programmes nationaux de technologie de France, d'Allemagne et du Royaume-Uni.

LE PROBLEME MAJEUR

Un préalable fondamental à la finalisation d'une politique technologique (pourra-t-elle d'ailleurs être finalisée un jour?) est celui de la définition des structures industrielles souhaitables pour l'Europe en matière spatiale. Une telle perspective est en effet nécessaire si l'on peut clarifier les interfaces entre la RT et: la spécialisation industrielle dans certains secteurs (lesquels?), la politique de standardisation visant à réduire les coûts des projets futurs (quel niveau de standardisation?), l'utilisation effective des résultats de la RT dans les projets de satellites réalisés par les consortiums... Deux réflexions de 'politique industrielle' au sens large sont nécessaires:

- sur la structure des consortiums industriels et son évolution souhaitable;
- sur la façon *d'associer la promotion des compétences technologiques à la création en Europe d'une infrastructure industrielle et commerciale* compétitive au plan mondial (l'un des objectifs explicités dans la Convention de l'ESA).

En ce moment en effet, en l'absence d'une perspective claire concernant cette structure industrielle spatiale future, l'allocation des contrats de RT se fait, sauf exceptions (spécialisation industrielle déjà reconnue dans quelques secteurs précis), en faisant jouer la compétition et en basant le choix principalement sur le critère de qualité technique, ce qui conduit à une distribution quelque peu désordonnée des activités de recherche, quelquefois d'ailleurs confiées à des firmes qui n'auront aucune chance d'utiliser les compétences acquises au niveau des projets. C'est en fait l'Agence, à travers son principal établissement technique, l'ESTEC, qui assure dans la majorité des cas le transfert des résultats des contrats de RT dans la définition des satellites. Un changement des rôles respectifs de l'ESTEC et de l'industrie dans l'application aux projets des technologies nouvelles serait souhaitable (en particulier pour les satellites d'applications proposés par l'industrie sur des marchés extérieurs); mais ceci suppose au préalable l'émergence d'une structure industrielle concentrée en quelques 'entités' techniquement efficaces (grâce à la disponibilité de la gamme des technologies avancées nécessaires), financièrement solides (préfinancement des opérations) et commercialement dynamiques, dont les possibilités de succès dans la concurrence mondiale seraient reconnues. C'est seulement dans le cas où de telles entités industrielles auraient pu être identifiées à l'avance, que l'allocation des contrats de RT pourrait être orientée de façon à participer activement à l'amélioration souhaitable de la compétitivité de cette industrie européenne restructurée.

La question qui se pose tout de suite est la suivante: est-il réaliste de penser à la mise sur pied de ces entités regroupant à la fois la puissance industrielle, commerciale et technologique, sans sacrifier la nécessité de la participation équitable de tous les Etats-membres à l'effort commun? *Cette question est au coeur du problème de la politique industrielle de l'Agence*, et il importe donc de lui trouver une réponse positive.

ESQUISSE D'UNE EVOLUTION POSSIBLE

Pour tenter de répondre, au moins partiellement, à la question ci-dessus, il convient d'abord de résoudre le problème de la promotion technologique des pays membres ne disposant pas d'un programme national. Examinons si une évolution de la structure de la RT en Europe ne permet pas d'avancer dans cette direction. Dans le passé récent, cette structure comportait trois volets relativement indépendants:

- la RT de base de l'ESA;
- le programme de technologie de soutien (dans le cadre du programme de télécommunications de l'ESA);
- les programmes nationaux de technologie.

Un premier progrès à faire réside d'une part dans la disparition de la distinction artificielle qui a été faite entre RT de base et technologie de soutien, et d'autre part dans l'harmonisation d'une partie au moins des programmes nationaux avec celui de l'Agence, selon le concept défini ci-dessus. Mais ceci ne fait pas avancer le problème de la promotion de la technologie de pointe dans les 'petits' pays, problème qui ne peut être résolu que si leur contribution à un programme de technologie géré pour leur compte par l'ESA est portée en valeur absolue à un niveau nettement supérieur à ce qu'il est actuellement: par exemple, pour le programme RT de base s'élevant à 5 MUC, la part 'normale' d'un pays dont le taux de contribution est de 3% s'élève à 150 kUC, soit l'équivalent de 3 à 4 ingénieurs par an! Ceci est nettement au-dessous du seuil nécessaire pour créer ou même maintenir une compétence technologique avancée dans un ou a fortiori plusieurs secteurs. Or le concept d'harmonisation déjà envisagé ne concerne que les 'grands' pays et quant aux mesures à moyen terme prises pour les autres, elles ne devraient constituer qu'un palliatif temporaire. D'un autre côté, nous avons déjà souligné que la politique technologique de l'Agence devrait être adaptée aux différences entre les Etats-membres, tant en ce qui concerne leurs taux de contributions, que leurs potentiels industriels spatiaux. Enfin la possibilité de réduire les fossés technologiques existants au moyen d'un accroissement important du budget RT de l'Agence risque de se heurter à l'opposition de certains pays qui ne désirent pas ce transfert vers l'Agence de leurs activités nationales.

Une solution à ce problème pourrait consister dans la création d'un *'programme spécial de technologie'* ouvert à tous les Etats-membres qui verraient un intérêt à faire développer leurs capacités industrielles dans le cadre de l'Agence, soit parce qu'ils ne disposent pas des organismes techniques nécessaires à la gestion d'un programme national, soit parce que les perspectives de débouchés offertes à leur industrie au niveau des projets ESA pourraient être plus larges du fait que la gestion des contrats de technologie est alors effectuée dans le cadre de l'Agence. Sur le plan de la gestion, la différence avec le programme de RT de base résiderait essentiellement dans le fait que les activités dont le développement serait confié aux firmes d'un pays donné correspondraient à sa contribution et seraient définies en accord avec la Délégation et l'industrie correspondantes.

La structure de la RT en Europe évoluerait ainsi vers un système à trois volets, dont la majeure partie serait coordonnée effectivement par l'Agence:

- *Programme de RT de base:* objectif principal axé sur la préparations des projets futurs (définition au niveau sous-système, standardisation, méthodes d'essais, études exploratoires pour l'avenir...); politique industrielle plutôt orientée par le soutien aux 'entités' dont nous avons déjà parlé.

- *Programme spécial de technologie:* objectif principal plutôt orienté par la politique industrielle (promotion technologique, spécialisation).

- *Programmes nationaux* dont une partie serait harmonisée avec les deux programmes précédents: objectif principal défini par des considérations de politique nationale.

On aurait ainsi la souplesse due à l'utilisation harmonieuse de trois outils différents, qui pourrait permettre éventuellement de réconcilier à long terme les trois objectifs généraux déjà cités: compétitivité de l'industrie, rationalisation et 'juste retour' industriel.

LE BUT FINAL

La lecture de ce qui précède pourrait faire croire aux esprits pessimistes que la 'politique technologique' est un mirage à l'horizon, et que plus on croit s'approcher du but, plus il recule. Elle pourrait également suggérer que l'on a tourné en rond, depuis 1974, autour de la difficulté que constitue la conciliation des objectifs de politique industrielle inscrits dans la Convention de l'Agence.

En réalité des progrès considérables ont été faits puisque la plupart des idées initiales sont maintenant acceptées par l'ensemble des parties intéressées (objectifs de la RT, rôle de l'Agence, harmonisation des programmes, actions de promotion technologique...) et que les dernières discussions avec les principaux Etats-membres sur la mise en oeuvre de l'harmonisation ont fait apparaître un esprit de coopération très positif. Ainsi, à travers à la fois une approche philosophique et une approche pragmatique et concrète, on a cerné le problème et ceci peut être interprété littéralement, car une dernière question reste au centre du chemin sur lequel nous avançons depuis quelques années: c'est celle de la *structure de l'industrie européenne la mieux adaptée à la compétitivité recherchée.* Une réflexion sérieuse reste à mener à bien sur ce point fondamental de la politique industrielle, et alors la politique technologique en découlera immédiatement. La route parcourue jusqu'à présent convergera alors, dans un mouvement spiral, vers le but final. □

Ultraviolet and Visible Astronomy from Space

F. Macchetto, Space Science Department of ESA, ESTEC, Noordwijk, The Netherlands

The opportunity to carry out astronomy from space has been the realisation of a dream that astronomers have had for decades. Such observations have already provided a wealth of information from which many exciting discoveries and surprises have appeared and they have significantly advanced our understanding of the universe.

Space astronomy provides distinct advantages over the traditional techniques of ground-based astronomy. First, the absence of atmospheric absorption greatly expands the range of the electromagnetic spectrum which is accessible. The atmosphere at ground level blocks out most of the radiation below 3000 Å and provides only a few 'windows' at wavelengths longer than 10 000 Å. This is clearly shown in Figure 1. In the ultraviolet, observations in the region 2000–3000 Å are possible from high-altitude balloons operating between 30 and 40 km, but for observations over the full wavelength range of interest rocket- or satellite-borne telescopes are needed. A second limitation imposed by the atmosphere on earth-based telescopes is due to the presence of night-sky emission and scattered light. Even in locations where there is very little dust in the air, auroral emission in the upper atmosphere and the airglow effectively set a lower limit to the surface brightness of any other source that can be detected against this background.

Finally, there is the problem that the mass of air around and above a ground-based telescope is in constant turbulent motion, with the result that the stellar images are seriously degraded. These atmospheric disturbances, referred to as 'seeing' by the visual astronomer, limit the angular resolution of a ground-based telescope to about 1 arc sec. In theory, the resolving power of a telescope is directly proportional to its aperture, but in practice there is no gain in resolving power when the aperture is larger than about 30 cm due to the degrading effects of 'seeing'. This limitation in spatial resolution is no longer a problem when observations are made from space. There is, however, a constraint on the range and performance even of a space telescope. The wavelength range usable in the extreme ultraviolet is limited by the hydrogen present throughout interstellar space, which effectively absorbs any starlight of wavelength shorter than 912 Å. It is not until the soft x-ray region is reached that radiation path lengths become comparable to the size of the galaxy.

Hitherto, balloon, rocket and satellite experiments launched to study the ultraviolet stellar radiation have tended to capitalise on the extended wavelength coverage achievable in orbit. Why should this be, and what are the scientific reasons for studying the various spectral regions? Indeed, it is pertinent to ask at this time of financial constraint what we can learn from space astronomy that cannot be learnt using ground-based observations.

We live by the sun; hence it is natural to want to understand the nature of this rather normal main sequence star. How is such a star created? Current ideas suggest that they originate as local condensations in the clouds of interstellar gas and dust. If such a protostar has a mass similar to that of the sun, it will continue to contract under the influence of its own gravity. At the same time, the density and the temperature at the centre of the protostar will rise until the values are those required to start thermonuclear reactions.

During these phases, the surrounding mass of dust effectively blocks the protostar from view, except at wavelengths in the infrared and radio regions. Observations from space at infrared wavelengths will give insight into these critical stages of condensation and stellar formation. During the life of a star, the nuclear-fusion process converts hydrogen into the heavier elements with the release of energy; the more massive the star, the more rapid its rate of energy production and hence the shorter its life expectancy. A star with a mass similar to that of the sun may last for about 50 000 million years. On the other hand, a more massive star, say one with 10 times the mass of the sun, will radiate 1000 times more energy per unit mass, it will be very much hotter than the sun, and it will radiate 10 000 times more energy per unit time. Its life cycle will therefore be about 50 million years, a thousand times shorter than that of the sun. Assuming that the age of our galaxy is about 10 000

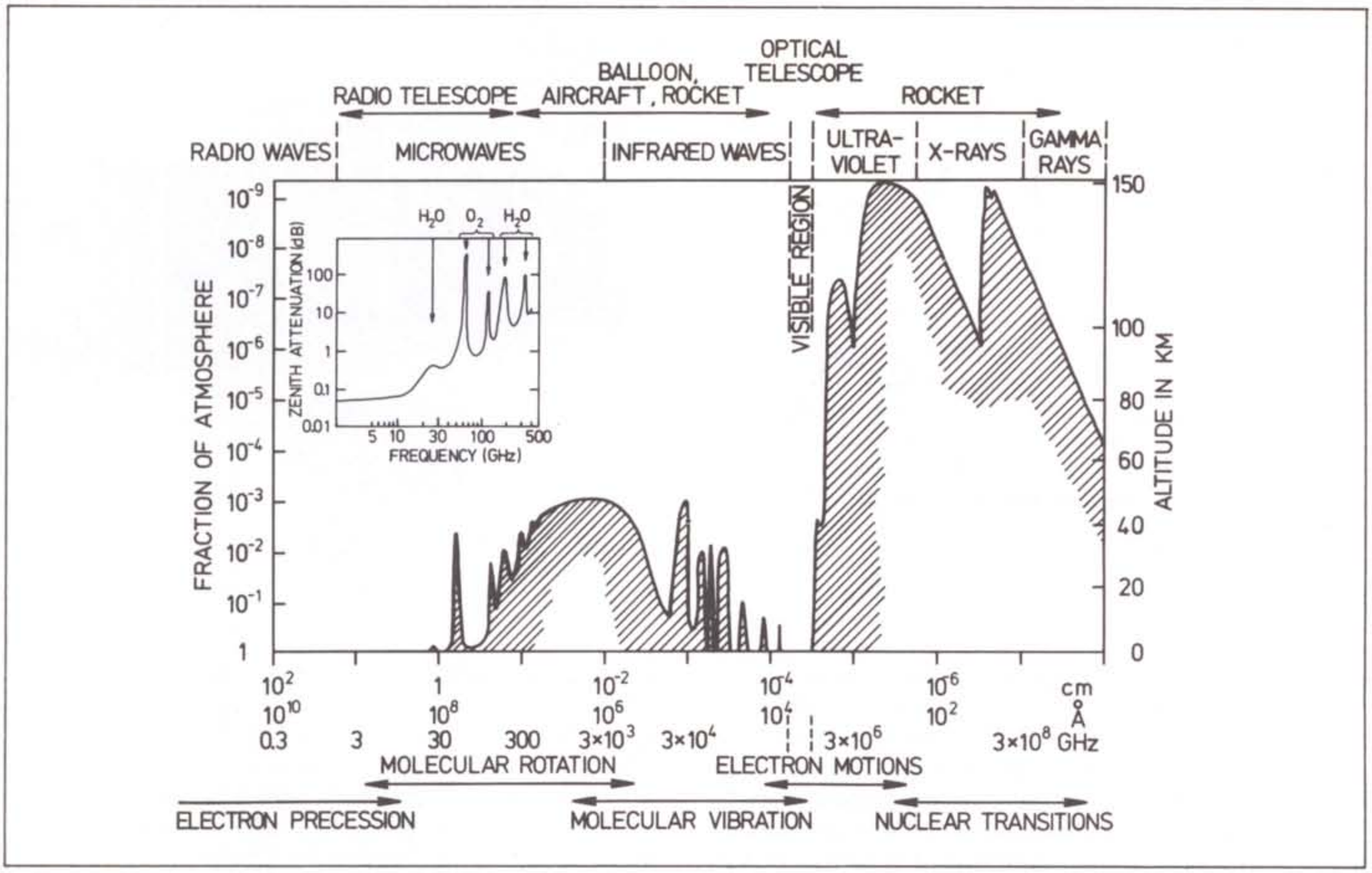


Figure 1 – Atmospheric attenuation as a function of wavelength.

million years, there has been enough time for several generations of hot massive stars to have lived and died. Thus, the hottest stars are those that will show the effects of aging most markedly, i.e. they will have a larger concentration of the heavier elements. As the temperature of an object increases, the wavelength at which the maximum emission occurs decreases. Since surface temperatures of hot stars range from 15 000 to 50 000 K, the peak in the emission and most of the emitted energy lie in the ultraviolet. A comparison between the spectral distributions of a hot star and a sun-like star is shown in Figure 2. It is obvious that in order to understand the physical processes that occur in hot stars, observations have to be made in the ultraviolet spectral region.

Another important consideration is that the hot young stars will contain proportionally more material which originated in earlier stars and was subsequently ejected into the interstellar medium by the powerful supernova explosion which terminates the life of these large-mass stars. The chemical composition of a young massive star is therefore very different from that of the sun, and measurements are crucial to test the details of the theory of stellar evolution. Measurements of chemical composition are best carried out in the ultraviolet, since the strongest lines of the most abundant elements such as H, He, C, N, O, Si, S, Fe, and Mg, all fall in this spectral region.

As the same elements that form the stars are also found in the interstellar medium, some of the absorption lines seen in a stellar spectrum are actually due to the absorption of the starlight as it passes through the interstellar medium. The intensity of an interstellar absorption line tells us how much of a given element is present in the medium in a particular state of ionisation. As it is seldom possible to observe spectral lines from all the states of ionisation in which a given element may exist in the interstellar medium, the fraction of ions in a given state must be calculated from theory. Since atoms in the interstellar gas are ionised by the action of the ultraviolet radiation field, it becomes essential to measure the flux of this radiation.

The interstellar medium contains small solid particles, or 'dust', which cause a wavelength-dependent absorption and scattering of the light from stars. This phenomenon is usually called 'reddening' as this extinction, at least in the visible portion of the spectrum, increases with decreasing

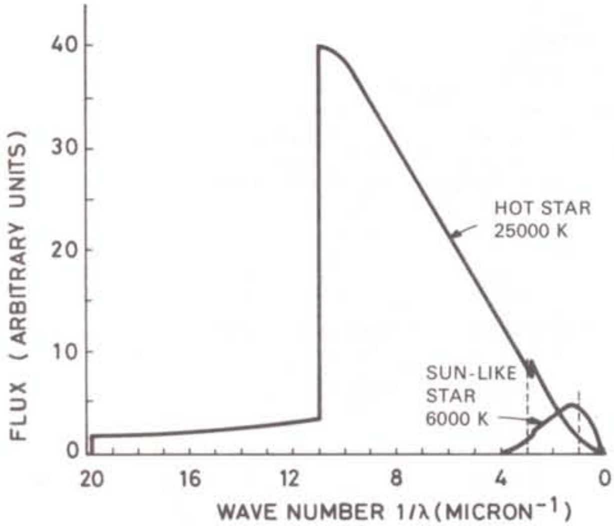


Figure 2 – Comparison of the spectral distributions of a hot star and a sun-like star.

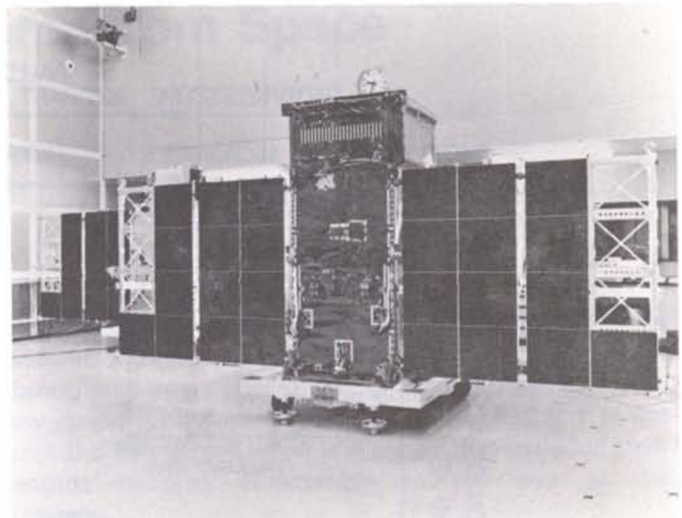


Figure 3 – The TD-1 astronomy satellite launched in 1972.

wavelength and therefore gives a redder appearance to the objects. Observations of this reddening curve in the ultraviolet are very important, since the observed electronic transitions and excitations can lead to an understanding of the chemistry and physical characteristics of the dust particle, whilst infrared observations can supplement this information by identifying the nature of the vibrational states in the crystals. These particles appear to play a most important part, e.g. as catalysts, in favouring the exchange reactions that lead to the formation of the complex molecules observed in the dense interstellar clouds at infrared and radio wavelengths. Knowledge of the physical characteristics and chemical identity of these interstellar grains is therefore essential to provide insight as to the role that these dense clouds play in the process of star formation.

The importance of studying the ultraviolet spectra of external galaxies has been recognised for many years, as this spectral region is particularly suited for detailed investigations of the type, population, and distribution of the hot stars. In the spiral galaxies, ultraviolet observations provide the information necessary to locate and establish the numbers of these recently formed stars. This data can then be combined with information obtained from visible, infrared and radio observations to test the predictions made by the theory of spiral structure. Observations in these wavelength regions also shed light on the distribution and nature of the interstellar dust and gas components in other galaxies. Any difference in composition between different classes of galaxies could provide important clues as to the evolutionary effects to be expected in these objects.

A more exotic group of extragalactic objects are the emission-line galaxies, radio galaxies, Seyfert galaxies, Markarian galaxies and the quasi-stellar objects. Their properties, intercorrelations and possible evolutionary effects are as yet poorly understood, despite considerable efforts by both observers and theoreticians. Ultraviolet observations, although not expected to provide the solution to all the problems, are a much needed piece of information. The spectra of galaxies are red-shifted due to the general expansion of the universe, this red shift being larger for the more distant objects. It is therefore possible, for the most distant galaxies, to see *their* ultraviolet spectrum red-shifted into *our* visible region. As the most distant objects are also those that we see progressively nearer to the time of their creation (due to the finite speed of light), to investigate any possible difference in the characteristics of such galaxies and those nearby and to study possible evolutionary effects it is imperative to have access to the ultraviolet spectrum of nearby galaxies.

PAST EXPERIMENTS

The era of space exploration in the field of ultraviolet astronomy began with a series of experiments carried by rockets and balloons in the late 1950s and early 1960s. The Orbiting Astronomical Observatory OAO-II was launched in December 1968, and was the first fully fledged astronomical satellite for the ultraviolet to be launched successfully. It was followed in 1972 by the first European satellite dedicated to astronomy, TD-1. Later, OAO-III, named Copernicus, and the Dutch ANS satellite joined the others in orbit.

It would be out of context to review here all the important results already obtained by these satellites. However,

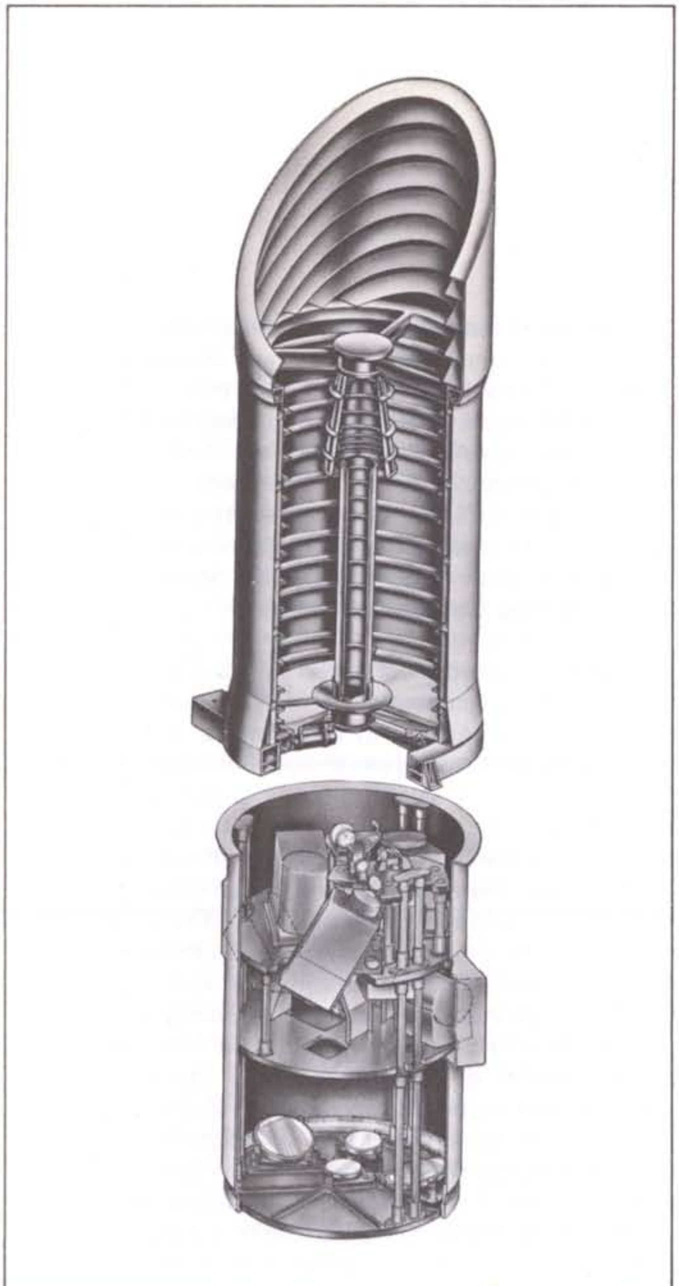


Figure 4 – The scientific payload of the International Ultraviolet Explorer (IUE) spacecraft to be launched in 1978.

some specific examples should be mentioned. In the area of interstellar-dust studies, observations of the interstellar extinction curve produced unexpected results. The striking feature is an absorption band centred at 2180 Å which, because of its symmetrical nature, cannot be produced by the same grains responsible for the general extinction throughout the ultraviolet and visible.

At least two types of particles are required to produce the observed curve. One type is responsible for the general extinction by scattering, and the other produces the 2180 Å band by absorption. Small graphite particles of 0.01 to 0.02 μm radius are strong candidates for these absorbing particles, but one problem is that all of the 'normal' cosmic abundance of carbon is required to be in this form to account for observations. The composition and distribution of interstellar gas has also provided unexpected results. The average density of hydrogen in the interstellar medium has been revised significantly from earlier predictions, molecular hydrogen has been found in dense clouds, and the hydrogen-to-deuterium ratio has been measured and found to be very different to the value previously assumed, with important implications for the origin of the elements. Finally, there seems to be a general underabundance of heavy elements in the interstellar medium compared with the accepted 'cosmic' abundances, raising questions regarding the validity of the previously accepted values.

Comparison of ultraviolet stellar spectra with theoretical models has led to a significant advancement in our understanding of stellar atmospheres, while at the same time highlighting the extreme complexity of the problem at hand. The main difficulty arises because, in computing theoretical models, assumptions and simplifications have to be made which severely limit the range of validity of the model. Although the basic physical principles, and therefore the remedies to the problem, seem to be understood, the complexity of any model attempting to match an observed spectrum is still very high even for present-day computers. One of the important discoveries made in the area of stellar atmospheres has been that mass-loss in the form of a solar wind is not an uncommon phenomenon among the hottest stars. Mass-loss rates as high as 10^{-4} solar masses per year have been measured. If this rate were sustained over most of hot star's lifetime, it would lose a large fraction of its mass through this mechanism, implying major departures from the normal evolutionary process for such stars.

Studies of other galaxies have been of a limited nature as the instruments flown so far have been best suited to studies of galactic objects. The ultraviolet observations made to date have been essentially integral measurements in selected bands. A complete mapping of the Magellanic Clouds has been obtained and the first observations of H II regions in the Large Magellanic Cloud suggest that a different reddening law is at work there, which would imply a different type of dust or a different chemical composition from those in our galaxy.

FUTURE SATELLITES

The previous satellites can be described as belonging to the era of exploration in the field of ultraviolet astronomy and their contribution has been of fundamental importance in establishing the basis and confirming the soundness of the scientific rationale. The next satellites will belong to the era of exploitation and the research that they carry out will be determined very strongly by the results obtained so far.

The first satellite in the new era will be the International Ultraviolet Explorer (IUE), a joint undertaking by NASA, the United Kingdom and ESA, aimed at providing an ultraviolet astronomy observatory in space for international use. IUE is to be placed in geosynchronous orbit in early 1978. The combination of this orbit's inherent operational simplicity and a direct video link between astronomer and telescope-acquisition and spectrum-analysis systems will permit the introduction of operational modes very similar to those used in normal ground-based observations.

The main scientific aims of the IUE mission can be summarised as follows: to obtain high-resolution spectra of stars of all spectral types in order to determine their physical characteristics more precisely; to study gas streams in and around some binary systems; to observe faint stars, galaxies and quasars at low resolution and to interpret their spectra by reference to high-resolution spectra; to observe the spectra of planets and comets as these objects become accessible; to make repeated observations of objects known or newly found to show variable spectra; and to define more precisely the way in which starlight is modified by interstellar dust and gas. IUE will carry a 45 cm Cassegrain telescope which will be used exclusively for spectroscopy. Two echelle spectrographs will also be carried and will cover the wavelength range 1150–3250 Å with a spectral resolution of about 0.2 Å. With this resolution stars as faint as the eighth magnitude could be reached with exposures lasting about one hour. The spectrograph can also operate with a lower resolution of just 6 Å, in which case the limiting magnitude will be approximately the thirteenth, thus bringing the brightest external galaxies and quasars into the accessible range.

The interest that such an instrument creates among the astronomical community can be best assessed from the number of observing programmes that it generates. Within ESA alone, more than fifty proposals for observation have been received for the first nine-month observing period, and similar numbers in the United Kingdom and the USA. This represents a large oversubscription of the available observing time and serves as an indication of the number of scientific problems that can only be tackled via space astronomy.

The satellites mentioned above have a common fundamental scientific motivation, namely to extend the wavelength range accessible to astronomers into the ultraviolet. None of them, however, apply the other advantage provided by space astronomy, the absence of 'seeing'. The Space Telescope will in fact be the first to take full advantage of the lack of atmospheric effects. Although it will be smaller than many ground-based telescopes, it will represent a large improvement in man's ability to investigate the universe and make observations that are impossible from the ground. It will be able to operate in the ultraviolet, visible and infrared wavelength ranges and so offer research opportunities to an extremely broad based section of the astronomical community. But perhaps most important, it will be able to achieve a spatial resolution ten times better than that obtainable from the ground and observe objects fifty times fainter. This will give it a unique ability to carry out those observations needed to determine the distances of galaxies and other indicators with a precision sufficient to establish the scale and curvature of the universe.

Several other instruments to be carried into space by Spacelab or to be left in orbit as autonomous 'satellites' are also in the study phase and no doubt the 1980s will see more and more astronomy being carried out from space. The cost of space observatories is such that they should not be used to make observations that can be conducted satisfactorily from the ground and if these new opportunities to study the universe are to be fully exploited great attention has to be given to the co-ordination of the space and ground-based activities. The traditional role of the ground-based telescope will be increased rather than diminished by the emergence of the new space techniques. □

Early Results from Geos

K. Knott, Space Science Department of ESA, ESTEC, Noordwijk, The Netherlands.

Since the successful firing of its Apogee Boost Motor on 25 April 1977, Geos has been operating in an eccentric, 12-hour orbit with an apogee of 38 000 km and a perigee of 2050 km. At the time of writing, data have been acquired from its experiments over a period of six months. The technical performance of the satellite has been excellent. The effects on the wave experiment of one minor drawback, stemming from the fact that one axial boom did not deploy fully, have been assessed and can be corrected for.

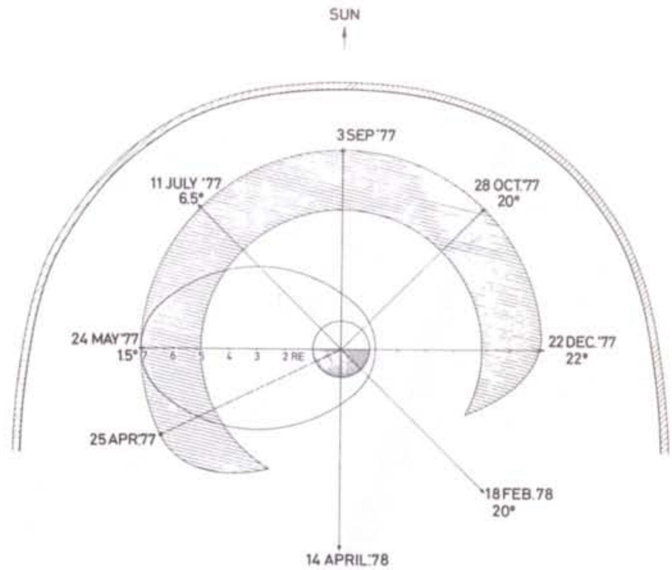


Figure 1 – Geos orbit (inclination 26.5°) in the frame of reference of the earth's magnetosphere, projected into the equatorial plane.

The failure of the launch vehicle to place Geos into a transfer orbit that would allow it to be injected into geostationary orbit by its apogee boost motor has meant that 24 hour/day data acquisition could no longer be achieved. With the 12-hour orbit now available the Odenwald (Germany) tracking station sees only every other Geos apogee, although every second apogee can be seen from Alaskan or Pacific S-band stations. Odenwald has provided an average of eight hours of data per day since early May and NASA's coverage of the opposite hemisphere has provided four to five hours per day since early June. Experiment operations from ESOC – although limited in duration – can still make full use of the powerful ground-based real-time computer system, an advantage that does not exist during the Alaskan passes, where experiments must be operated in a constant mode without any real-time data display or command possibility.

The Geos orbit and its temporal development in the magnetospheric frame of reference is shown in Figure 1. On 25 April, apogee occurred in the early evening sector. The position of apogee in local time has since drifted by approximately 0.88° per day, so that by the end of December it will occur in the late night sector. Measurements over the past six months have hence been carried out in the afternoon and evening sectors of the magnetosphere (shaded in Fig. 1). Radial coverage is limited by the fact that the magnetometer saturates just below five earth radii and most particle experiments saturate inside the radiation belts. Nevertheless, the volume of data recorded so far by ESA and NASA has already exceeded that from any previous ESA/ESRO satellite and it has become clear that the data being obtained are outstanding in terms of scientific novelty and quality. In spite of some initial difficulties encountered at ESOC in providing refined spacecraft attitude data, the scientific processing has progressed well during the last few months. This article is an attempt to highlight just a few of the initial results.

ELECTRIC-FIELD MEASUREMENTS

Geos carries two experiments for the measurement of electric fields, one using an electron-beam-deflection technique and one using a double-potential-probe technique. The first experiment fires an electron beam from the spacecraft perpendicular to the local magnetic field. This beam is deflected by both the external magnetic and electric fields and returns by a nearly circular path of several kilometres to the spacecraft. The distance between the source of the beam (an onboard electron gun) and the

Figure 2 – Typical results from the Geos electron-beam experiment. Each of the superimposed traces represents the output from the detector during one satellite spin period. The separation of these peaks quantifies the electric field in the frame of reference of the satellite (courtesy of F. Melzner and G. Metzner, MPI, Garching).

point of return (determined by an onboard electron detector) serves to quantify the external electric field. Figure 2 shows initial results from this experiment. Each of the superimposed lines represents the electron detector output during consecutive spacecraft spin periods (~6 s). Apart from the very pronounced signal caused once per spin by the sun, the signal caused by the returning beam can be clearly recognised twice during most spin periods. The signature indicated is exactly what one would expect as the result of an external electric field. The most remarkable feature in the data presented is the rapid directional change in the field. On the basis of these results, it can be concluded that the experiment is capable of measuring electric fields with a sensitivity of 0.05 mV/m.

The second electric-field experiment on board Geos employs two spherical potential probes. These are mounted some 40 m apart at the tips of two 20 m long cable booms and any potential difference between them is indicative of an electric field. Extreme care must be taken to eliminate any influence of fields generated by the asymmetric photoelectron cloud which surrounds the spacecraft and this disturbance has been calibrated and can be corrected for. Under most conditions, the experiment is capable of measuring the external electric field with a sensitivity of approximately 1 mV/m. An example of data generated by the long-boom experiment is shown in Figure 3.

While the long-boom experiment continues to deliver good electric-field data, a failure in its electron gun has

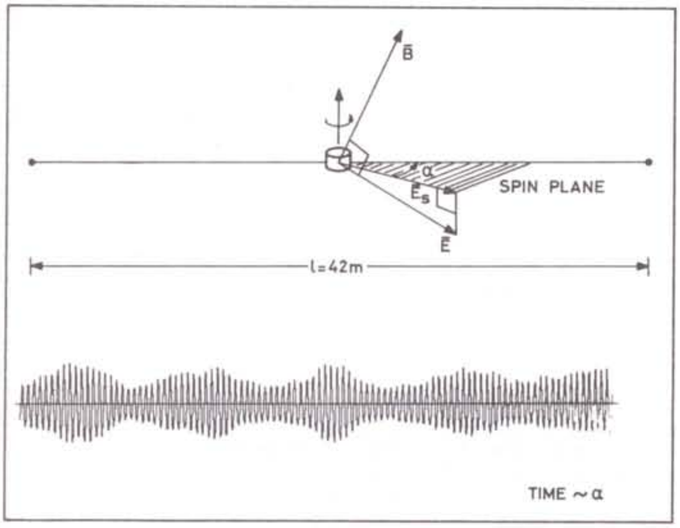


Figure 3 – Illustration of the geometry employed by the double-probe electric-field experiment on Geos. The potential difference between two spherical probes at the tips of two cable booms provides a measure of the electric field. A sample of raw data from this experiment – giving both DC and ULF field information – is shown at the bottom of the figure.

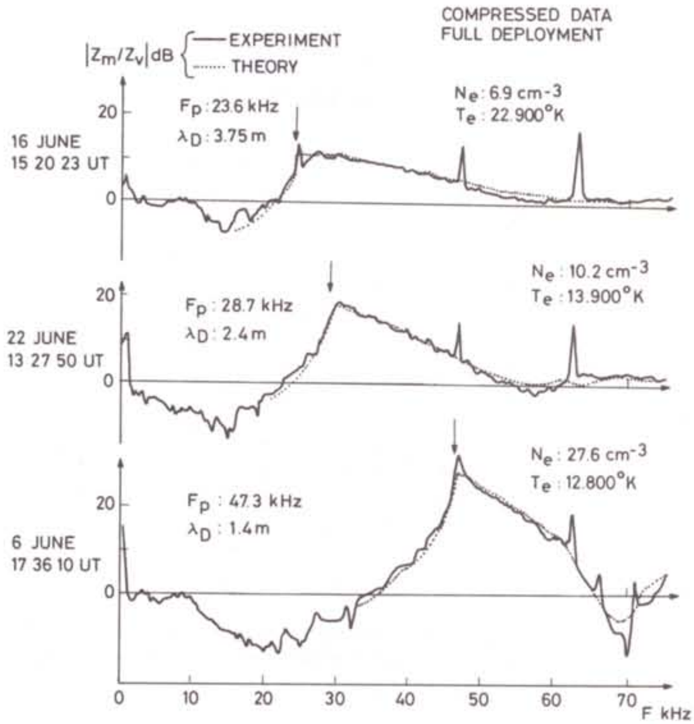


Figure 4 – Results from the mutual-impedance experiment on Geos, for three different periods. The frequency of maximum impedance gives the plasma frequency, which is directly related to the plasma density (courtesy of P.M.E. Décréau, C. Béghin and M. Parrot, Orléans).

regrettably curtailed the electron-beam experiment. Nevertheless, several passes of good data have been recorded and it has been established beyond any doubt that this, the most novel of all Geos's experiments, is sound in its principle.

PLASMA MEASUREMENTS

Another quantity that is of the utmost importance in magnetospheric physics is the cold-plasma density, or in other words the density of the electron and ion populations with very small kinetic energies. It has proved very difficult in the past to measure the density of these particles because of their small energies, and so two active experiments were designed for Geos for reliable cold-plasma density measurement.

Both experiments excite the characteristic resonance, the so-called 'plasma frequency' of the plasma, which is directly related to its density. One employs a powerful transmitter to send shortwave pulses into the plasma and determines the echo frequency of its resonance. The other measures the AC impedance of the plasma between two probes by monitoring the AC signals from an emitting and a receiving probe some 20 m apart. The resonance at the plasma frequency causes a maximum in plasma impedance, which can again be translated into density.

Figure 4 shows normalised plasma impedance as a function of frequency on three different occasions. In all cases the maximum is uniquely defined and the density can be derived. The shape of the curves depends critically on plasma temperature, i.e. the mean kinetic energy of the plasma particles, and curve-fitting techniques can be used to quantify this important parameter too. Although these plasma-density and temperature results appear quite reliable, the influence of parasitic photoelectrons

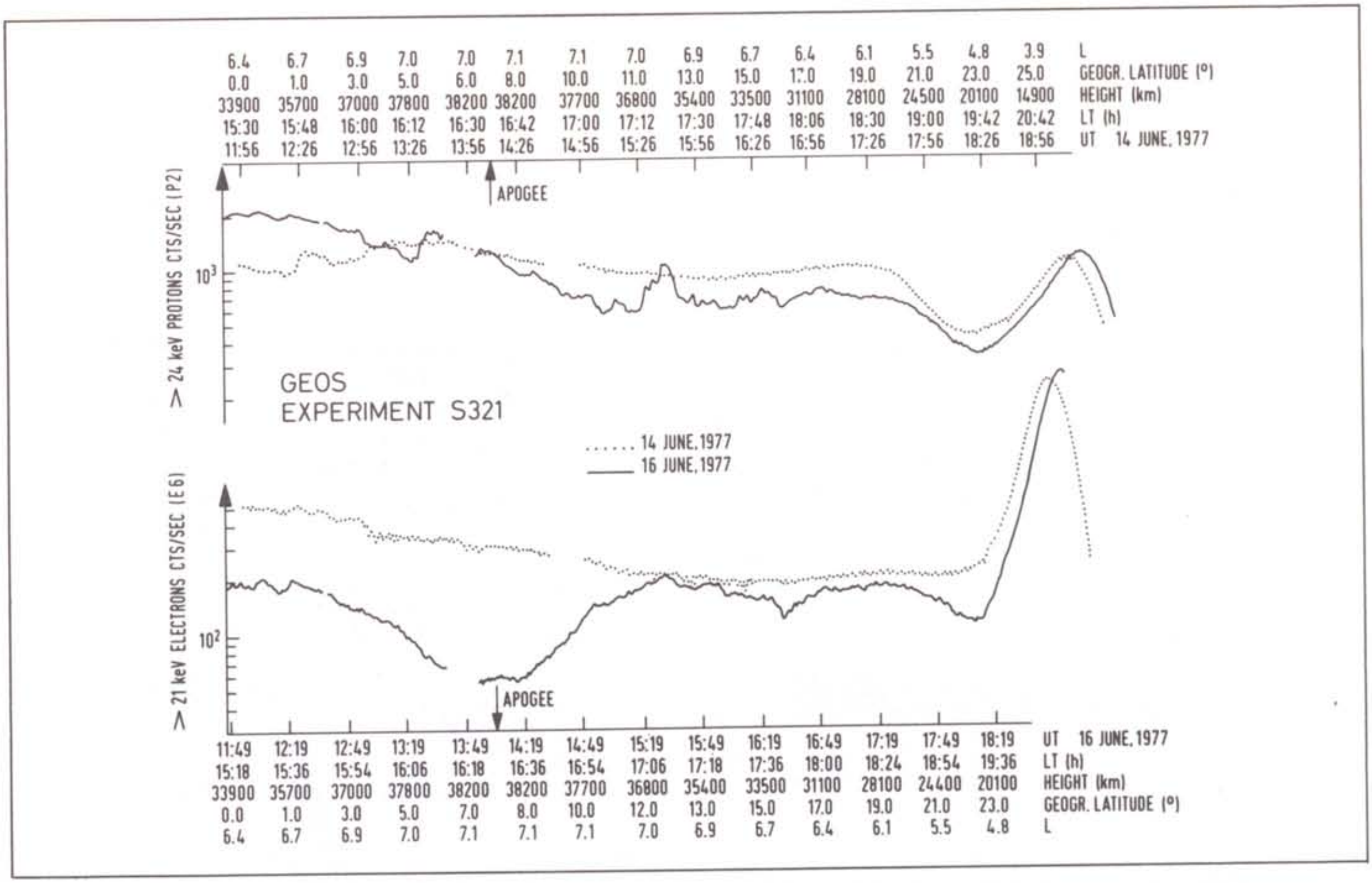


Figure 5 – Results from the Geos high-energy particle experiment. Integral count rates from an electron and a proton detector are shown. The dotted curves correspond to a geomagnetically quiet, and the solid curves to a geomagnetically disturbed day (courtesy of A. Korth, B. Wilken and G. Kremser, MPI, Lindau).

from the spacecraft must also be considered. A unique opportunity to study their role occurs during the transition phase into solar eclipses and in mid December Geos will start to encounter such eclipses at high altitudes. It is hoped to prove at this time that the influence of parasitic photoelectrons is small or even nonexistent.

ELECTRON/PROTON MEASUREMENTS

Geos carries a large number of electron and proton detectors spanning the zero to MeV energy range, which includes the whole magnetospheric particle population. Except for very low energies, this population had been explored quite extensively by previous magnetospheric spacecraft. The basis for continuing these measurements with Geos stems from the need to obtain better temporal and spatial resolution, the simultaneous observation of particle population and measurement of fields and waves being of particular importance.

The analysis of Geos results is not yet sufficiently far advanced for us to present correlated experimental results here, but Figure 5 shows some results from the high-energy particle experiment. The data in this figure originate from two complete passes over the Odenwald ground station; one on 14 June, a magnetospherically 'quiet' day (small variations in geomagnetic field), and one on 16 June, a day with pronounced variations in geomagnetic field and therefore classified as 'disturbed'. It can be seen that the electron populations in particular were quite different on the two days. The precise nature of this difference and the reason for it will be analysed further by studying the spatial and energy distributions of the measured populations and by comparing them very carefully with the measured field and wave distribution in the vicinity of the spacecraft on those days. Correlation with ground-based magnetometer recordings and x-ray measurements in the upper atmosphere will also be attempted.

COMPOSITION MEASUREMENTS

The Geos payload also contains a sophisticated mass-spectrometer to determine the mass of ions in the energy

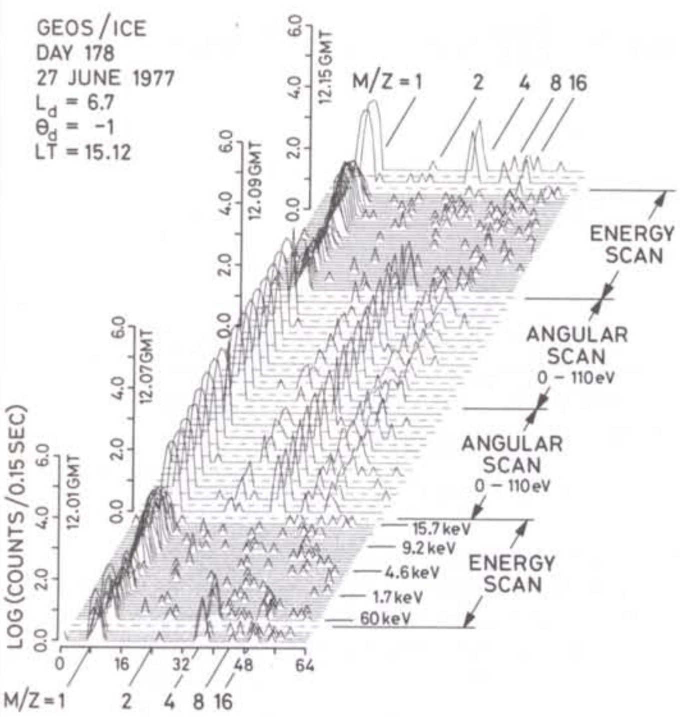


Figure 6 – Typical Geos mass spectra for different energy ranges and instrument viewing directions. One energy scan takes about 6 min; an azimuthal scan is obtained during one satellite period and subdivides the latter into 9 angular intervals. (From 'Discovery of He^{2+} and O^{2+} ions of terrestrial origin in the outer magnetosphere', by D.T. Young, J. Geiss, H. Balsiger, P. Eberhardt & A. Ghielmetti, Geophys. Res. Lett., December 1977).

range from nearly 0 to just below 20 keV. The mass range covered extends from protons (mass 1) to singly-charged barium ions (mass 138). In previous satellite experiments, both resolution and mass coverage have been much lower and the Geos mass-spectrometer has therefore already provided significant new discoveries only a few months after launch. Consequently, our conventional picture of ion composition in the magnetosphere would appear to need revising. It has been found, for example, that two hitherto unexpected ion species, doubly-charged helium and doubly-charged oxygen, are fairly common in the region which has been explored so far. The density and energy of these species indicate very strongly that they must be primarily of terrestrial origin. These observations, which must be further substantiated during Geos's remaining lifetime, have already demonstrated that this experiment will make a significant contribution to a better understanding of the origin of the magnetospheric particle population. Figure 6 shows a series of mass spectra obtained by this experiment at different energies.

The mass-spectrometer experiment has also yielded very spectacular results during periods when the spacecraft, in the course of special attitude manoeuvres, has been oriented such that the mass-spectrometer sensor viewed exactly in the direction of the local magnetic field. These results are currently being evaluated.

CONCLUSIONS

An overall assessment of the value of the present Geos mission is impossible at this stage, as only preliminary data are available so far and final data processing is still in progress, but it is certainly of less value than the foreseen geostationary mission would have been. It will be difficult to quantify this statement even when all scientific data have been evaluated in detail.

After the first six months of orbital operation, we can however say that the technical performance of spacecraft and payload have been excellent. It has been demonstrated conclusively that the novel experiments carried are able to measure plasma densities, electric fields and ion compositions in ranges and with precisions not previously attainable. The coverage in radial distance is of course better than would have been achieved with the geostationary mission. All experiments make useful measurements between five and seven earth radii altitude and those that do not saturate operate all the way down to two earth radii (the experiments are tuned for conditions at 6.6 earth radii). A thorough study of the afternoon and morning sectors of the magnetosphere, and of the plasmapause and the plasma bulge in particular, has been possible. New results can be expected especially from the plasma, field and ion-composition experiments. Because a satellite in highly elliptical orbit travels relatively slowly near apogee, Geos spends a reasonable time at close to geostationary altitude and has permitted some of the planned correlations with ground-based measurements to be made despite the 12-hour orbital period.

On the negative side, the duration of the mission will be limited by radiation damage to the solar array. The complete payload can be operated at least until mid December and, with some time sharing, until April 1978. Power limitations will make it impossible to operate experiments simultaneously when the most interesting part of the magnetosphere is reached early in 1978. Ground-based computer control, important for many experiments, is limited to a few hours per day and data acquisition is reduced by more than 50%. The temporal overlap with ISEE-A and B will be limited to six months, and then with experiments in the time-sharing mode, and although Geos was chosen as the reference spacecraft for the International Magnetospheric Study, it cannot adequately fill that role in its present orbit, particularly as its nonstationary character reduces the value of planned complementary ground-based observations. □

Is Europe's Space Power Technology Competitive?

J.J. Capart, Spacecraft Power Supplies Division, ESTEC, Noordwijk, The Netherlands

Almost ten years have elapsed since the launches of ESA's first generation of satellites. The flawless operation of their power supplies and those of their successors may have given some the impression that power technology is straightforward. Yet, the need exists for an intensive development effort. This article sets out to show that this effort responds to a deep evolution in the traditional drivers of power-system design. It reviews the results achieved so far and the remaining weak areas, and speculates on the strong impact that the booming terrestrial effort in the energy field could have on space power systems.

EVOLUTION OF POWER-SYSTEM DESIGN REQUIREMENTS

MASS AND PAYLOAD REQUIREMENTS AS TRADITIONAL DESIGN DRIVERS

It is certainly not necessary to stress here the criticality of the power system for spacecraft survival and the need to maintain nominal operation in a number of failure modes. Suffice it to say that this is perhaps the only requirement that has not changed over the years. The main reason for the continuing evolution of power technology is the strong interdependence of this system and payload and mission requirements, one example being the large variety of solar-array configurations used on ESA space missions. This variety is not the result of an excessive taste for optimisation, and it is interesting to note that solar arrays are practically the only equipment that NASA has been unable to standardise on its Multimission Modular Spacecraft (MMS).

For power engineers in quest of R&D funding, the magic selling word has traditionally been mass. The two orders of magnitude increase in the power needed for ESA satellites (from 40 to 4000 W) in the last ten years would not have been possible without a continuous reduction in power-system mass. Nevertheless, the power supply remains the heaviest subsystem in a number of applications satellites, where it limits both payload mass and available power and therefore has a direct impact on mission cost-effectiveness.

THE NEED FOR PHOTOVOLTAIC SYSTEMS

Whether mass will remain the prime design constraint for power systems in the coming years is not yet clear. With the advent of new vehicles such as Ariane and the Shuttle, it will depend on whether the need for higher and higher powers continues. Three potential customers for high-power systems can, however, be identified: applications satellites, manned missions, and planetary exploration with electric propulsion, the latter not having been considered so far in Europe.

Telecommunications satellite experts claim that the exploding growth in user requirements that they forecast can mainly be accommodated by progress in high-gain multibeam antenna technology. In the short term, they would be satisfied with powers in the order of 6 to 8 kW, essentially for broadcast-type missions. However, they are insisting more and more on continuous operation of their telecommunications payloads in eclipse, which makes the development of lightweight batteries a task of high priority.

On the other hand, as recently illustrated by Spacelab's power crisis, manned missions have an immediate need for powers up to 25 kW. These needs can be expected to grow by a factor of ten for permanent space stations and space industrialisation. Since such missions exceed the one to two week duration compatible with fuel cells, there is a clear need for a new generation of photovoltaic systems. Only a moderate effort on mass improvement is likely to be required in this case and emphasis should be put on cost reduction and compatibility with manned missions and orbital maintenance.

Finally, the advent of gigawatt space power stations, one of the power engineer's rosiest dreams, might again bring a mass-reduction challenge, but it is still too early to consider a specific development effort – NASA's assessment of the viability of such a concept is expected to be completed in 1980.

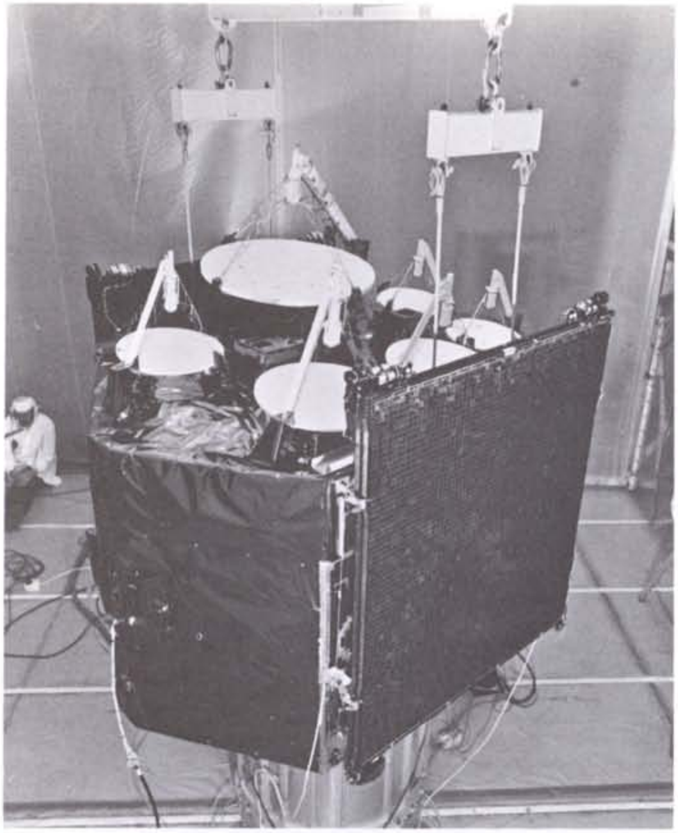


Figure 1 – MBB carbon-fibre solar arrays carried by ESA's OTS communications spacecraft.

THE ECONOMICS OF EUROPEAN POWER-SYSTEM DEVELOPMENT

LIMITED SCOPE OF R&D POSSIBILITIES

In view of Europe's limited resources, the decision taken some ten years ago not to venture into the development of space-related radio-isotopic supplies, nuclear reactors, solar concentrators, thermo-ionic converters, dynamic engines and fuel cells, was a valid one. Trying now to 'hoist Europe's flag' in these areas would require budgets two orders of magnitude higher than the existing ones. In addition, the forced choice of photovoltaic systems proved to be the right one, as this concept still leads the favourites in the gigawatt power race. In fact with an annual power technology development budget traditionally below one million Accounting Units (1 AU equivalent to 1.1 US $), or about 10% of NASA's funding level, the Agency's choices are even more limited. The objectives must mainly be those of identification of promising concepts and the solution of selected problem areas. Most of the development and qualification effort over the last ten years has therefore been funded by the 'user' projects themselves and by national programmes. A good example of the latter is the key role played by Germany in the development of solar cells, cell modules and lightweight arrays (1 MAU per year in the last three years).

MARKET CONSIDERATIONS

A second major constraint stems from the size of the European space market, when compared to the situation in the USA where a major role is played by the large production volume and by the strong development needs of the US military programme. This aspect is particularly apparent in the fields of solar-cell modules and advanced energy storage.

A partial remedy to this situation lies in the concentration of industrial effort, thereby providing selected firms with the necessary continuity of workload and the incentive to invest company funds. This objective has already been achieved in the solar-cell and battery markets, which are each dominated by single firms, namely AEG-Telefunken and SAFT, and where credible back-up suppliers are available.

In other areas we are far from achieving this state of affairs, with power-conditioning electronics and rigid solar arrays in particular still representing areas of excessive competition.

PROSPECTS FOR REDUCTIONS IN HARDWARE COSTS

The selection of reasonable performance requirements could also play a role in the competitiveness of European industry. In the case of power conditioning, for instance, accepting nonoptimised designs would reduce the development effort needed from project to project. Although hardware standardisation would in general not be practicable, significant gains could result from the repeated use of well-proven modular circuits, and from the enforcement of uniform electrical interface standards compatible, if possible, with those applied in the USA.

A different approach is required for solar arrays, which account for the major part of the cost of power systems producing more than 1 kW. Here efforts should be directed rather to the reduction of flight hardware manufacturing and testing costs. This will be essential for multisatellite missions where high solar-array costs would have a recurring impact on spacecraft cost. Currently, these costs are of the order of 1 MAU per

TABLE 1

Main Objectives of Medium-Term Power-Technology Efforts in Europe

TITLE	OBJECTIVE	APPROACH	EXPECTED TECHNOLOGY READINESS DATE
Hybrid Solar Arrays	Make a geostationary mission in the 3-6 kW range feasible with Ariane (and later, the Shuttle) Specific mass ~ 30 kg/kW	Combination of a deployable rigid array, used for the transfer orbit, with a flexible fold-up blanket	mid 1979
Low-Cost Arrays	Reduce the cost of present arrays by a factor of at least 2 Make technology compatible with manned missions (maintainability, modularity); Specific mass ~ 15-20 kg/kW	Adapt module and solar-blanket technologies to the use of large-area cells derived from terrestrial development	end 1980
NiCd Batteries	Improve the specific capacity of NiCd batteries to 35 Wh/kg without degrading their life expectancy	Modification of cell containers and use of electrochemical electrode impregnation. Improve battery packaging	1981
Metal-Hydrogen Batteries	Attain or exceed 55 Wh/kg on high-capacity batteries with a cycle life in excess of 500 cycles and for missions beyond 5 years	Finalise the comparative assessment of nickel- and silver-hydrogen cells. Produce the mechanical design for the battery selected.	1983
Modular Power-Conditioning	Develop re-usable power-regulator concepts for sunlight power up to 6 kW and eclipse power up to 2 kW	Detailed development of fault-tolerant modular circuits. If possible implementation in lightweight packaging (hybrid circuits).	1981
High-Voltage Technology	Design readiness for the supply of TWTs beyond 200 W, of electric thrusters and of scientific instruments	Development of efficient high-voltage circuits; final definition of packaging and insulation methods.	1980

kilowatt at end-of-life, to which about 0.4 MAU should be added for testing. As discussed below, the best and probably the only solution to this issue will come from a close link with the terrestrial market.

EUROPEAN DEVELOPMENT OBJECTIVES

Table 1 lists the main objectives of Europe's current power-system technology effort. They are inspired by the factors that we have already identified; namely a need to adapt to payload requirements, the full utilisation of the Ariane launcher's potential, a hardware cost reduction and a readiness for manned missions.

The marked preference for cost reduction rather than performance optimisation is evidenced by, for instance, the rather modest weight reduction sought for solar arrays, from the present 30 kg/kW to 15-20 kg/kW.

NASA are also faced with a similar cost/performance dilemma. Their more demanding missions and greater resources have, however, led them to fund two distinct development programmes; one oriented towards cost reduction and the other aimed at very high performances for specific applications. Examples of the latter are the development of a 5 kg/kW solar array and the development of high-performance molten-salt batteries.

EUROPE'S TECHNOLOGY TODAY

With the constraints and limited resources described above, Europe's progress is bound to vary somewhat from technology to technology and the brief discussion that follows is by necessity an oversimplification on a number of issues; nor can proper credit be given in the space available here to the firms and national agencies who have contributed (the interested reader can find a detailed description in three technological dossiers on power technology issued by the Agency for the benefit of its Member States).

SOLAR ARRAYS

Array and Module Technology

In a number of joint American-European co-operative projects in which ESA has participated in recent years, European solar arrays have been selected for flight in preference to other European hardware. This choice has been governed primarily by three main technical 'trumps':

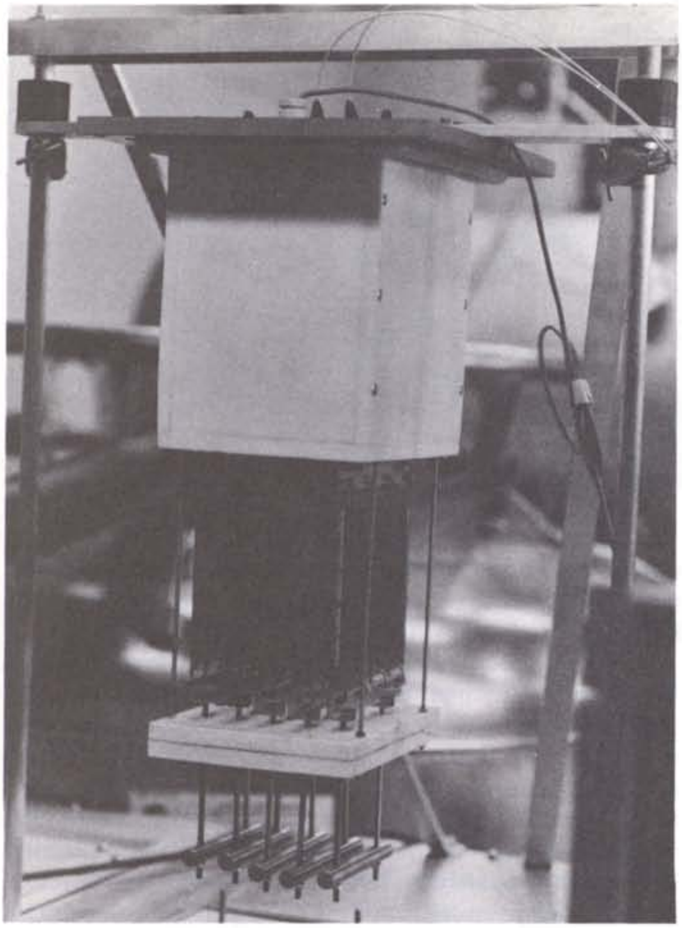


Figure 2 – *Accelerated thermal-cycling test on lightweight solar-cell modules (ESA contract with K. Weiss, Germany).*

our solar-cell interconnect welding, our carbon-fibre array structures and our flexible solar-cell blankets.

Europe's lead in welding is due in part to an early start, with AEG's invention in 1976 of a passivated contact, the rapid optimisation in Europe of parallel-gap welding, and the successful adaptation of this process to large-scale automated assembly.

Since 1972, when this technology was first flown on the German Aeros satellite, solar-cell welding has been used on practically all European satellite missions, whereas most American spacecraft still rely on soft soldering.

Europe's welding development is complemented by the availability of theoretical interconnector optimisation models and extensive test experience. This allows a wide range of mission requirements to be met, from the deep geostationary eclipse temperatures experienced by NASA's IUE spacecraft, to the 70 000 thermal cycles specified for NASA's low-orbiting Space Telescope.

Also beginning around 1967 and using welding as a key manufacturing process, Europe's development of flexible solar-cell blankets has been mainly aimed at achieving high resistance to deep thermal cycling. Here too a number of supporting studies led to the first demonstration of a flexible array in geostationary orbit, powering Canada's CTS communications spacecraft, in January 1976. Similar technology which should form the backbone of Europe's future low-cost solar arrays will be used in manufacturing the 4 kW blankets for the Space Telescope.

As a third example of European technological skill, we might mention carbon-fibre solar-array technology, which is practically unknown outside Europe, but is already being applied on OTS, Marots, ECS, IRAS and Intelsat-V. Great stiffness and excellent thermal matching with the solar-cell modules make this technology the best choice for rigid solar arrays producing up to about 2.5 kW. A second generation of carbon-fibre rigid arrays, in which the honeycomb substrates are replaced by a frame-and-blanket concept to achieve a significant reduction in manufacturing cost, has already appeared in Germany and France. With specific masses in the order to 30 kg/kW, these arrays are proposed for such missions as the Heavy Telecommunications Platform and are suitable for powers of up to 4 kW. Beyond this limit, problems associated with stowage under the launcher fairing and deployment reliability tip the balance in favour of flexible arrays.

Solar-Cell Technology

Solar-cell development in the last five years has been dominated by the US effort, and particularly by the work at Comsat's Laboratories. The list of improvements proposed in recent years is long; it includes for instance violet-and-black cells, thin cells (50 μm), large-area cells, vertical junctions and reflective rear contacts, not to mention progress on other cell types, such as the gallium-arsenide. In certain cases, they amount to the reactivation of fairly old concepts: for instance, a thin 'wrap around' cell (with two terminals on its rear face) similar to one currently being evaluated by NASA was developed by Ferranti (UK) as long ago as 1972.

It would be unwise to expect Europe's solar-cell suppliers to incorporate all of these improvements in their production lines. In certain cases it can readily be done – a violet cell is currently being flown on ISEE-B – but in most others it would involve the addition of extra manufactur-

Figure 3 – *Experimental nickel-hydrogen 23 Ah battery cell developed by SAFT for CNES.*

ing steps and the expensive revision of assembly techniques, such as welding and the application of adhesives.

In fact, Europe's best strategy might be not to attempt to continue to compete in solar-cell technology for space application per se. Rather than maintaining a space-dedicated production line which might preclude the drastic cost reductions hoped for, one might rather derive a space cell from a terrestrial product and refrain from introducing improvements that are not specifically needed for the space environment. This approach would make best use of Europe's fast-growing funding for terrestrial solar cells (around 4 MAU in 1977, which is about 7% of the photovoltaic budget of the US Department of Energy). With assets such as Wacker-Chemie's (Germany) outstanding single crystal silicon technology, and PPE's (UK) leading position in the cover-glass market, this approach could lead to the incorporation of terrestrial- cell technology in a spacecraft solar-array blanket in the early 1980s.

Mechanisms

Another area in which a strong European effort is urgently needed is the development of deployment actuators for multikilowatt solar blankets. ESA's development of flexible arrays for Ariane and Shuttle missions depends on the availability of long booms or masts similar to the US/Canadian Bi-Stem and Astromast devices. Two attractive European concepts already exist, one in France and the other in the UK, but their growth potential, deployment reliability and adaptability to manned missions have yet to be demonstrated.

BATTERIES

Nickel-Cadmium Cells

The 'value' of a space battery lies mainly in the available test information and in-orbit experience. For this reason, nickel-cadmium batteries remain the workhorse of space projects on both sides of the Atlantic. The thousands of test years accumulated at the Crane Laboratory in the USA overshadow the results of the few test contracts placed by ESA since 1969. Nevertheless, these contracts have played a substantial role in helping ESA to define its battery-charge-control concept (based essentially on avoiding degradation produced by overcharging). The urgently needed increase in our European test effort has now been made possible by the recent completion of ESTEC's Battery Test Centre.

The main advantage that SAFT's NiCd batteries have over their leading US competitors probably lies in the manufacturing reproducibility of the electrode plates, a process through which SAFT's US subsidiary has acquired a foothold in the American market. Although this process tolerates depths of discharge that are significantly larger than considered a safe limit in the USA, the specific mass of European NiCd cells is not as low as achieved in recent US products. While the OTS battery mass produces some 27 Wh/kg (calculated for the complete battery on the basis of nominal capacity), some US projects have already achieved 37 Wh/kg and NASA's development programme even aims at 45 Wh/kg.

In following this example, care should be taken not to pursue mass savings at the expense of cell lifetime, particularly in view of the in-orbit anomalies experienced by some recent American satellites.

Other Cell Couples

Despite the improvements, NiCd cells remain heavy, the eclipse operation of a 3 kW satellite still needing 200 kg of batteries. There is therefore a strong incentive to produce higher density cells.

In the short term, metal-hydrogen batteries appear the most promising. Two types are available: the nickel-hydrogen concept which has been flown successfully in 1977 by two US manufacturers and the silver-hydrogen cell which is under active study in several US laboratories. The latter offers the best prospects for mass savings (up to 60-70 Wh/kg) despite the fact that even by the 'black magic standards' of battery technology the silver electrode is known to be quite temperamental.

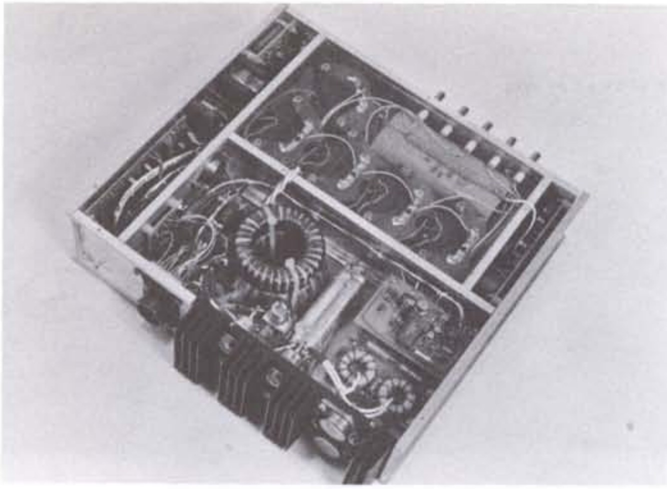


Figure 4 – *Demonstration model of a 600 W electronic power conditioner adapted to spacecraft AC power distribution (Dornier).*

The European metal-hydrogen cell effort has suffered much from the stretching of development funds. Although the nickel-hydrogen concept developed by CNES is ready for life testing and good laboratory models of silver-hydrogen cells are available, the first flight of a European metal-hydrogen cell is not expected before 1983.

Metal-hydrogen cells are expensive and have so far been ignored in the large effort devoted to terrestrial applications. It is therefore unlikely for this very reason that they will form a long-term and economical solution to the growing needs of space energy storage. NASA and the US Air Force, who foresee a need for battery capacities of up to 2000 Ah, are already turning their attention to iron sulphide – lithium and molten-sodium – sulphur couples. Similar monitoring of terrestrial battery development should be undertaken in Europe.

POWER CONDITIONING

'Regulated' or 'Unregulated' Distribution?

The controversy regarding the merits or otherwise of regulated and unregulated onboard power distribution has some analogies with the traditional discussion on the merits of spin and three-axis satellite attitude stabilisation. Anyone who has analysed the Intelsat-IV power subsystem will have appreciated the simplicity of the unregulated bus. On the other hand, the regulated-bus concept flown on about 70% of the European missions, like three-axis stabilisation, compensates its unquestionable complexity by a corresponding simplification of payload interfaces. For scientific missions, it means a low-noise bus such as ISEE-B carries, where voltage fluctuations over the whole range of operation remain below the threshold of one telemetry bit. For applications missions such as ECS, it means a high efficiency in sunlight and excellent isolation against the transients and current fluctuations generated by the repeater.

An indirect result of the choice of a regulated bus was the impetus given in Europe to development of solar-array shunt and battery boost discharge regulators. The progressive elimination of dissipative regulation and the design of fault-tolerant circuits are now providing Europe with a new generation of modular concepts capable of covering a wide range of applications, and hence achieving a marked reduction in hardware cost.

AC Distribution and High-Voltage Technology

The choice of different DC voltage standards on different sides of the Atlantic also remains a barrier to the export of European hardware and prevents commonality between Spacelab and spacecraft equipment. In addition, DC distribution lacks the growth potential required by future missions. A possible solution could be afforded by the AC distribution concept developed over the last five years on behalf of the German government and ESA, a concept that is particularly well-suited to powering the standardised data-handling and attitude-control hardware under development for ESA.

In most other areas of power-conditioning electronics, European development status is similar to that in the USA. This is not the case, however, for high-voltage converters, since the demands of European missions have so far been much more modest than those on the other side of the Atlantic, particularly with respect to high-power microwave tubes and electric-propulsion thrusters.

CONCLUSION

Budget limitations have forced Europe to specialise in a narrow sector of the space power field. The development carried out on photovoltaic systems has provided its industry with some critical technologies that have good growth potential, and these assets can hopefully be capitalised upon, in part by seeking further co-operative projects with the United States. More opportunities also need to be found to demonstrate new hardware on experimental flights. Finally, the competitiveness of European industry can only be maintained through a substantial reduction in production costs, which implies close co-ordination of the space effort with the very great terrestrial development activity that has been triggered by the energy crisis. □

In Brief

Four European Candidates chosen for First Spacelab Flight

From the 53 candidates from 12 European countries (Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom) pre-selected last September from some 2000 applicants for the first Spacelab mission in 1980, ESA has selected four candidates, one of whom will finally be chosen to fly as payload (experiment) specialist together with one American payload specialist.

The four candidates, named at a press conference in Paris on 22 December, are:

- Franco Malerba (31), an Italian engineer working in the computer field for the Digital Equipment Corporation in Milan
- Ulf Merbold (36), a German research scientist working at the Max-Planck-Institut für Metallforschung in Stuttgart
- Claude Nicollier (33), a Swiss researcher and pilot who has been a visiting scientist at ESTEC since 1976
- Wubbo Ockels (31), a Dutch physicist doing research and lecturing at Groningen University.

By May 1978, three of the four candidates will be selected for appointment to the staff of ESA as European experiment specialists to undergo training for the first Spacelab flight. One of the three will eventually be chosen to become the first European to travel and work in space. The other two will act as back-up specialists and will participate in ground-based mission activities.

About 70 experiments will be carried out on the first Spacelab mission, in the fields of stratospheric and upper atmosphere physics, materials processing, space plasma physics, biology, medicine, astronomy, solar physics, earth observation, thermodynamics and lubrication. ESA's Spacelab Integration and Co-ordination in Europe (SPICE) organisation will manage European experiment training activities. □

Presentation of the four Spacelab candidates to the Press at ESA Head Office in Paris on 22 December.

Spacelab Utilisation – Summer School

A Summer School with the title 'Manned Space Activities' will be held at Alpbach, Austria from 2-11 August 1978. The School is being organised under the auspices of the Austrian Solar and Space Agency (ASSA), with ESA and other Agencies as co-sponsors. Although the School will be devoted mainly to the utilisation of Spacelab, speakers from the USA and USSR will summarise their countries' past activities in manned space flight. The applications of the advanced Space Transportation System (STS), which includes the Space Shuttle, will also be described. Spacelab-related topics to be presented at the School will include:

- Spacelab system aspects
- Payload accommodation
- Planned European missions
- Experiment hardware and software design
- SPICE organisation and functions
- NASA payload operations
- Payload data management
- Role of principal investigator and payload specialist.

The course will comprise morning lectures, workshops in the afternoons, and film presentations in the evenings (all conducted in English). The course fee is 500 Austrian Schillings (excluding accommodation) and the number of participants will be limited to sixty.

Further information can be obtained from:
The Austrian Solar and Space Agency
Attention: Dr. Mondre
Garnisongasse 7
A-1090 Wien, Austria. □

First picture of the earth's surface and cloud cover taken by Meteosat in the visible region of the spectrum on 9 December shortly after midday.

First Earth Pictures from Meteosat

The European Space Agency's Meteosat satellite, launched from Cape Canaveral on November 22 (see ESA Bulletin no. 11), has taken its first pictures of the earth's surface and cloud cover in the visible and infrared. The clarity and excellent detail of these pictures, received in the visible on 9 December and in the infrared on 11 December by Meteosat Operations Control Centre at ESOC, Darmstadt (Germany) confirm that the satellite and its 'camera', a high-resolution radiometer, are working very satisfactorily.

Meteosat reached its on-station position in geostationary orbit (at 0° longitude above the Gulf of Guinea) on 7 December. The satellite had been stopped by telecommand as it drifted westward on the residual impetus of its thrust from transfer to geostationary orbit 17 hours after launch, and was telecommanded to drift 6.3° per day eastward to reach its scheduled position. From 36 000 km directly above the equator at 0° longitude, ESA's first weather satellite will provide total and continuous coverage of Europe, Africa and the Middle East for at least three years.

Meteosat was built for ESA by firms in eight European countries, with Aérospatiale (France) as Prime Contractor for the COSMOS Consortium. The radiometer was built by Matra (France). □

Observation spatiale de la terre et gestion des ressources planétaires

L'Agence Spatiale Européenne et le Centre National d'Etudes Spatiales (France) organisent à Toulouse, du 6 au 11 mars 1978, dans le cadre des Journées d'Etudes Scientifiques et Techniques de Toulouse (JET) et sous l'égide de l'Assemblée Parlementaire du Conseil de l'Europe, de la Commission des Communautés Européennes et de l'Association Européenne de Laboratoires de Télédétection (EARLSeL) un colloque international sur l'Observation Spatiale de la Terre et la Gestion des Ressources Planétaires (OST).

Les résultats obtenus à l'aide des premiers satellites d'observation de la Terre confirment déjà les larges perspectives d'applications des techniques de télédétection dans des domaines très variés.

De telles possibilités seront exploitées et déboucheront sur une utilisation fructueuse permanente lorsque les échanges entre gestionnaires, utilisateurs et usagers d'une part, scientifiques et techniciens d'autre part, auront permis d'accorder les préoccupations des uns avec les possibilités qu'envisagent les autres.

Ce colloque se propose, dans cet esprit, de dresser un bilan des résultats obtenus pendant les premières années d'expérimentation et de traiter, en s'appuyant sur les projets à l'étude qui déboucheront pendant la prochaine décennie, les problèmes scientifiques de base associés à ces nouvelles disciplines.

Pour tout renseignement, s'adresser à:
OST-B.P no. 4130 – 31030 TOULOUSE CEDEX, France
Tél.: (61) 53.11.12 – Poste 50.12 – Télex: 531.081 □

ESA Publications

The documents listed here have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table inside the back cover and using the Order Form on page 69.

ESA Journal

The following papers were published in Vol. 1, No. 4.

A Survey of Earth-Surface Observation Satellites and the Interface between Remote Sensor and Attitude Control System, *by M.J. Hammond*

A brief survey of earth-observation satellites is presented, including possible future developments. Consideration is given to the flow of information from remote sensor to user and the areas where satellite attitude measurement and control have a direct impact on reconstruction of the original scene. An overview of the performance specifications for and implementation of candidate systems is presented, which is concluded by an assessment of a 'common-bus' philosophy related to various system options.

On donne un bref aperçu des satellites d'observation de la terre et de leurs perspectives d'évolution. L'accent est mis sur la masse d'informations qui parviennent à l'utilisateur à partir de télédétecteurs et sur les domaines où les mesures d'attitude et la stabilisation du satellite peuvent affecter directement la restitution de l'image d'origine. Les spécifications de performance et les modalités de mise en oeuvre des systèmes envisageables sont également présentées et on conclut par une évaluation du principe d'un 'circuit commun' qui servirait de lien entre différentes options du système.

Advances in Spacecraft Power Conditioning – New Concepts from Old, *by D. O'Sullivan & A. Weinberg*

This paper summarises three essentially new power-conditioning concepts which represent a significant advance over conventional techniques in the domain of high-power modular system design. All three concepts described employ a derivative of limit cycle or hysteresis control, but in a manner significantly different to conventional applications. The applications treated are:
- low-dissipation, switching shunt regulator design
- conductance-controlled, energy-storage regulators
- solid-state switch with overload protection.

On présente brièvement trois nouvelles méthodes inédites de conditionnement de puissance qui constituent un progrès par rapport aux techniques classiques de conception des systèmes modulaires à grande puissance. Ces méthodes sont toutes trois dérivées de la régulation par cycle limite ou par hystérésis, mais d'une façon tout à fait différente par rapport aux applications traditionnelles. Les applications dont il est question ici sont:
- *régulateurs shunt à découpage, à faible dissipation;*
- *régulateurs à stockage d'énergie commandés par conductance;*
- *interrupteurs intégrés à protection contre les surcharges.*

RF Gain Degradation in High-Power Microwave Bipolar Transistors under Multicarrier Operation, *by M.H. Gibson et al.*

The use of RF transistor power amplifiers under multi-carrier operating conditions in satellite transponders can create reliability problems incompatible with a long mission life, due to the high instantaneous voltage levels incurred, particularly in the emitter-base junction. These high emitter-base voltages in the reverse direction can lead to h_{FE} degradation as the junction breakdown voltage is approached, with a corresponding degradation in RF performance. This paper describes a series of RF/DC experiments conducted in an attempt to correlate the RF emitter-base reverse-voltage stress levels and consequent h_{FE} degradation with computer predictions based on a large-signal model of the transistor.

L'utilisation dans les répondeurs de satellite d'amplificateurs de puissance à transistors haute fréquence fonctionnant en multiporteuse peut poser des problèmes de fiabilité incompatibles avec des missions de longue durée, à cause des niveaux élevés de tension instantanée, en particulier dans la jonction avec l'émetteur. Ces hautes tensions dans le sens inverse peuvent conduire à une *dégradation de h_{FE} à mesure que l'on approche de la tension de rupture de la jonction, avec une baisse corrélative des performances en haute fréquence. Cet article décrit une série d'expériences en courant continu à haute fréquence menées dans le but d'établir une corrélation entre, d'une part, les niveaux de la tension inverse à la jonction émetteur-base et la dégradation correspondante de h_{FE}, et, d'autre part, les résultats de calcul sur ordinateur basé sur un modèle à grands signaux du transistor.*

Improvements in Distortion and Ripple-Current Performance of High-Power Transmitters under Multicarrier Operation, *by M. Blanke & T.P. McElhone*

Different control-loop techniques useful in suppressing intermodulation distortion and ripple current inherent in nonlinear systems are described and hybrid computer techniques for optimising loop designs and evaluating performance are presented.

On décrit différentes techniques de boucles d'asservissement utilisées pour supprimer les phénomènes de distorsion d'intermodulation et d'ondulation résiduelle, phénomènes qui sont propres aux systèmes non-linéaires. Des méthodes de calcul hybride pour l'optimisation des boucles et l'évaluation de leurs performances sont également présentées.

ESA Dynamics and Technology Activities related to the Presence of Liquids aboard Spacecraft, *by J.L. Cendral & W. Berry*

The presence of significant volumes of liquids on board spacecraft gives rise to problems with the design of the containers for effective liquid management in the presence of satellite motion and the dynamic integration between liquid and satellite motions which affects the design of the attitude control systems. ESA's past and current activities in these domains are presented. In particular, experience gained in the dynamics of unstable spinning satellites, liquid-type nutation dampers and bipropellant apogee boost motors is reported. The Agency's work on the development of positive-expulsion and surface-tension propellant tanks for three-axis-stabilised missions is also summarised. Finally, future problems and new developments for future spacecraft are discussed in the light of current technological trends.

La présence d'importantes masses de liquides à bord de satellites pose des problèmes d'une part dans la conception des réservoirs qui doivent les contenir en présence du mouvement du satellite, d'autre part dans les interactions des mouvements du liquide et du satellite qui affectent la conception des systèmes de stabilisation. On dresse un bilan des activités présentes et passées de l'Agence spatiale européenne dans ces domaines: en particulier l'expérience acquise sur la dynamique des satellites en rotation instable, les amortisseurs de nutation passifs à liquide et les moteurs d'apogée bi-liquides. Les travaux entrepris par l'Agence dans le domaine des réservoirs à expulsion positive et capillaire pour les missions stabilisées trois axes sont brièvement décrits. Enfin, à partir des tendances actuelles, on s'efforce de prévoir l'évolution technologique des satellites futurs.

Le programme du CNES depuis 1971 sur le comportement des liquides dans les véhicules spatiaux, *par J.L. Marcé, L. Torres & P. Duchon*

La nécessité d'une étude systématique des problèmes liés à la présence de liquides à bord d'un véhicule spatial est apparue au CNES depuis 1971, notamment à l'occasion du projet D5A et de l'avant-projet de Météosat. Sont rappelés les deux grands types de problèmes étudiés, à savoir:

- *comportement des liquides en rotation,*
- *comportement des liquides en pesanteur réduite.*

On présente ensuite les différentes études théoriques et expérimentales développées sous la responsabilité du CNES pour étudier ces problèmes. En particulier, le palier à air tournant du CNES mis au point pour étudier les dissipations d'énergie dans les liquides en rotation est décrit. Enfin, on conclut sur le programme futur du CNES en ce domaine.

A systematic study of problems related to the presence of liquids on board space vehicles has been undertaken at CNES since 1971, particularly during the D5A satellite project and the Meteosat design study. The two principal problems studied, namely the behaviour of rotating liquids and that of liquids under reduced gravity, are reported. Various related theoretical and experimental studies performed for CNES are presented, including the rotating air bearing employed in studying energy dissipation in rotating liquids. In conclusion, CNES's future programme in this field is outlined.

An Algorithm for the Treatment of Outliers in the Linear Least-Squares Fitting Process, *by G.L. Webb*

The algorithm reported has been developed specifically for the case in which a number of linear coefficients have to be determined repeatedly from a large volume of data measured at fixed points. It provides an economical method of achieving this, while still removing the influence of spurious outlying points.

Un algorithme spécial a été mis au point pour le cas où l'on a à déterminer de façon répétitive un certain nombre de coefficients linéaires à partir d'une masse importante de données relevées en des points fixes. Cet algorithme constitue une solution économique à ce genre de problème et permet d'éliminer les points correspondant à des valeurs aberrantes.

ESA Reports

SPECIAL PUBLICATIONS

ESA SP-126 *SPACECRAFT POWER CONDITIONING, PROC SEMINAR NOORDWIJK, THE NETHERLANDS, 21-23 SEPTEMBER 1977 (NOV 1977)*
HOGSHOLM, A./GUYENNE, T.D. (EDS)
PRICE CODE C2

ESA SP-128 *ATTITUDE AND ORBIT CONTROL SYSTEMS, PROC CONF NOORDWIJK, THE NETHERLANDS, 3-6 OCTOBER 1977 (NOV 1977)*
MARKLAND, C.A./ROWLEY, C./BATTRICK, B. (EDS)
PRICE CODE C3

ESA SP-130 *LIFE SCIENCES RESEARCH IN SPACE – PROC SYMP PORZ/COLOGNE, GERMANY, 24-26 MAY 1977 (SEPT 1977)*
OSER, H./BURKE, W.R./GUYENNE, T.D. (EDS)
PRICE CODE C2

ESA SP-131 *ATS-6 PROPAGATION EXPERIMENTS IN EUROPE, PROC MEETING NOORDWIJK 6-7 SEPTEMBER 1977 (OCT 1977)*
BRUSSAARD, G./BATTRICK, B. (EDS)
PRICE CODE C1

TECHNICAL MEMORANDA

ESA TM-178 *THE DETERMINATION OF SYMMETRICAL SPHERICAL HARMONIC DISTRIBUTIONS FROM LIMITED DATA (SEPT 1977)*
WEBB, G.L.
PRICE CODE E1

TECHNICAL NOTES

ESA TN-137 *ACOUSTIC NOISE CONTROL IN A MANNED SPACE VEHICLE – THE OVERALL APPROACH OF SPACELAB (SEPT 1977)*
WYN-ROBERTS, D.W.
PRICE CODE E1

PROCEDURES, STANDARDS AND SPECIFICATIONS

ESA PSS-07/QRM-01 (ISSUE 3) *GUIDELINES FOR SPACE MATERIALS SELECTION (JUL 1977)*
PRODUCT ASSURANCE DIVISION, ESTEC
PRICE CODE E1

ESA PSS-37/QRM-06T (ISSUE 1) *GUIDELINES FOR THE SIMULATION OF THE DEGRADATION OF SURFACE PROPERTIES UNDER COMBINED UV/PARTICULATE RADIATION (OCT 1977)*
PRODUCT ASSURANCE DIVISION, ESTEC
PRICE CODE E1

CONTRACTOR REPORTS

ESA CR-868 *STUDY OF STATE ESTIMATION AND PARAMETER IDENTIFICATION APPLIED TO SPINNING FLEXIBLE SATELLITES/PART I - DYNAMICS/PART II - ESTIMATION AND IDENTIFICATION/PART III - USER'S GUIDE FOR NUMERICAL PROGRAMMES (SEPT 1977)*
LOUVAIN UNIVERSITY, BELGIUM
ESA PRICE CODES/VOL I - C1/VOL II - C1/VOL III - C1

ESA CR(P)-955 *REALISATION D'UN MODELE THERMIQUE DE DEVELOPPEMENT D'UN SYSTEME DE PROTECTION CRYOGENIQUE POUR APPLICATIONS SPATIALES*
SNIAS, FRANCE

ESA CR(P)-956 *FEASIBILITY STUDY ON THE OPTIMISATION OF OPERATIONAL SUPPORT REQUIRED FOR SATELLITE CONTROL/VOL 1 - FINAL REPORT/VOL 2 - ANNEXES 1 AND 2 (JAN 1977)*
ETUDES-LOGICIEL-SYSTEM, FRANCE

ESA CR(P)-957 *DESIGN AND DEVELOPMENT OF THE STAR-MAPPER PROTOTYPE PHASE IV – FINAL REPORT (APR 1977)*
TPD-TNO, THE NETHERLANDS

ESA CR(P)-958 *DESIGN AND DEVELOPMENT OF A GAS-CONTROLLED HEAT-PIPE RADIATOR FOR COMMUNICATION SPACECRAFT APPLICATIONS – PHASE II REPORT (FEB 1977)*
DORNIER SYSTEM, GERMANY

ESA CR(P)-960 *DEVELOPMENT OF A 2 KW AC POWER SYSTEM WITH MULTIPLE APPLICATIONS – FINAL REPORT (MAR 1977)*
DORNIER SYSTEM, GERMANY

ESA CR(P)-962 *MODELE DYNAMIQUE SIMPLIFIE D'UN SATELLITE STABILISE TROIS AXES A MOTEUR D'APOGEE BI-LIQUIDE (JUIN 1977)*
CNES, FRANCE

ESA CR(P)-963 *EVALUATION DES PROBLEMES D'UTILISATION D'UN CARCINOTRON DECIMILLIMETRIQUE RAPPORT FINAL (MAI 1977)*
THOMSON-CSF, FRANCE

ESA CR(P)-966 *DESIGN OF A PMA FOR FOCUSING A 4-STAGE IMAGE INTENSIFIER – FINAL REPORT (APR 1977)*
TPD-TNO-TH, THE NETHERLANDS

ESA CR(X)-967 *ANALYSIS OF SHOCK AND VIBRATION DATA RECORDED DURING THE TRANSPORTATION OF SPACELAB COMPONENTS (MAY 1977)*
CAMBRIDGE CONSULTANTS LTD, UK

ESA CR(P)-969 *MODELISATION DE COMPOSANTS POUR L'ANALYSE DES CIRCUITS ELECTRONIQUES (JUIL 1977)*
CIE INTERNATIONALE DE SERVICES EN INFORMATIQUE, FRANCE

ESA CR(P)-970 *UNIFIED SYSTEM FOR ORBIT COMPUTATION (USOC) – VOLUME 2: ORBITS IN THE SOLAR SYSTEM (JUN 1977). (VOL 1 WAS ISSUED AS ESA CR(P)-852)*
ACM SCHAENIS AG, SWITZERLAND

ESA CR(P)-971 *FATIGUE PROPERTIES OF SOLAR CELL INTERCONNECTORS (JUN 1977)*
INTERNATIONAL RESEARCH AND DEVELOPMENT CO LTD, UK

ESA CR(P)-972 *STUDY OF SATELLITE COMMUNICATIONS SYSTEM SERVING OFF-SHORE OIL AND GAS EXPLOITATION ACTIVITIES IN EUROPEAN SEA AREAS-VOL 1 TO 4 – FINAL REPORT/VOL 5 – SUMMARY REPORT (JUN 1977)*
MARCONI, UK

ESA CR(P)-973 *ETUDE DES PROBLEMES TECHNOLOGIQUES ASSOCIES AU CONCEPT D'UN DISPOSITIF A TRANSFERT DE CHARGES – RAPPORT FINAL (MAI 1977)*
THOMSON-CSF, FRANCE

ESA CR(P)-974 *I.R.F.E.S. – INFRARED FAN BEAM EARTH SENSOR PROTOTYPE MODEL (NOV 1976)*
OFFICINE GALILEO, ITALY

ESA CR(P)-975 *STUDY OF MICROCHANNEL PLATE INTENSIFIERS FOR PHOTON COUNTING (JAN 1977)*
EMI ELECTRONICS LTD, UK

ESA CR(X)-976 *LES SERVICES DE TELEDIFFUSION ASSOCIES A LA TELEVISION DIRECTE PAR SATELLITE/VOL 1 – PARTIES A – E/VOL 2 – ANNEXES ET BIBLIOGRAPHIE (JUL 1977)*
EUROSAT, SWITZERLAND

ESA CR(P)-977 *QUICK-LOOK CAPABILITY IN A EUROPEAN EARTH RESOURCES SATELLITE DATA NETWORK – FINAL REPORT (APR 1977)*
SWEDISH SPACE CORPORATION, SWEDEN

ESA CR(X)-978 *ETUDE DE FAISABILITE D'UNE MEMOIRE SEMI-CONDUCTEUR POUR METEOSAT – RAPPORT FINAL/VOL 1 – PRESENTATION TECHNIQUE (NOV 1976)*
CROUZET, FRANCE

ESA CR(P)-979 *DESIGN AND DEVELOPMENT OF A HEAT PIPE DIODE. PHASE I: FINAL REPORT (JUL 1977)*
IKE, GERMANY

ESA CR(P)-980 *SECA – RAPPORT FINAL/VOL 1 – TEXTE/VOL 2 – FIGURES (MAR 1977)*
CROUZET, FRANCE

ESA CR(P)-981 *DEVELOPMENT OF A COMPUTER SYSTEM FOR THE CALCULATION AND MANAGEMENT OF THERMAL MATHEMATICAL MODELS – FINAL REPORT (MAY 1977)*
ENGINS MATRA, FRANCE

ESA CR(P)-988 *SURVEY AND ASSESSMENT OF ACCELEROMETERS FOR POTENTIAL USE IN SPACELAB MATERIALS-SCIENCE PAYLOADS – FINAL REPORT (AUG 1977)*
BATTELLE, GERMANY

ESA CR(P)-989 *THERMAL VACUUM LIFE TEST OF AN HSD SOLAR ARRAY DRIVE (HSD NO. 2) (FIRST TWO YEARS OF OPERATION) (MAR 1977)*
ESTL/UKAEA, UK

ESA CR(X)-990 *RESULTATS DES EXPERIMENTATIONS POUR LA COMPARAISON AU T.S.C. DES MODEMS UTILISABLES POUR LE SYSTEME AEROSAT (JUIL 1977)*
TRT, FRANCE

ESA CR(P)-991 *STUDY ON ACOUSTICAL MIXING AND POSITIONING OF MOLTEN MATERIALS IN SPACE – PHASE 3 (JUL 1977)*
BATTELLE, GERMANY

ESA CR(P)-992 *DEVELOPMENT OF MODAL TECHNIQUES USING EXPERIMENTAL MODAL DATA – END OF PHASE 1 REPORT (AUG 1977)*
DFVLR, GERMANY

ESA CR(P)-993 *EUROPEAN SPACE TRIBOLOGY LABORATORY – PROGRESS REPORT FOR 1976*
ESTL/UKAEA, UK

ESA CR(P)-994 *STUDY OF ON-BOARD COMPUTER SYSTEMS FOR LONG-LIFETIME SATELLITES – FINAL REPORT/VOL 1 – SURVEY OF MICROPROCESSORS/VOL 2 – TASK ANALYSIS/VOL 3 – PROCESSING SYSTEMS: MAIN OPTIONS/VOL 4 – PROCESSING SYSTEMS: FURTHER SYSTEM DEFINITION (APR 1977)*
HOLLANDSE SIGNAALAPPARATEN BV/ PHILIPS DATA SYSTEMS BV, THE NETHERLANDS

TECHNICAL TRANSLATIONS

ESA TT-364 *ACOUSTIC EMISSION FROM COHERENT STRUCTURES IN A TURBULENT JET*
DAHAN, C., ONERA, FRANCE

ESA TT-368 *A METHOD FOR CALCULATING TURBULENT BOUNDARY LAYERS USING A FORMULATION OF FIRST GRADIENT TYPE*
RIBOUD, P.-M., ONERA, FRANCE

ESA TT-369 *SHOCK RECOMPRESSION OF A SUPERSONIC INTERNAL FLOW IN THE PRESENCE OF A BOUNDARY LAYER BLEED*
MEAUZE, G., ONERA, FRANCE

ESA TT-370 *MULTIPLE AND UPSTREAM TRAVELLING WAVES IN FREE JETS*
BECHERT, D., DFVLR, GERMANY

ESA TT-372 *AERODYNAMIC STUDY OF THE FLOW IN CAVITIES WITH WALL INJECTION*
CHAUMETTE, J., ONERA, FRANCE

ESA TT-374 *UNSTEADY PRESSURE MEASUREMENTS IN ROTOR BLADE TIPS WITH INCIDENCE IN INCOMPRESSIBLE FLOW*
TRIEBSTEIN, H., DFVLR, GERMANY

ESA TT-376 *CALCULATION OF THE PRESSURE DISTRIBUTION ON HARMONICALLY OSCILLATING BODIES IN INCOMPRESSIBLE FLOW*
GEISSLER, W., DFVLR, GERMANY

ESA TT-377 *THEORY OF THE HIGH-TEMPERATURE, HOLLOW CATHODE, A MODEL OF THE CATHODE MECHANISM*
BESSLING, H., DFVLR, GERMANY

ESA TT-378 *CALCULATION OF FLOW FIELDS WITH SEPARATION BUBBLES AT HIGH REYNOLDS NUMBER*
GEROPP, D./GRASHOF, J., DFVLR, GERMANY

ESA TT-379 *NONLINEAR, TRANSFORMATION MATRIX OF THE ELONGATED, BENT AND TWISTED ROD*
PETERSEN, D., DFVLR, GERMANY

ESA TT-380 *NUMERICAL INTEGRATION OF THE GOVERNING EQUATIONS FOR THE DOMAIN OF PURE SUPERSONIC FLOWS*
WEILAND, C., DFVLR, GERMANY

ESA TT-382 *STUDY OF A DRAG-FREE SATELLITE: PRESENTATION OF THE PROJECT AND SATELLITE PILOTING*
BISMUT, M. ET AL, ONERA, FRANCE

ESA TT-383 *STUDY OF A DRAG-FREE SATELLITE: ITS USE FOR NAVIGATION*
BESSON, J. ET AL, ONERA, FRANCE

ESA TT-384 *MODELLING OF QUARTZ OSCILLATORS*
BRESSY, P., ONERA, FRANCE

ESA TT-385 *PROGRESS IN THE CALCULATION OF TWO AND THREE DIMENSIONAL TURBULENT BOUNDARY LAYERS*
COUSTEIX, J., ONERA, FRANCE

ESA TT-386 *INTRODUCTION TO HYDRODYNAMICS OF REACTIVE PLASMAS*
FOURNIER, G., ONERA, FRANCE

ESA TT-387 *QUALIFICATION OF THERMAL CONTROL COATINGS FOR ULTRAVIOLET AND PARTICLE RADIATION IN SPACE*
PAILLOUS, A., ONERA, FRANCE

N.B. FOR HARD-COPY CHARGES, SEE INSIDE BACK COVER

ESA and NASA Scientific/Technical Publications ORDER FORM

Before using this Order Form

read the important information on the reverse.

To: Mme A. Luong
ESA SPACE DOCUMENTATION SERVICE
8—10, Rue Mario Nikis
75738 Paris Cedex 15
France

From: ______________________

____

____

PLEASE SUPPLY:

Customer's Ref ______________________

Date ______________________ Signature ______________________

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

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

MAILING LABEL (Print or type carefully)

Customer's Ref ______________________

ESA Order No.

To Name or Function ______________________

Organisation ______________________

Street Address ______________________

Town, Province, Postal Code ______________________

Country ______________________

ESA/NASA PUBLICATIONS ORDER FORM

INFORMATION

1. Use this form for your order.

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

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

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

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

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

EXECUTION OF ORDER

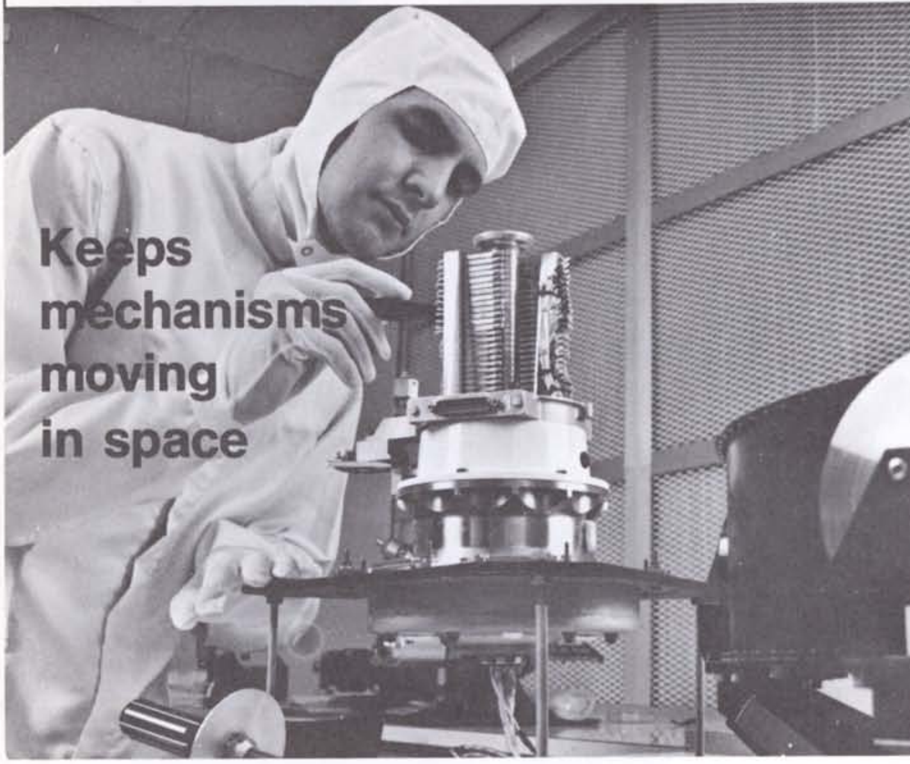
3. After the handling of your order has been completed, the form will be returned to you, marked with the following symbols:–

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

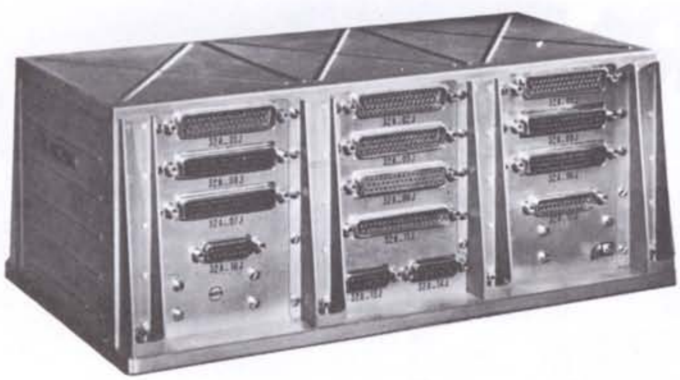
4. In any subsequent correspondence, please QUOTE THE ESA ORDER NUMBER.

5. Printed copies are despatched from ESTEC, and microfiche and photocopies from ESA Head Office. They will arrive in different packages at different times.

SUPPLIES OF THIS ORDER FORM ARE AVAILABLE FROM ESA SPACE DOCUMENTATION SERVICE AT THE ADDRESS SHOWN OVERLEAF



Keeps mechanisms moving in space



Availability of ESA and NASA Publications

PUBLICATION	Availability Note	DISTRIBUTION OFFICE
REPORTS		
ESA Scientific Reports etc. (ESA SR, SN, SM)	(1) and (2)	
ESA Technical Reports etc. (ESA TR, TN, TM)	(1) and (2)	
ESA Scientific and Technical Reports (ESA STR)	(1) and (2)	
ESA Scientific and Technical Memoranda (ESA STM)	(1) and (2)	
ESA Special Publications (ESA SP)	(1) and (2)	
ESA Contractor Reports (ESA CR)	(1) and (2)	Mme A. Luong ESA Space Documentation Service Reproduct. Service 8-10 rue Mario Nikis 75738 PARIS 15 France (Telex ESA 202 746)
ESA Contractor Reports (ESA CR(P))	(2)	
ESA Contractor Reports (ESA CR(P)* and CR(X))	(3)	
ESA Technical Translations (ESA TT)	(2)	
ESA Electronic Component Databank Catalogues (ESA ECDB)	(1)	
NASA Scientific & Technical Publications	(2)	
PROCEDURES, STANDARDS & SPECIFICATIONS		
ESA PSS	(1) and (2)	
PERIODICALS		
ESA Bulletin (quarterly)	(4)	
ESA Journal (quarterly)	(4)	
PUBLIC RELATIONS MATERIAL General literature, brochures, posters, photographs, films, etc.	–	ESA Public Relations Service 8-10 rue Mario Nikis 75738 PARIS 15 France

(1) – Available in hard (printed) copy against a charge as long as stocks last (see I).
(2) – Available in microfiche or photocopy against a charge (see II).
(3) – Restricted distribution only; further copies NOT available from ESA.
(4) – Available without charge either as a regular issue or as back numbers (as long as stocks last).

I. CHARGES FOR ESA PUBLICATIONS (PRINTED DOCUMENTS)

CATEGORY E

Number of Pages	Code	Price (French francs)
1-100	E1	25
101-200	E2	50
201-500	E3	100
Over 500	E4	150

CATEGORY C

Number of pages	Code	Price (French francs)
1-200	C1	25
201-500	C2	50
Over 500	C3	75

The above charges apply to Member States, Austria, Canada and Norway. A 20% surcharge will be levied on orders from 'other States'.

II. CHARGES FOR ESA & NASA MICROFICHE AND PHOTOCOPIES

Microfiche (up to 98 pages per fiche) FF 5.00
Photocopies (enlargement of one microfiche page) FF 2.40/page

NOTE 1. Minimum orders of FF 36.— per monthly invoice.
NOTE 2. Photocopies are supplied if original document out of print, unless microfiche is specified (see Order Form).

MEMBER STATES
Belgium
Denmark
France
Germany
Italy
Netherlands
Spain
Sweden
Switzerland
United Kingdom

ETATS MEMBRES
Allemagne
Belgique
Danemark
Espagne
France
Italie
Pays-Bas
Royaume-Uni
Suède
Suisse