esa bulletin

number 25

february 1981

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr. J. Stiernstedt (Sweden).

Director General: Mr. E. Quistgaard.

agence spatiale européenne

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

Président du Conseil: M. J. Stiernstedt (Suède).

Directeur général: M. E. Quistgaard.

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Back cover: Computer console at ESOC, Darmstadt.

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

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

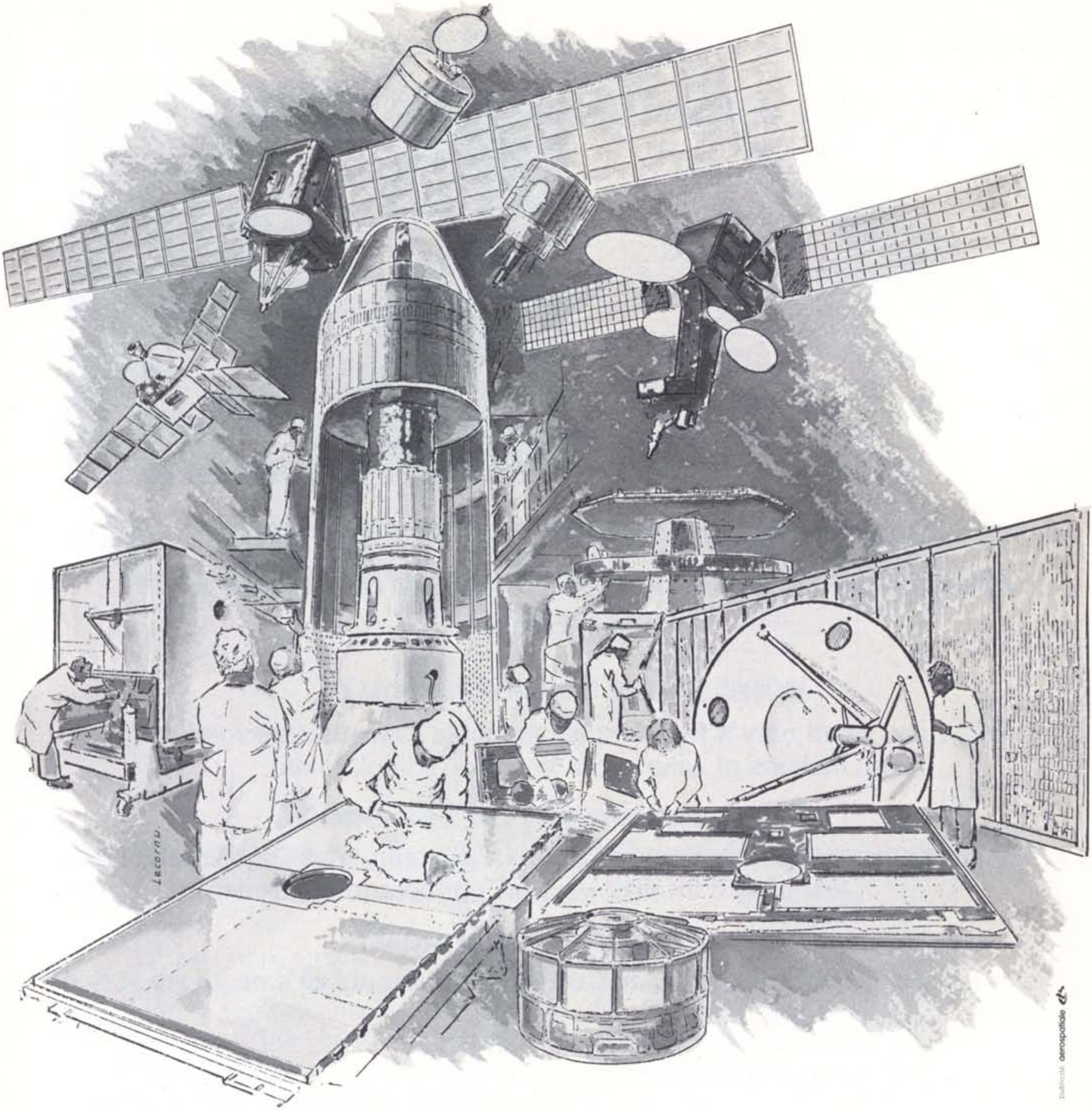
Editorial Assistants
Jacqui Mort, Gabrielle Lévy

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

Printed in The Netherlands by ESTEC Reproduction Services 803821
ISSN 0376-4265

european space agency
agence spatiale européenne

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



La Convention portant création de l'Agence spatiale européenne est maintenant entrée en vigueur

M. Bourély, Conseiller juridique, ESA, Paris

Le 30 octobre 1980, jour où la France a procédé au dépôt de son instrument de ratification de la Convention portant création d'une Agence spatiale européenne, restera, dans l'histoire de celle-ci, comme étant la date de sa création officielle. Il est notoire que, depuis plus de cinq ans, l'Agence fonctionne sous son nom actuel et qu'elle s'est déjà acquis, par ses réalisations, une renommée incontestable dans l'opinion publique tant en Europe que dans le reste du monde. On pourrait dès lors considérer que l'entrée en vigueur formelle de la Convention de l'ASE est un événement de portée très limitée et qui ne peut intéresser queles spécialistes du droit des institutions internationales. Or, la réalité est tout autre: cette entrée en vigueur constitue en fait une étape importante dans la politique spatiale des pays européens car elle scelle définitivement les engagements souscrits par les Etats signataires de la Convention: elle entraîne, en outre, un certain nombre de conséquences capitales pour le fonctionnement de l'Agence elle-même.

Conséquences de l'entrée en vigueur formelle

Comme les lecteurs du Bulletin s'en souviendront[1], la Convention portant création d'une Agence spatiale européenne avait été ouverte à la signature au cours d'une réunion, qui s'était tenue le 30 mai 1975, des Plénipotentiaires des Etats membres de la Conférence spatiale européenne. Elle avait été effectivement signée, ce même jour, par les représentants des Etats membres des deux organisations spatiales européennes, le CERS/ESRO[2] et le CECLES/ELDO[3] auxquelles l'Agence devait se substituer à l'avenir. Conformément aux principes généraux du droit international, l'entrée en vigueur de la Convention de l'Agence était toutefois subordonnée à l'exécution des formalités de ratification ou d'adhésion par les instances compétentes des pays signataires; cette Convention ne pouvait ainsi entrer en vigueur qu'après le dépôt du dernier des 'instruments' constatant l'exécution desdites formalités. Le fait qu'il se soit écoulé cinq ans et cinq mois avant que les conditions requises pour l'entrée en vigueur de la Convention soient effectivement remplies – délai qui dépasse, de loin, ceux qui avaient été nécessaires pour l'entrée en vigueur des Conventions spatiales antérieures – ne découle pas seulement de la lourdeur intrinsèque des procédures à accomplir. Il révèle les hésitations que certains pays ont éprouvées, postérieurement à la signature de la Convention, en raison des difficultés rencontrées par l'Agence dans l'exécutionde ses activités depuis 1975. On sait que ces difficultés ont empêché notamment pendant plusieurs années la prise de certaines décisions vitales pour l'Agence telles que la fixation du niveau triennal de ses ressources et gêné la poursuite de ses programmes les plus importants.

Ces obstacles ayant été finalement tous surmontés au cours des derniers mois, plus rien ne s'opposait à ce que certains pays abandonnent leurs réticences passagères vis-à-vis de l'institution dont la collectivité européenne avait décidé de se doter.

Il faut ajouter que l'entrée en vigueur de la Convention de l'ASE a des conséquences importantes sur la situation de deux Etats qui participent déjà aux activités de l'Agence:

– l'Irlande, qui avait signé la Convention le 31 décembre 1975, et qui avait conclu avec l'Agence un accord 'ad hoc' pour la période transitoire devient, par le dépôt (qui a eu lieu le 10 décembre 1980) de son propre instrument de ratification, le onzième Etat membre de l'Agence;
– l'Autriche, qui était liée à l'Agence par divers accords de participation à certains programmes, acquiert désormais la qualité de 'membre associé' de l'Agence – ce qui constitue une innovation de la nouvelle Convention.

Il convient donc de ne pas sous-estimer l'importance politique que revêt l'entrée en vigueur formelle de la nouvelle Convention dont l'application s'impose désormais à tous les Etats membres de l'Agence et qui permet à ceux-ci de disposer d'un organisme chargé de

[1] Voir Bulletin ESA no 1 - juin 1975, page 12
[2] Organisation européenne de recherches spatiales
[3] Organisation européenne pour la construction et la mise au point de lanceurs d'engins spatiaux

Entry into Force of the ESA Convention

The 30 October 1980, the day when France deposited its instrument of ratification of the Convention for the establishment of a European Space Agency, will be recorded in the Agency's annals as the date of its official creation. The organisation has of course been using the name ESA for more than five years and its achievements have secured its reputation in the public eye both in Europe and around the world. The formal entry into force of the ESA Convention could then be regarded as a minor event of interest only to specialists versed in the laws of international institutions, but this is far from being the case. The Convention's ratification in fact marks a major milestone in the space policy of European countries by setting the final seal on the undertakings entered into by the Member States who have signed the Convention. It also has a number of important consequences for the running of the Agency itself.

Consequences of the Convention's entry into force

As regular readers of the Bulletin may recall, the Convention for the Establishment of a European Space Agency was opened to signature at a meeting on 30 May 1975 of the Plenipotentiaries of the Member States of the European Space Conference, and was in fact signed on that day by the representatives of the Member States of the two European space organisations, ESRO (European Space Research Organisation) and ELDO (European Organisation for the Construction and Development of Space Vehicle Launchers) which the Agency was intended to replace. In keeping with the general principles of international law, the entry into force of the ESA Convention was however contingent on completion by the authorities of the signatory countries of the formalities of ratification or adherence; the Convention could not therefore enter into force until the last of the 'instruments' attesting completion of these formalities had been deposited. The fact that it has taken five years and five months for the conditions for the entry into force of the Convention to be satisfied – a period far exceeding that needed for the entry into force of previous space Conventions – has not resulted only from the inherent unwieldiness of the procedures involved. It reflects the hesitation that some countries felt subsequent to signing the Convention in view of the difficulties encountered by the Agency in carrying out its tasks since 1975. These difficulties prevented the taking of certain vital Agency decisions for several years, such as the fixing of its three-year level of resources and the pursuit of its most important programmes.*

With all these hurdles finally overcome in recent months, the temporary misgivings that certain countries had about the new institution that the European space community had decided to form have been removed.

The entry into force of the ESA Convention also has major consequences for two countries already participating in the activities of the Agency:

- *Ireland, which signed the Convention on 31 December 1975, and concluded an 'ad hoc' agreement with the Agency for the transitional period has, become, by depositing (on 10 December 1980) its instrument of ratification, the eleventh ESA Member State, and*
- *Austria, which has been linked to the Agency by various agreements on participation in certain programmes, now acquires the status of an 'associate member' of the Agency, one of the innovations of the new Convention.*

All in all then the political importance of the formal entry into force of the new Convention, which will now be binding on all the ESA Member States and provide them with a body charged with implementing the space policy that they will jointly determine, should not be underrated.

* *See ESA Bulletin No. 1, June 1975, page 12.*

Figure 1 – Arrival of Mr. Gaston Geens, then Belgian Minister of Science Policy and Budget, at the first ESA Council Meeting at Ministerial Level (Paris, 14–15 February 1977) / *Arrivée de M. Gaston Geens, ministre belge de la Politique et du Budget scientifiques, à la première réunion du Conseil de l'ASE au niveau ministériel (Paris, 14–15 février 1977)*

mettre en oeuvre la politique spatiale qu'ils définiront en commun.

Fin de l'application 'de facto'
Il n'en est pas moins vrai, comme cela a été signalé plus haut, que l'Agence fonctionne déjà comme telle depuis le jour de la signature de la Convention du 30 mai 1975: le CERS/ESRO et le CECLES/ELDO ont, en effet, cessé leurs activités propres; la première Organisation a poursuivi les siennes sous le nom d''Agence spatiale européenne' et c'est elle qui a constitué le noyau de la nouvelle institution; la seconde Organisation, qui avait déjà mis fin à ses programmes, a été liquidée. D'autre part, en exécution du voeu formulé par les Plénipotentiaires, signataires de la Convention du 30 mai 1975, les dispositions de celle-ciont été appliquées dans tous les cas où cela était possible – c'est-à-dire chaque fois que la nouvelle Convention ne se trouvait pas en conflit avec celle du CERS/ESRO.

Ainsi, la période transitoire qui vient de s'achever avec l'entrée en vigueur formelle de la Convention de l'ASE, s'est-elle caractérisée par une application 'de facto' de celle-ci. Une telle situation, qui a permis, en particulier, d'utiliser la nouvelle procédure d'adoption des programmes facultatifs, n'a toutefois pas manqué de causer quelques difficultés dans le fonctionnement de l'Agence: il est toujours délicat pour le Conseil et les autres organes délibérants de prendre des décisions qui s'appuient sur un 'consensus', précaire par définition, plutôt que sur les dispositions d'un texte qui s'impose à tous. D'autre part, la Convention de l'Agence contient certaines dispositions qui modifient celles qui étaientinscrites dans la Convention du CERS/ESRO et qu'il n'était donc pas encore possible de mettre en oeuvre, par exemple dans le domaine financier.

En revanche, on peut se féliciter de ce que la décision d'appliquer 'de facto' la Convention de l'ASE ait permis de préparer à loisir la mise en place ou la révision (lorsqu'elle s'imposait), d'un certain nombre de textes d'application de la nouvelle Convention (règlement du personnel, règlement financier, règlement des contrats). L'Agence pourra ainsi commencer immédiatement à fonctionner sous sa forme définitive.

Sécurité juridique assurée
Telle est donc la portée, politique et juridique, de l'entrée en vigueur formelle de la Convention, signée le 30 mai 1975, et portant création de l'Agence spatiale européenne. Malgré la longueur inaccoutumée de la période transitoire qui s'achève, l'institution nouvelle a cependant pu fonctionner 'de facto' sur presque tous les plans, et aucun délai supplémentaire n'est nécessaire pour que la Convention soit désormais appliquée dans toutes ses dispositions.

La sécurité juridique étant maintenant acquise, il appartient aux Etats membres de l'Agence de tirer parti des possibilités nouvelles que leur ouvre la Convention dans certains domaines et de veiller à ce que celle-ci soit appliquée non seulement à la lettre mais aussi conformément à l'esprit de ceux qui, en la signant, voulaient donner à l'Europe un moyen d'action à sa mesure dans le domaine spatial.

Figure 2 — Session of the Agency's Council at ministerial level (Paris, 14–15 February 1977) / *Session du Conseil de l'Agence au niveau ministériel (Paris, 14 – 15 février 1977)*

The end of 'de facto' Convention provisions

The fact remains however, that as already pointed out, the Agency has been functioning as such since 30 May 1975, the day on which the Convention was signed. ESRO and ELDO were in fact wound up, the activities of the former being continued under the name of the 'European Space Agency' thus constituting the core of the new institution, while the latter, which had already terminated its programmes, was dissolved. Also, in keeping with the wish expressed by the Plenipotentiaries who signed the Convention on 30 May, the Convention's provisions have been applied wherever possible, i.e. wherever the new Convention did not conflict with that of ESRO.

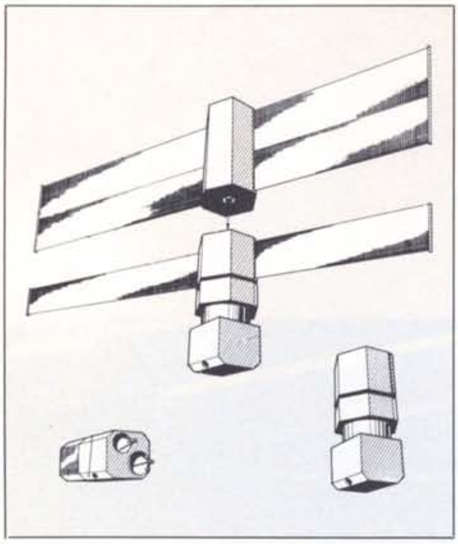
The transitional period that has just ended with the formal entry into force of the ESA Convention has therefore been characterised by 'de facto' application of the Convention's provisions. This situation, which made it possible in particular to use the new procedure for adopting optional programmes, did give rise to some difficulties in running the Agency. It was difficult for the Council and the other delegate bodies to take decisions based on a 'consensus', which is precarious by definition, rather than on the provisions of a text binding to all. The ESA Convention also contains certain provisions that modify those of the ESRO Convention and which it has not therefore been possible to put into effect until now, for example, in the financial area.

On the other hand, there has been the welcome aspect that the decision to apply the ESA Convention 'de facto' provided a respite for introducing or revising, where required, a number of texts applying the new Convention (e.g. personnel regulations, financial regulations, contract regulations). The Agency was thus able to start functioning immediately in its eventual form.

Juridical security assured

Such therefore is the political and legal scope of the full entry into force of the Convention signed on 30 May 1975 and establishing the European Space Agency. Despite the unusual length of the transitional period, the new organisation has however been able to operate 'de facto' in nearly all areas and all the provisions of the Convention can now be implemented without further delay.

Juridical security now having been assured, it is for the Member States of the Agency to take advantage of the new possibilities offered by the Convention in certain areas and to ensure that it is applied not only to the letter but also in keeping with the spirit of those who, by signing it, wished to provide Europe with an appropriate means for space activities.



Satellite Assembly in Geostationary Orbit – A Plug-and-Socket Concept

A.W. Preukschat, ESA Communications Satellites Department, Directorate of Applications Programmes, ESTEC, Noordwijk, Netherlands

The capabilities of today's communications satellites are limited by launch-vehicle-related mass constraints, which require the use of several satellites in orbit in order to satisfy the requirements of a particular communications mission. The resulting costs of such a space segment are high. A new space-segment construction concept – satellite assembly in geostationary orbit – is described here which, subject to certain assumptions, can effectively remove these mass constraints and which appears to have the potential to reduce procurement costs for future communications space segments.

Communications satellites, like many other types of spacecraft, consist essentially of two functional modules integrated into a common structure: the Payload Module – carrying repeaters and antennas in the case of communications satellites, for the provision of the communications service – and the Service Module – carrying the supporting-subsystems equipment.

This satellite design concept is cost-effective as long as the mission requirements – communications capability, space-segment reliability and lifetime – can be achieved with a single satellite in orbit. Today's mission requirements have, however, grown to a degree where the corresponding mass of a single, appropriately sized satellite exceeds the capabilities of the available launch vehicles. Consequently, a modified space-segment concept is being adopted in which several smaller satellites are put into orbit to meet the system requirements.

While this approach is a technically valid one for extending the application of conventional satellite design methods to communication missions that would otherwise not be feasible with today's launchers, it results in substantially increased procurement costs because of the lower cost-effectiveness of using the individual satellites. For a typical operational mission there might be two satellites in orbit, one launched as an in-orbit spare, and several on the ground ready for launch if and when an in-orbit satellite fails. Only one satellite is then in operation and the others remain on standby without actively contributing to the communications service proper. Furthermore, should the active satellite fail to meet mission requirements because of some equipment failure, it may need to be turned off completely, thereby representing a total loss although much of its equipment may still be in perfect working order.

To illustrate the difference between multiple-satellite and single-satellite systems, we can examine here a hypothetical space-segment mission requirement, with the communications service capacity represented by a number of repeater channels, several specified antenna coverage areas, a seven-year space-segment lifetime, and a space-segment probability of operation of 0.95.

To meet these requirements with a space segment consisting of 'small' satellites, as illustrated in Figure 1, would require procurement of, typically:

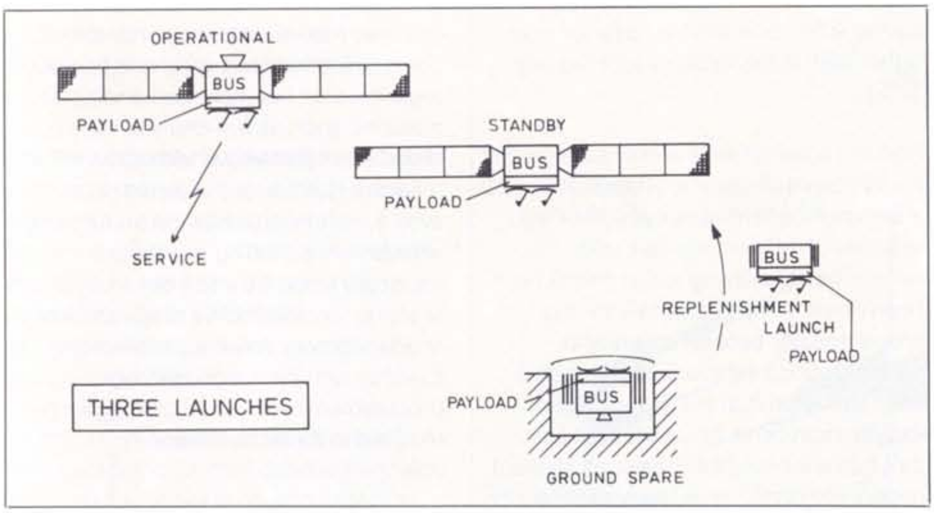
- three satellites in orbit (launched sequentially)
- one spare satellite on the ground (to be launched in the event of a launch-vehicle failure)
- three launches each of 1000 kg
- one spare launch (as a standby)
- launch and in-orbit-operation services for the three-satellite space segment.

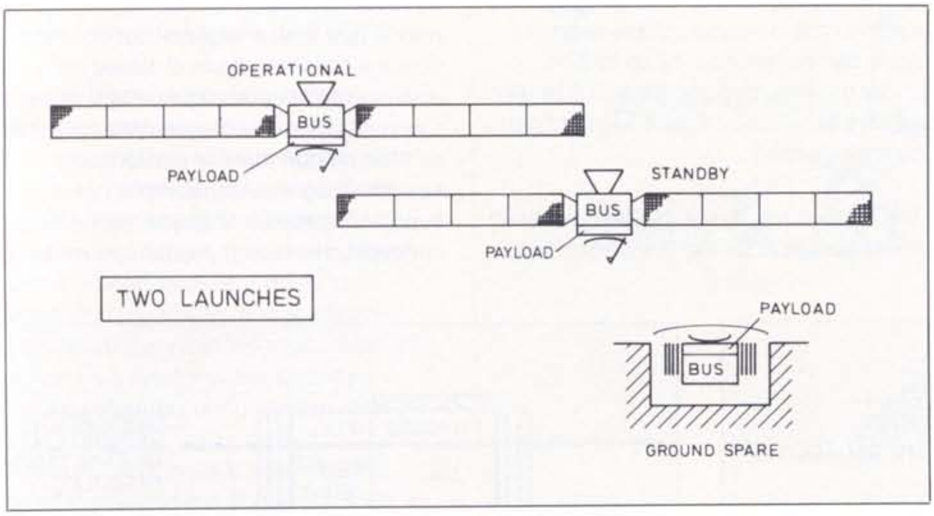
All four satellites would then have equal performance, and would be individually compatible with both the communications service capacity and operational lifetime. Due to an assumed launch-mass limitation of 1000 kg, however, satellite

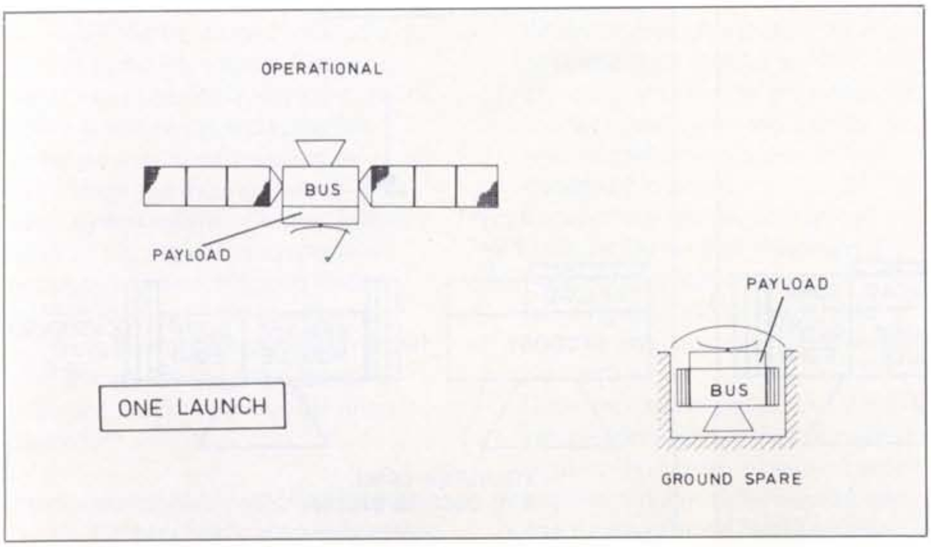
Figure 1 – Space-segment construction using three 'small' satellites to meet mission-success probability requirements

Figure 2 – Space-segment construction using two large satellites (one operational, one in-orbit standby) to meet mission-success probability requirements

Figure 3 – Single-satellite space-segment concept. The large satellite is capable of meeting the full mission requirements by itself







reliability would only be of the order of 0.53 and thus the mission-reliability requirement would call for several satellites. The procurement cost of the system corresponds to 4000 kg of satellite hardware, 3000 kg of launch-vehicle capability, plus the service costs for the satellites.

Figure 2 illustrates a space-segment configuration with the same performance at system level as the three-satellite system, for which the launcher mass constraint has been relaxed somewhat. An additional 160 kg of equipment for redundancy, bringing the hypothetical satellite budget to 1160 kg, has improved satellite reliability to 0.7. This would mean that a two-satellite space segment could meet the mission requirements, and we would then have:

- two satellites in orbit
- one spare satellite on the ground
- two launches, each of 1160 kg
- one spare launch
- launch and operation services for two satellites.

The procurement cost for this space segment corresponds to 3480 kg of satellite hardware (cost saving 13%), 2320 kg of launch-vehicle capability (cost saving 23%), and service costs for two rather than three satellites (cost saving 17%).

It has been calculated that to meet the above hypothetical communications-mission objectives fully with a single satellite would involve a satellite mass of 1800 kg (Fig. 3). Space-segment procurement would correspond to:

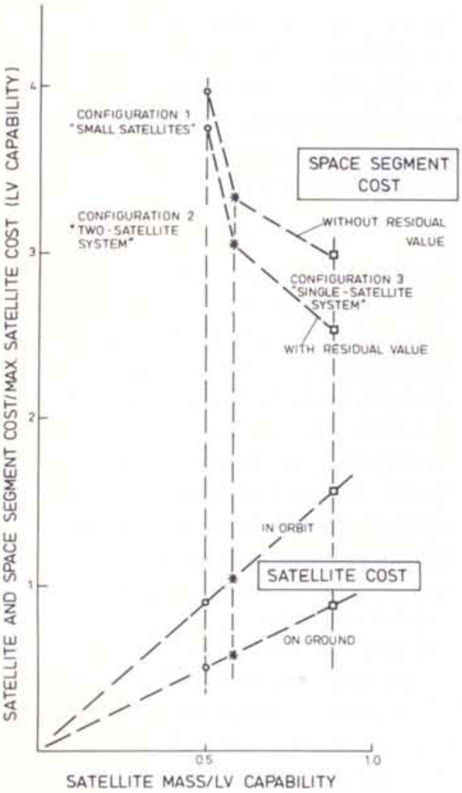
- one satellite in orbit
- one spare satellite on the ground
- one launch of 1800 kg
- one spare launch
- launch and operation services for one satellite.

The procurement cost for this space segment corresponds to 3600 kg of satellite hardware (cost saving 10%), 1800 kg of launch-vehicle capability (cost

Figure 4 – Satellite and space-segment costs for three space construction models (three small, two large and one very large satellite)

Figure 5 – Today's space-segment construction concept based on 'vertical separation' of space-segment requirements (reliability)

Figure 6 – Proposed space-segment construction concept based on 'horizontal separation' of satellite functions (payload and service-housekeeping modules)

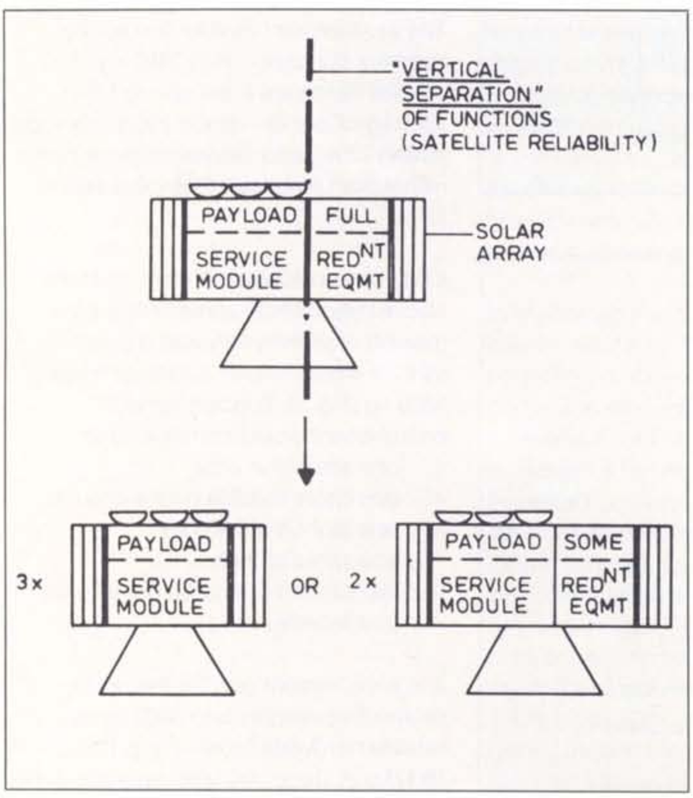


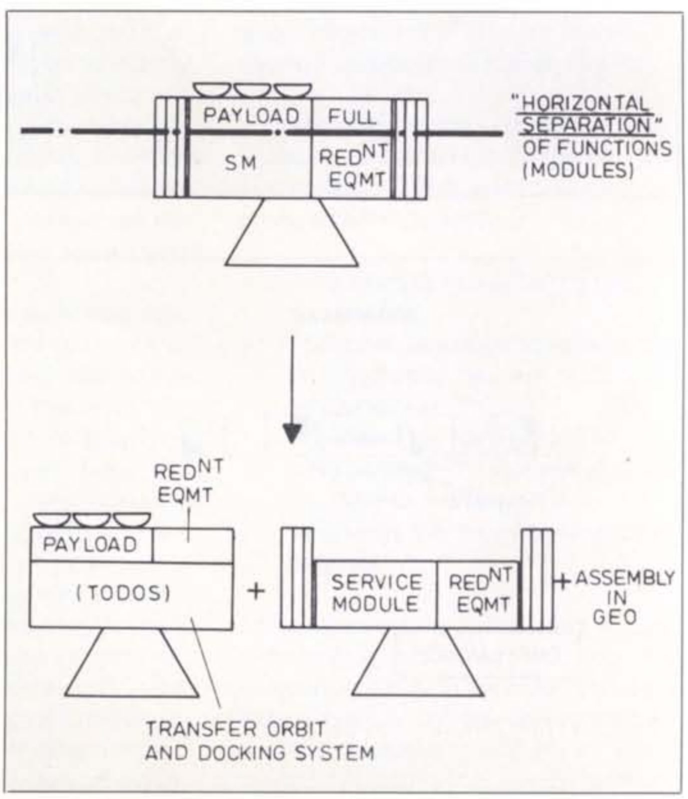
saving 40%), and service costs for one rather than three satellites (cost saving 37%).

Figure 4 summarises the cost savings that could potentially accrue when building up a communications space segment with satellites of different masses and reliabilities. Simplifying assumptions have been made in the computations, e.g. proportionality between mass and satellite/launch vehicle cost. It has also been assumed that the ground-spare satellite represents an investment cost that has a recoverable (residual) element depending on the probability of its launch and on the modifications required for its re-use. Figure 4 shows that, although unit satellite cost increases, space-segment costs can be reduced, by up to 32% under the assumptions made, if a single-satellite-per-mission space segment can be implemented.

The mission requirements that have been taken as typical for the comparison are relatively modest in terms of number of communications channels and power requirements. For more demanding missions, such as five-channel television broadcast satellites with 64 dBW EIRP (effective isotropically radiated power), even a launch capability on an Ariane-3 vehicle with a 2400 kg of payload capability could be insufficient for realising a cost-effective single-satellite space segment. A two-satellite system, together with the associated high procurement cost, would then again be required to meet the mission objectives.

To pursue the cost reductions identified above, and possibly additional savings also, a new space-segment construction concept has been devised, based on an analysis of the basic requirements of the functional modules of a communications satellite, independent of conventional satellite design concepts. While not supplanting the other space-segment concepts, this new approach, under the





conditions described here, is felt to be capable of providing a cost-effective solution.

Satellite assembly in geostationary orbit
Analysis of previous multi-satellite space segments shows that compatibility between satellite performance and system requirements has been achieved by 'vertical separation' of system performance (reliability) into a number of small satellites (Fig. 5).

An alternative approach, which leads to the basic idea of in-orbit satellite assembly, proposes separating satellite performance 'horizontally' at the level of the functional modules: Payload Module (PM) and Service Module (SM) (Fig. 6).

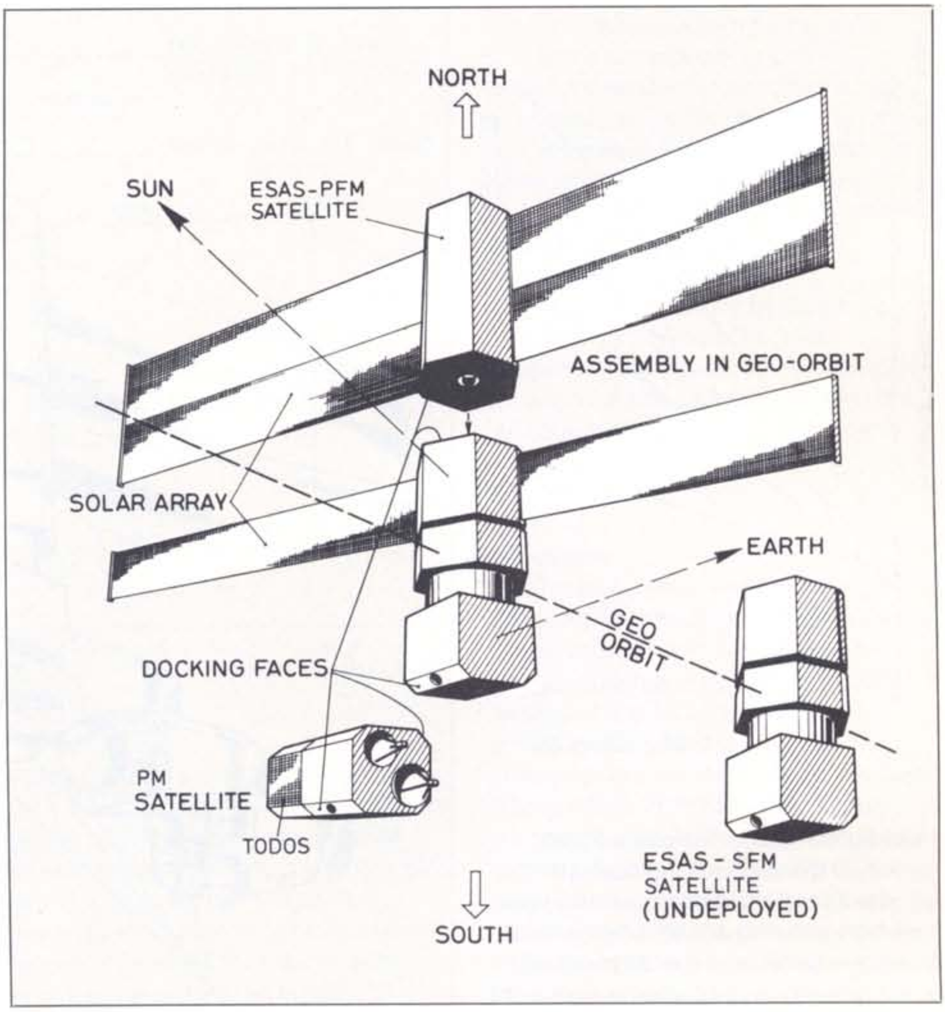
Like the former approach, the new approach also requires separate launchings of individual space-segment elements: functional-module satellites instead of autonomous integrated satellites. In addition, the new approach calls for rendezvous and docking in geostationary orbit to re-assemble the modules to complete the space segment, as well as a system to 'support' the Payload Module during transfer orbit.

The concept of satellite assembly in geostationary orbit is illustrated in Figure 7. It foresees the phased launch of individual satellite modules by Ariane. First to be launched would be the SM satellite, followed by the PM satellite. Following rendezvous in geostationary orbit, the PM satellite would be docked to the SM. Further payload satellites could be docked later to the opposite face of the initial payload satellite to further extend the assembly. Figure 7 also shows the rendezvous and docking of a Power Function Module (PFM) satellite, illustrating the concept of increasing the functional service capability (power, propellant, etc.) of the basic SM when required.

The modular satellite-assembly concept offers a number of new, potentially cost-saving advantages which are not feasible with the old concept:

- 'Apparent capability growth' for existing launch vehicles for the construction of almost any size of space segment, allowing a better return on the development investment in Ariane.
- It offers the possibility of sharing common SM hardware between a number of payloads, thereby reducing unproductive 'overhead costs' for the communications service payloads.
- Once the basic investment for the SM satellite has been made, procurement costs for the communications space segment reduces to the incremental cost for the payload satellites proper.

Figure 7 – Plug-and-socket assembly of satellites in geostationary orbit

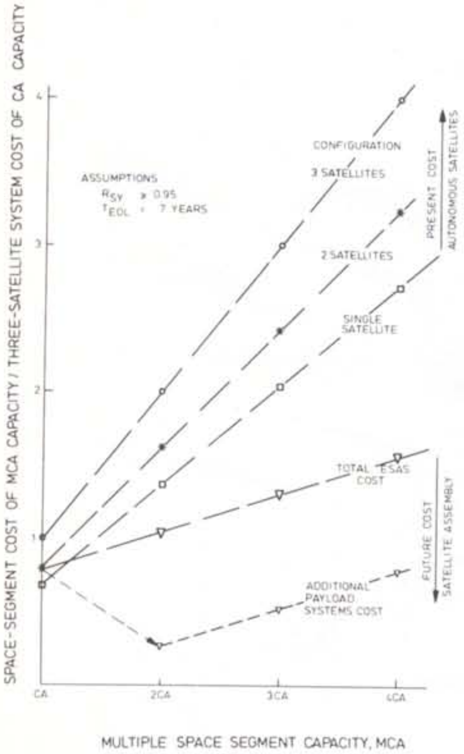


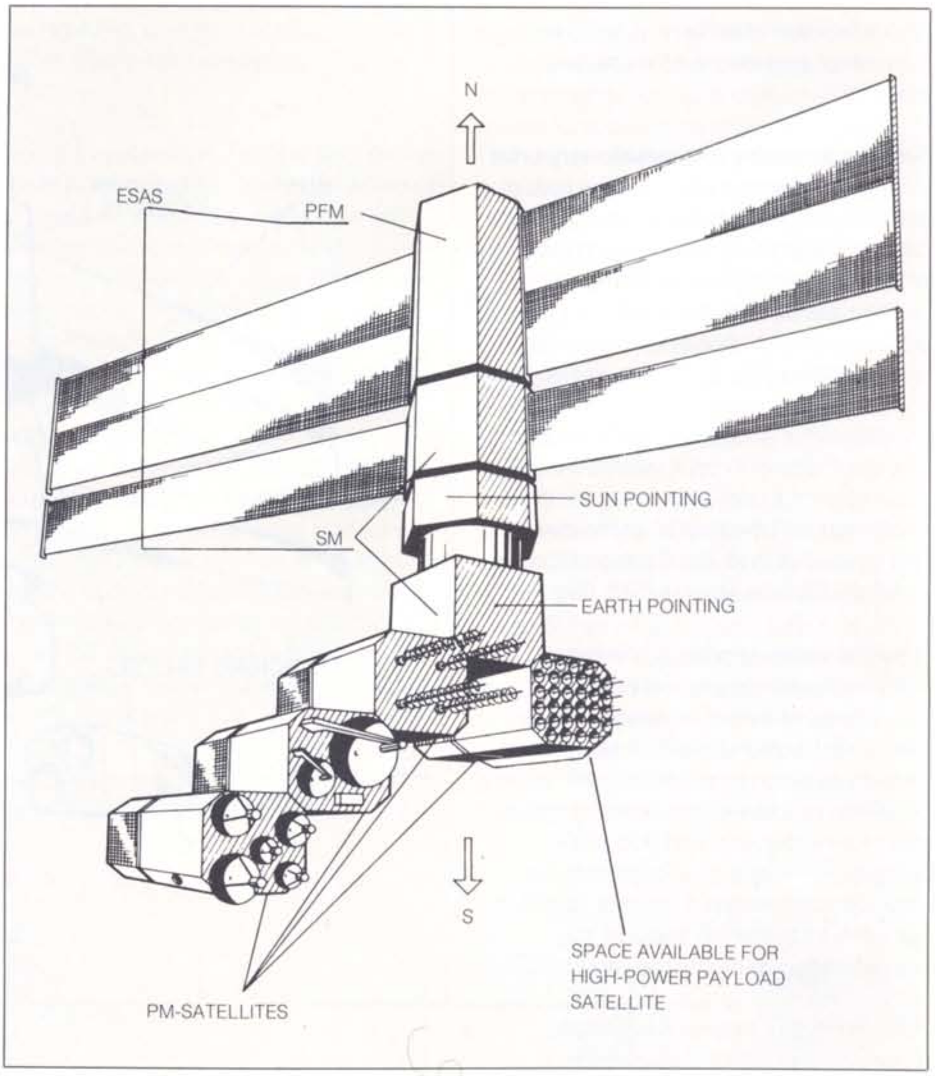
The ability to fully realise the cost advantages of the new concept depends on the cost effectiveness of the additional systems required, i.e. the Rendezvous and Docking (RVD) system and the Transfer Orbit and Docking System (TODOS) required to support Payload Modules between launch and attachment to the already orbiting SM satellite.

Both the rendezvous and docking of the various elements of the space segment can use to advantage the 24-hour visibility from the ground offered by the geostationary orbit. An RVD concept has been derived that limits the recurring hardware requirements for the payload satellites to the docking adapters. The SM satellite carries the sensing equipment

Figure 8 – Mass breakdown for payload-module and service-function-module satellites launched on Ariane (2300 kg)

Figure 9 – Artist's impression of a possible configuration for an in-orbit-assembled geostationary telecommunications space segment





required to measure the position and velocity of the approaching payload satellite. Evaluation of measurement data, trajectory planning and verification, and command generation can be performed in the ground control station using the SM satellite as a remote station in orbit. Consequently, the cost of performing the rendezvous and docking in geostationary orbit should not differ substantially from the mission-support costs for injecting a conventional satellite into orbit.

Additional hardware needed for the rendezvous and docking operations consists of a sensor subsystem on the SM satellite to measure the range, direction of travel, and velocity of the approaching satellite and to transmit these data to the ground station.

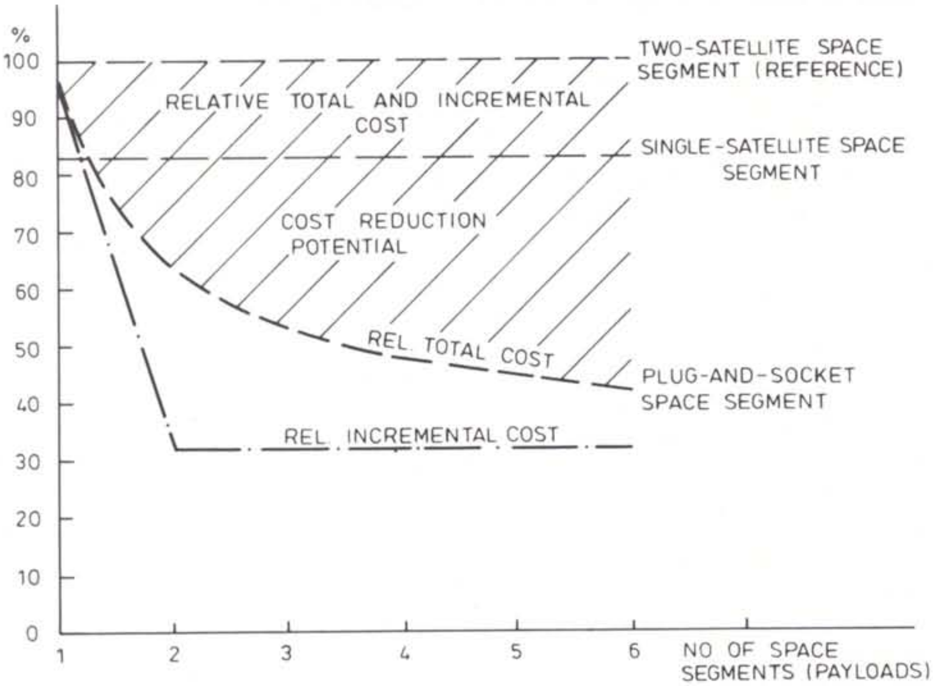
The TODOS represents a cost element that needs to be kept low in order not to upset the cost-effectiveness of the assembly system. Since its task is to support the Payload Module in transfer orbit, it requires a full complement of service support subsystems. However, since it does not need to service the payload actively, and since its basic mission duration need only cover the time in transfer orbit until docking, i.e. some 30 days, its performance requirements are very modest. The corresponding TODOS design consists of a launch-vehicle/payload-module interface structure carrying the apogee boost motor system, transfer-orbit attitude and orbit control, power and telemetry and telecommand subsystems, as well as the docking adapters and power-signal interfaces to the SM. In the light of the repetitive, short-duration mission requirements, a standardised, low-cost design for the TODOS should be feasible.

Figure 8 shows a payload mass breakdown for Ariane for the launch of SM and PM satellites.

With an estimated maximum dry mass for the TODOS of 280 kg, the 'apparent' growth capability for Ariane (maximum payload 2300 kg) is extended to 813 kg of communications payload; this is more than twice the payload mass generally available on an equivalent conventional satellite.

The SM capability that could be launched corresponds to 1100 kg of service-

Figure 10 – Cost-reduction potential of plug-and-socket space-segment construction, with respect to today's two satellite systems



function hardware (for a launch mass limit of 2300 kg), again representing almost twice that of conventional satellites. It should be noted here that the available mass for the SM satellite could be used to increase the redundancy of the SM beyond conventional seven-year lifetime requirements to 10 or more years. Consequently, the requirements for operational system reliability could also be met, with later launched PM satellites representing additional communication systems.

Plug-and-socket concept for communications space segments

The objective, then, of reducing the procurement costs for future space communication systems by assembling satellites in geostationary orbit can be met by the application of novel design concepts that allow:

- the necessary communications mission performance to be provided with a single set of satellite hardware in orbit, with satisfactory reliability and lifetime, and
- the service support performance to be shared between several payloads.

Figure 9 shows a possible configuration for a 'European Satellite Assembly System' (ESAS), with a power-augmented SM satellite system (the socket) and four PM satellites attached (the plugs). The assembly sequence could be as follows: launch of the basic SM satellite; launch and docking of the three (small) PM satellites; launch and docking of the PFM satellite to augment the system's power capabilities prior to launch and docking of a large, high-power Payload-Module satellite; subsequent launch and attachment of the fourth (small) PM satellite.

The cost-reduction potential of the ESAS system (without PFM satellite) compared with the conventional two-satellite and single-satellite systems is illustrated in Figure 10. For comparison purposes, it has been assumed here that the specific cost of all service module and payload module equipment is the same, and that the cost of satellite hardware and of a launch is then proportional to the total mass of the individual satellites. The actual cost savings would depend on the number of PM satellites serviced by the ESAS, but they could amount to up to 57% of the corresponding total investment needed for six conventional two-satellite systems, or 40% of the total cost of the equivalent single-satellite systems (assuming they could be launched by an available launch vehicle). The relative incremental cost for establishing an additional communications service by launching and docking a PM satellite, after establishing the basic ESAS in orbit, is shown to be 32% (respectively 39%) of the equivalent cost of a conventional system.

Conclusion

With present satellite and space-segment design techniques, major reductions in system procurement cost are unlikely. New approaches therefore need to be developed and satellite assembly in geostationary orbit is considered a promising concept that removes the cost-driving effects of launch-vehicle mass constraints on satellite design and space-segment construction. It is believed that, should such a concept be developed, significant savings in future procurement costs, could be achieved, thereby opening the way to expansion of demand for European satellite systems and space-communication services.

Meteosat Tracks Kármán Vortex Streets in the Atmosphere

P. Berlin, Earth Observation Programme Office, ESA, Toulouse, France

Vortex streets appear in the wake of bluff bodies suspended in a flowing medium as a result of periodic vortex shedding. This little-known phenomenon is the cause of such familiar occurrences as singing automobile roof-racks and the oscillatory movements of a rod pulled through water. In the past periodic vortex shedding has caused fatigue in and collapse of mechanical structures dimensioned only for static loads. Meteosat images provide the data necessary for studying the genesis and evolution of vortex streets in the atmosphere leeward of islands in the Earth's oceans.

One morning in the autumn of 1940 a man drove his car in a leisurely manner onto the newly-built suspension bridge spanning the breezy Tacoma Narrows in the State of Washington, USA. He never reached the other side. Halfway across, he felt the car swerve and stopped to inspect the tyres. Realising that in fact the entire bridge was swinging, he abandoned the car and ran back to the bridgehead. For the next couple of hours, amid a growing assembly of police, firemen, reporters and photographers, the driver watched the bridge span twisting and undulating until the cables snapped and the span collapsed into the water, car and all.

The suspension bridge failed because the wind, blowing at 65 km/h, induced oscillations in the structure which coincided with the bridge's natural frequencies. The phenomenon that caused the resonance is known as periodic vortex shedding; it is the same effect that makes a rod waver when pulled through water.

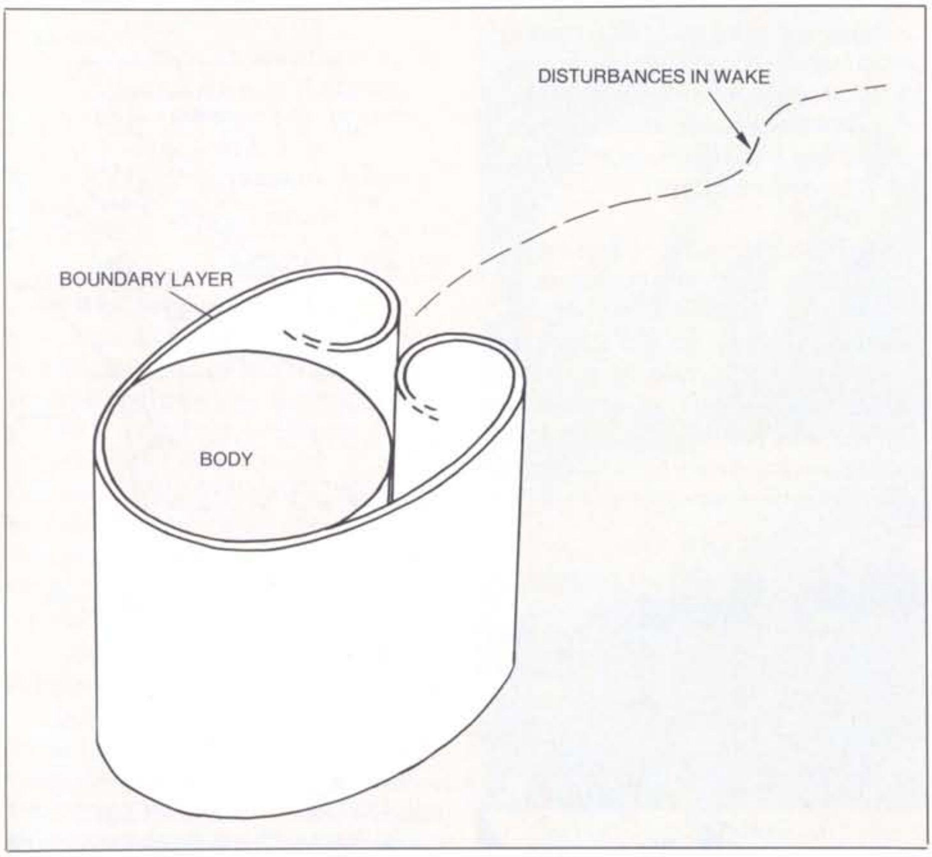
Any solid, bluff body suspended in a laminar flow will, under certain conditions, give rise to periodic vortex shedding in its wake, leaving behind a trail of eddies in the flowing medium – be that water, air, or any other liquid or gas with a low viscosity. At very low free-flow velocities, two stationary but counter-rotating vortices form behind the body and remain anchored at the points where the boundary layers on each side separate from the body surface (Fig. 1). As the flow speed increases, one of the vortices detaches itself and begins to travel downstream on one side of the wake's centreline. Moments later, while a replacement vortex is forming to fill the gap, the twin vortex follows suit on the other side of the centreline. Each separating vortex imparts a lateral push to the body, according to the laws of momentum conservation; hence the alternating sideways movement, or oscillation, of the rod being pulled through water. The next pair of eddies behaves in a similar manner, and gradually the wake becomes adorned with two staggered rows of vortices rather like a tree-lined Parisian boulevard (Fig. 2). Perhaps it is this street-like pattern which gave rise to the name Kármán Vortex Street, after the Hungarian-born physicist Théodore von Kármán, who formulated the first mathematical description of the phenomenon in 1911.

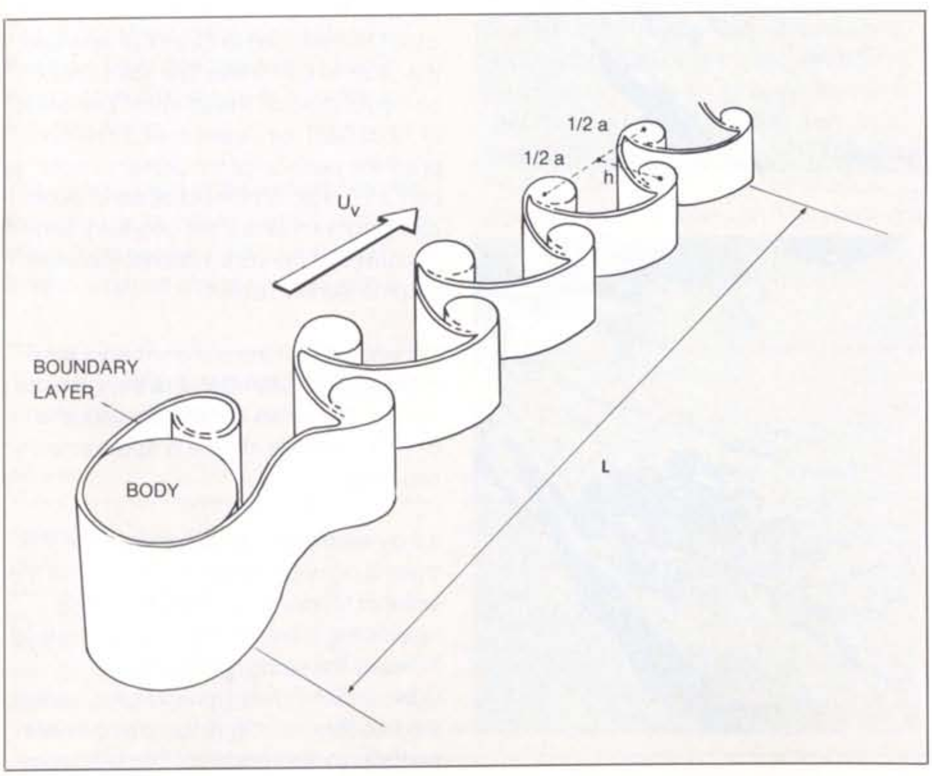
But vortex streets were observed and reported long before von Kármán made his analysis. As early as the 10th century, Archbishop Dunstan of Canterbury – who devoted more time to music and science than to preaching – built an Aeolian harp the strings of which were played by the wind through periodic vortex shedding. As a reward he was accused of practising witchcraft and had to seek asylum in Belgium. Even the indefatigable Leonardo da Vinci remembered to report on the vortex street in his illustrated treatise 'Del moto e misura dell'acqua'.

In modern times the problem of periodic vortex shedding has been encountered and resolved in connection with unforeseen vibrations in power lines,

Figure 1 – Stationary vortices in the case of a low rate of free flow

Figure 2 – Periodic vortex shedding in the case of a moderate rate of free flow





factory chimneys, ship propellers, submarine periscopes, rockets on the launching pad, etc. In the realm of aerodynamics, the phenomenon known as 'tail buffeting' is often ascribed to periodic vortex shedding behind wings at high angles of attack. Sometimes the shedding causes disturbing noises, as is the case with certain car roof-racks even at moderate driving speeds.

The main concern is nevertheless the resulting fatigue symptoms in structures that have been dimensioned solely for static loads. The remedy is relatively simple in most applications, e.g. a fixed vane mounted along the trailing edge of the body so as to impede the formation of vortex pairs.

Space research has matured to become as dedicated to expanding our knowledge about the Earth as about the heavens. The first observations of vortex streets in the Earth's atmosphere were made in 1962 by the American weather satellite Tiros-V. Two parallel streets were seen extending in a southwesterly direction along the west coast of the Sahara: one on the leeward side of Gran Canaria, the other behind Tenerife. The streets were 40 to 50 km wide and about 500 km long, while the vortex diameters grew downstream from 10 to 20 km. Given their immense size, it is no wonder that vortex streets in the atmosphere had never before been observed from ships or aircraft. Additional images of the phenomenon were later sent back by Tiros-VI, ESSA-7 and 8, and by astronauts on board Gemini-V, VI and VII, showing vortex streets behind Madeira, Cape Verde, Guadeloupe, Réunion and Mauritius, as well as behind the Canaries.

The problem with these early observations from space was that the satellites travelled in low orbits and passed over the points of interest only once every twelve hours. Since the life span of vortex streets in the atmosphere is usually limited to a few days, it was almost impossible to obtain a

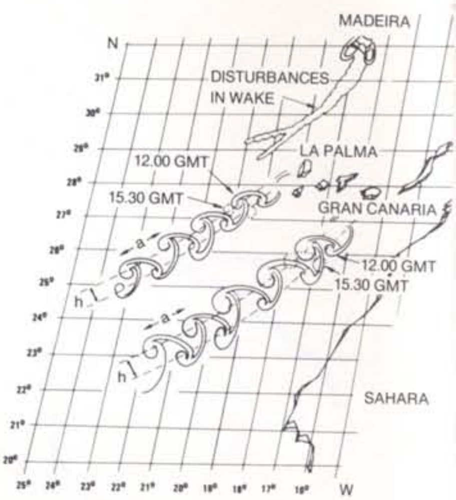
Figure 3 – Sequence of Earth imagery taken by Meteosat-1 (visible channel) on 31 March 1978 at 09.30 GMT (a), 11.30 GMT (b), 12.00 GMT (c), 12.30 GMT (d) and 15.30 GMT (e)

Figure 4 – Sketch of the geometry of the vortex streets over the Canary Islands at 12.00 GMT on 31 March 1978 (cf. Fig. 3c)


(a)

clear picture of the vortex development, particularly the separation rate and transport velocity of vortex pairs. Some researchers questioned whether these vortices had anything whatsoever to do with Kármán vortex streets.

During the last ten years, however, the United States, Japan and Europe have deployed geostationary meteorological satellites around the equator which can take a high-resolution picture of the Earth's disc every half hour, 24 hours per day, year after year. These spacecraft provide an ideal means for achieving continuity in the observations of the




(b)


(d)


(c)


(e)

genesis and evolution of vortex streets.

Figure 3 shows a sequence of Earth imagery taken on 31 March 1978 by ESA's geostationary meteorological satellite Meteosat-1. The sequence focuses on vortex streets shown up by low-inversion tracer clouds on the leeward side of the Canary Islands. The illustration in Figure 4 is meant to facilitate the interpretation of the two most pronounced streets, one of which is anchored to Gran Canaria and the other to La Palma. The solid vortex contours indicate the situation prevailing at 12.00 GMT, while the dotted contour gives the position of the primary vortex pair 3.5 h later. A number of conclusions can be drawn about the geometry and dynamics of the vortex streets; these are summarised in Table 1.

It is evident that there is a stronger wind blowing over Gran Canaria than over La Palma. The vortex separation period is 8–10 h, and their lifetime is approximately two days.

It may seem strange at a first glance that there is no vortex street to be found in the wake of Madeira, but that something resembling a smoke trail appears instead. In reality the same conditions as illustrated in Figure 1 prevail here; namely, the free-flow velocity is too low to initiate periodic vortex shedding. The U-shaped, cloud-free contour in the wake immediately behind the island is accommodating the pair of stationary vortices, while the 'smoke trail' reveals a retardation of the wind current downstream with respect to the adjacent free flow.

Von Kármán's mathematical model of the vortex street assumed the flow to be nonviscous and initially laminar. By mathematically simulating microscale perturbations in the flow, such as those created in reality by ocean waves, convection and wind shear, he succeeded in proving that the ratio h/a must have a constant value throughout the vortex street if it is to remain stable. The ratio he found was h/a = 0.28.

In Table 1, however, this ratio is seen to vary between 0.28 and 0.40. The explanation lies in the molecular viscosity of the atmosphere. This inner friction of the flowing medium causes the street to widen downstream and the individual eddies to weaken and expand until they overlap and finally annihilate each other. The vortex street in the atmosphere will therefore have dissipated all its kinetic energy some 700 km away from the initiating island.

The vortex streets in the atmosphere still maintain the record for proven size, but they will perhaps not do so for much longer. Gigantic ocean vortices with a seemingly periodic pattern are being studied near Hawaii. The free-flow water velocity, induced by the trade winds, is in the order of 7 cm/s and it appears that a new vortex is formed every 40 days. The street width is estimated to be 80 km, while the distance between vortices of equal orientation approaches 220 km, yielding a perfectly plausible h/a ratio of 0.36. And what about the turbulence in the atmosphere of Jupiter observed not long ago in the spectacular images from Voyager-1? Huge pillars of convective gases penetrate to the atmosphere's surface from the interior, and appear stationary with respect to the planet's hidden core. Winds are raging around the pillars at horizontal speeds of 100 m/s. In the wake behind the pillars one discerns.... Kármán vortex streets?

Figure 5 – Photograph of Jupiter's Great Red Spot (upper right) taken on 1 March 1979 from a distance of 5 million kilometers by Voyager-1. Apparent in the turbulent region beneath and to the left of the spot are gas shear, cyclonic motions, etc. and .... Kármán vortex streets?

photo nasa

Table 1 – Characteristics of the vortex streets apparent in Figure 3

Parameter	Symbol	Unit	Gran Canaria	La Palma
Length	L	km	800	600
Width	h	km	45–65	38–50
Distance between vortices	a	km	130–165	135–140
Ratio h/a			0.35 – 0.40	0.28 – 0.35
Velocity downstream	U_v	km/h	18	13
Free-flow velocity ($U \simeq 1.4\,U_v$)	U	km/h	25	18
Rate of separation ($N = U_v/a$)	N	h^{-1}	0.13	0.10
Vortex lifetime ($T_v = L/U_v$)	T_v	h	45	45

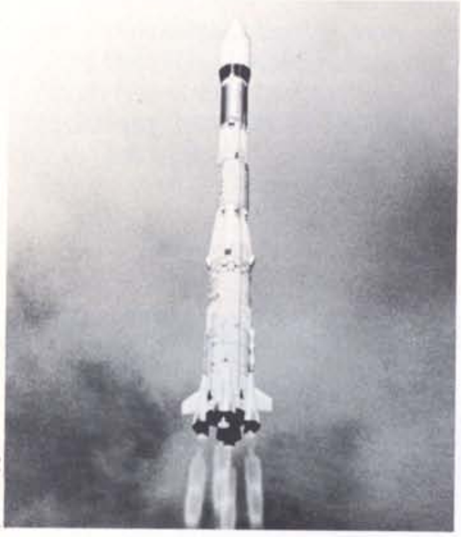


photo sygma

Le programme Ariane-3

A. Lemarchand, Département Systèmes de Transport spatial, ESA, Paris

Le programme Ariane-3 constitue la première étape d'un programme de développement complémentaire du lanceur Ariane, destiné essentiellement à accroître les performances et à assurer la compétitivité du lanceur européen. Ce programme couvre la développement de deux configurations Ariane-2 et Ariane-3 dont les performances en orbite de transfert sont respectivement de 2000 et 2420 kg au lieu de 1700 kg pour la configuration initiale Ariane-1.

Contexte général

Avec les essais de qualification en vol, le lanceur Ariane est entré dans une phase décisive de son développement. Le premier essai, effectué en décembre 1979, fut un succès total, mais le second essai, en mai 1980, s'est soldé par un échec dû à la défaillance de l'un des injecteurs des moteurs Viking dès les premières secondes du vol. Des mesures sont prises afin de remédier au problème, et le lanceur européen devrait être opérationnel d'ici la fin de l'année 1981.

Aux Etats-Unis, la Navette spatiale a subi des retards importants en raison de difficultés de développement, notamment au niveau des moteurs et de la protection thermique; son premier vol devrait intervenir en mars 1981 et son utilisation opérationnelle pour le lancement des satellites a été repoussée au printemps 1983. Par ailleurs, la production des lanceurs classiques non récupérables tels Atlas Centaur et Delta est maintenue alors qu'on avait envisagé leur disparition dès la mise en service de la Navette. Ces lanceurs sont proposés en remplacement de la Navette et des programmes d'améliorations vont être entrepris. S'agissant du lanceur Delta, 38 lancements sont prévus entre 1980 et 1985; de plus, une nouvelle configuration Delta 3920-PAM va succéder au 3910-PAM: elle aura une capacité de 1310 kg en orbite de transfert (28° d'inclinaison) au lieu des 1150 kg de la configuration 3910 et sera disponible en 1982.

Ainsi donc, entre d'une part les actuels lanceurs américains et soviétiques – ces derniers n'étant d'ailleurs pas commercialement accessibles – et d'autre part des lanceurs qui seront développés dans un proche avenir par la Chine, le Japon et l'Inde mais dont la disponibilité sur le marché est loin d'être acquise, Ariane aura un créneau assuré pour la présente décennie.

Objectifs du programme

L'un des objectifs assignés au programme Ariane est la mise au point d'un lanceur *économiquement compétitif* face aux moyens de lancement disponibles sur le marché. Il faut remarquer, à ce sujet, que

- à performances équivalentes, l'Atlas-Centaur est plus cher qu' Ariane-1;
- pour un prix inférieur d'environ 25%, le Delta 3920 n'atteindra que la moitié de la performance d'Ariane-3.

La mise en service de la Navette spatiale imposera des mesures rigoureuses pour maintenir la compétitivité du lanceur Ariane. Le programme de développement complémentaire dont la première étape est Ariane-3 qui doit être disponible en 1982–83, a pour but de préparer cette phase de la compétition en tenant compte de l'évolution du marché.

L'évolution des besoins des utilisateurs pour la mise en orbite de *satellites géostationnaires* peut se caractériser de la manière suivante:

- pour les satellites de la classe Atlas-Centaur, ou STS-SSUS-A ou Ariane-1, il y aura une demande très nette de performances supplémentaires. Intelsat-V, par exemple, est limité dans son évolution par la capacité

The Ariane-3 Programme

The Ariane-3 programme is the first phase of an Ariane follow-on development (FOD) programme, aimed essentially at increasing the performance and ensuring the competitiveness of the European launcher. The programme comprises the development of two configurations, Ariane-2 and Ariane-3, with capabilities in transfer orbit of 2000 and 2420 kg respectively, compared with 1700 kg for the initial configuration, Ariane-1.

Background

With the qualification test flights, Ariane entered a decisive phase in its development. The first flight, in December 1979, was a complete success whereas the second, in May 1980, failed when an injector in one of the Viking engines malfunctioned in the first few seconds of flight. Remedial steps have been taken and the European launcher should be operational by the end of 1981.

In the USA, the Space Shuttle is considerably behind schedule owing to development difficulties, particularly with its engines and thermal protection. Its first flight is currently planned for March 1981 and its operational availability for launching satellites has been put back until Spring 1983. Production of conventional, expendable launchers such as the Atlas-Centaur and Delta has, moreover, been continued, whereas the original intention was to phase them out as soon as the Shuttle was available. These launch vehicles are being offered in lieu of the Shuttle, and uprating programmes are to be undertaken. For the Delta launcher, 38 launches are planned between 1980 and 1985. Also, a new Delta 3920-PAM configuration is to succeed the 3910-PAM: it will have a capability of 1310 kg in transfer orbit (inclination 28°) compared with the 1150 kg of the 3910, and will be available in 1982.

Hence between the existing American and Soviet launchers – the latter moreover are not commercially available – and the launchers shortly to be developed by China, Japan and India, which are still far from being commercially available, Ariane will have a secure place in the current decade.

Programme objectives

One of the objectives assigned to the Ariane programme was to develop a launcher that was economically competitive with other launch systems on the market. It should be borne in mind therefore that:

- *for an equivalent performance, the Atlas-Centaur costs more than Ariane-1;*
- *at three-quarters of the cost, the Delta-3920 will achieve only half the performance of Ariane-3.*

The entry into service of the Shuttle will call for vigorous action to keep Ariane competitive. The aim of the FOD programme – of which Ariane-3 is the first phase, and is due to be available in 1982/83 – is to prepare for this competitive period in the light of market trends.

User requirements for the orbiting of geostationary satellites are likely to develop as follows:

- *For satellites of the Atlas-Centaur, STS-SSUS-A or Ariane-1 classes, there will be a very keen demand for increased performance. The evolution of Intelsat-V, for example, is limited by the capacity of the launcher, particularly when it comes to adding new services such as the maritime service.*
- *For satellites of the Delta or SSUS-D classes, mass will be limited for some time to come by the performance of*

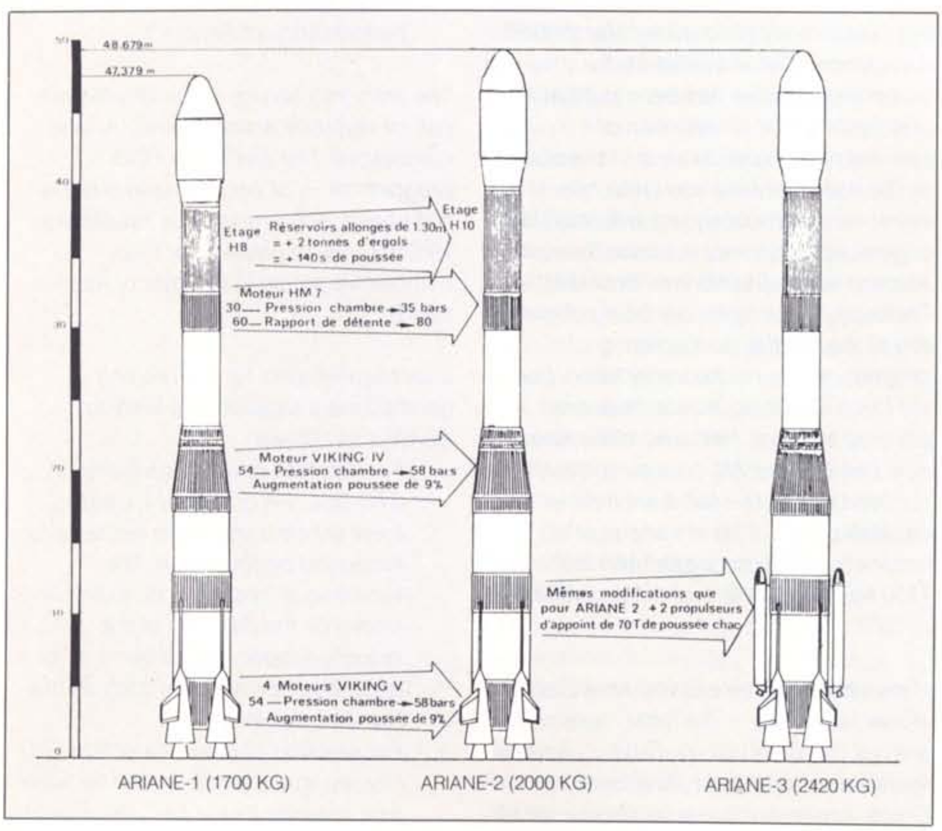


Figure 1 – Ariane-1, 2 and 3 configurations/*Configuration des lanceurs Ariane-1, 2 et 3*

du lanceur, en particulier pour l'incorporation de nouveaux services comme le service maritime;

– pour les satellites de la classe Delta ou SSUS-D, le développement de la version 3920 fige, pour un certain temps, la limite de capacité de cette classe. Ramené aux conditions de lancement par Ariane, ceci se traduit par une masse en orbite de transfert de 1130 kg. Afin d'être en mesure de lancer simultanément deux satellites de cette classe, Ariane devra donc être capable de satisfaire les exigences de masse suivantes:

Deux satellites de 1130 kg:	2260 kg
Système de lancement double	+200 kg
Adaptateur standard Ariane	−40 kg
	2420 kg

Tel est l'objectif de performances qui a été fixé au lanceur Ariane-3.

L'analyse des besoins des programmes d'application envisagés par l'Agence et ses Etats membres confirme cet objectif. Les projets de satellites de télédiffusion directe tels que le satellite franco-allemand TV Sat et le satellite ESA L-Sat se situent dans la fourchette de performances des lanceurs Ariane-2 et 3. D'autre part, les besoins définis par Eutelsat intérimaire pour les télécommunications intra-européennes et ceux prévisibles dans le même domaine à l'échelon national correspondent à une classe de satellites d'environ 1100 à 1150 kg en orbite de transfert pouvant être lancés en lancement double par Ariane-3.

Le respect de l'objectif général de compétitivité implique également un effort dans deux domaines:

– une action continue dans le domaine de la *fiabilité* pour permettre de maintenir celle-ci à un haut niveau en améliorant les organes ou sous-systèmes qui ne donneraient pas, de ce point de vue, une satisfaction totale;
– un effort de *réduction des coûts* qui se traduise par des modifications des procédés de fabrication et, le cas échéant, par des modifications limitées de matériels, destinées à diminuer les prix de revient. Une action importante dans ce domaine consiste à étudier la récupération en mer du premier étage afin de réutliser ses éléments après remise en état.

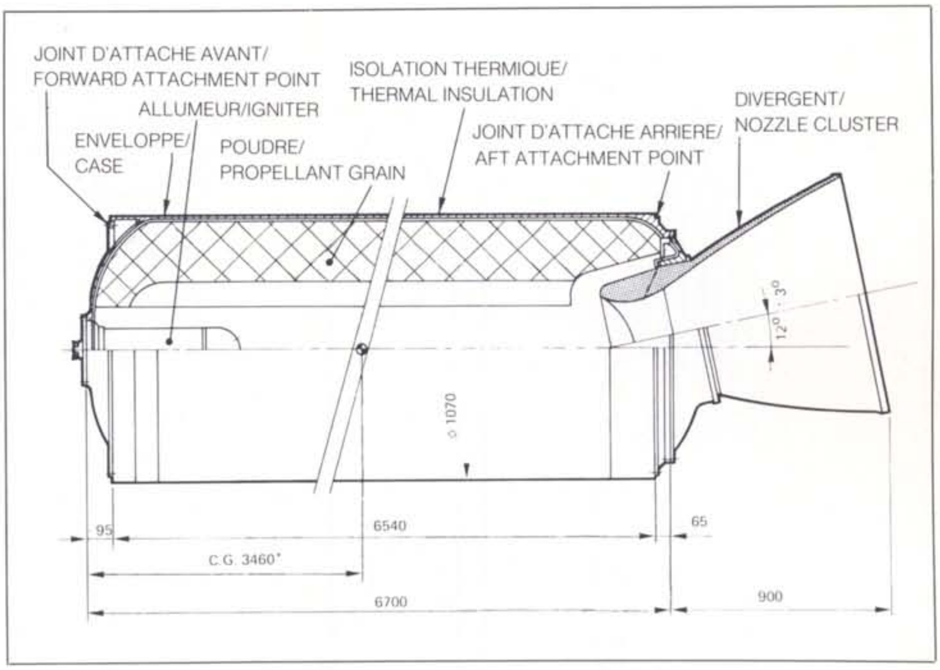
Lignes directrices du programme

Les lignes directrices suivantes ont limité la liberté de conception des modifications à apporter au lanceur:

– rester dans le cadre des technologies qualifiées pour le programme Ariane, afin de limiter les aléas de développement et, également, de ne pas avoir à faire de nouveaux vols d'essai;
– éviter des investissements nouveaux en moyens d'essais, limiter les modifications d'outillage, maintenir la compatibilité du lanceur avec la table et la tour de lancement actuelles;
– garder la compatibilité d'Ariane-3 avec le programme de production et de lancement d'Ariane-1;
– permettre un lancement opérationnel fin 1982 ou début 1983;
– s'inscrire dans une perspective d'évolution sans avoir à reprendre, dans une étape ultérieure, les sous-systèmes déjà modifiés.

L'application de ces lignes directrices a conduit à rejeter certaines options. Citons par exemple le remplacement du deuxième étage par un étage modulaire équipé de moteurs HM7, exigeant un développement technologique important et incompatible avec les moyens d'essais et de lancement actuels. De même, l'augmentation de la masse d'ergols du premier étage de 140 à 165 t n'étant pas jugée compatible avec la tour de lancement, l'adjonction de deux propulseurs d'appoint procurant une amélioration de performances

Figure 2 – Basic booster assembly/*Ensemble propulseur nu*



the Delta-3920. Under Ariane launch conditions, the equivalent mass in transfer orbit would be 1130 kg. To be capable of launching two such satellites simultaneously, Ariane must be able to meet the following mass requirements:

Two satellites, 1130 kg each	*2260 kg*
Dual-launch system	*+200 kg*
Standard Ariane adaptor	*−40 kg*
	2420 kg

These are the performance objectives that have been adopted for Ariane-3.

A study of the requirements of the applications programmes envisaged by ESA and its Member States confirms that this choice is the right one. The direct TV-broadcasting satellite projects, such as the Franco-German TV Sat and ESA's L-Sat, are within the performance ranges of Ariane-2 and 3. Also, the requirements stated by Interim Eutelsat for intra-European telecommunications and those to be expected in the same field at national level represent a satellite class of about 1100 to 1150 kg in transfer orbit, suitable for dual launches by Ariane-3.

To achieve the general aim of competitiveness, efforts must be made in two domains:

- *Constant efforts to maintain a high level of reliability, while improving any devices or subsystems that may not give complete satisfaction in this respect.*
- *An effort to cut costs, by modifying manufacturing processes and by making limited modifications to hardware where appropriate. A major activity in this field is a study of how to recover the first stage from the sea, with a view to re-using its constituent parts after refurbishment.*

Guidelines for the programme

The freedom in devising modifications to the launcher is subject to the following guidelines:

- *Only technologies qualified for the Ariane programme may be used, in order to limit development risks and to avoid the need for further test flights.*
- *Further outlay on test facilities must be avoided, tooling modifications must be limited, and the launcher must remain compatible with the existing launch pad and servicing tower.*
- *Ariane-3 must remain compatible with the Ariane-1 production and launch programmes.*
- *An operational launch in late-1982 or early 1983 must be feasible.*
- *Care must be taken to ensure that those systems already modified will not need to be redesigned later.*

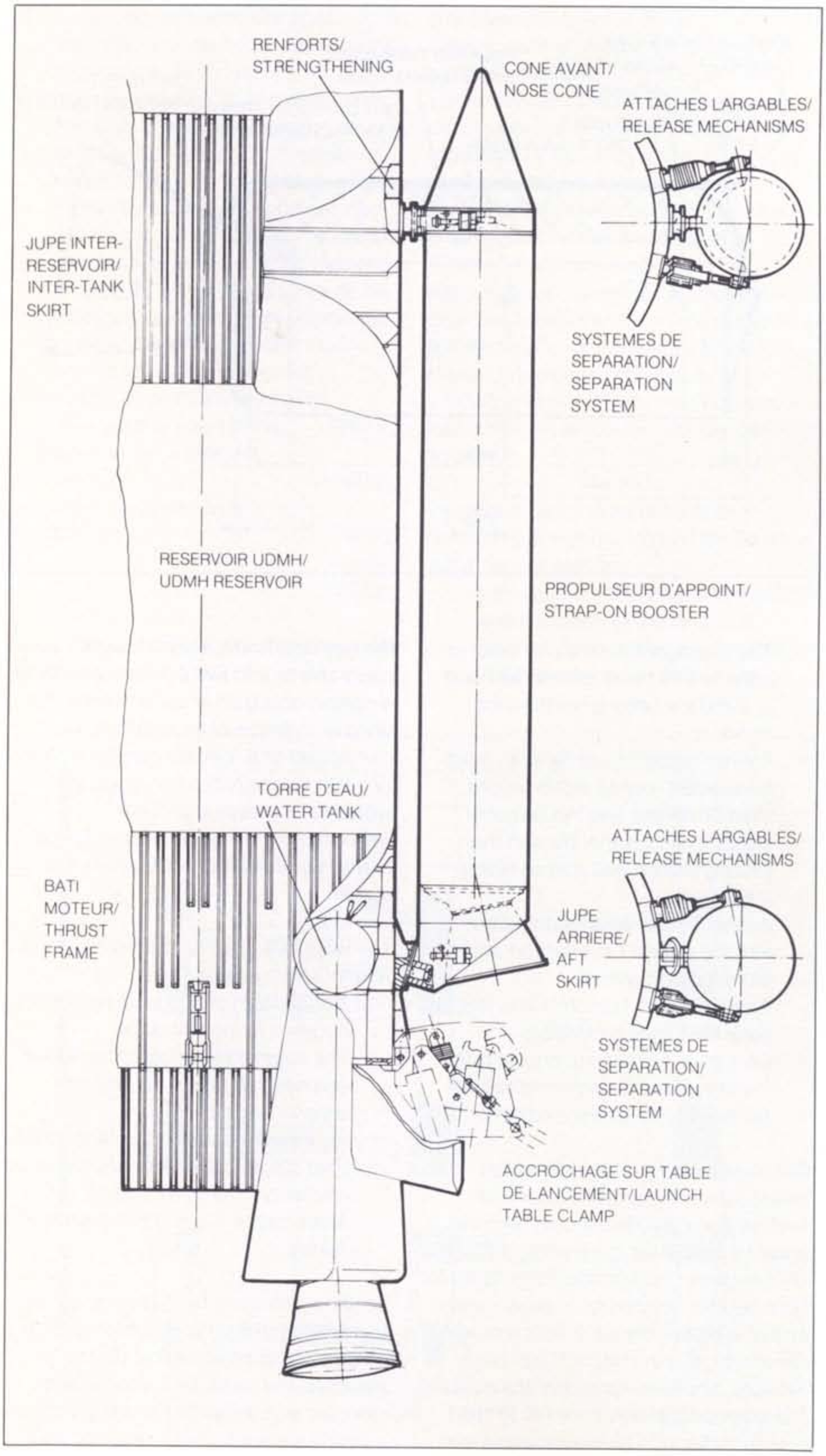
Observance of these guidelines has meant scrapping certain earlier ideas such as the replacement of the second stage by a modular stage powered by HM7 engines — this would have called for considerable technological development and would have been incompatible with the existing test and launch facilities. Similarly, since an increase in the mass of first-stage propellants from 140 to 165 t was considered to be incompatible with the servicing tower, it was thought preferable to add two boosters providing a comparable gain in performance. Yet another example of an idea that was considered and rejected was the addition of a fifth engine to the first stage; this would have greatly improved performance, but would have required a major requalification of the propulsion system.

The main features that distinguish Ariane-3 from Ariane-1 are:

- *The addition of two solid-propellant boosters to the first stage;*
- *The augmented thrust of the Viking engines that power the first and second stages;*
- *Increased mass of propellants in the third stage, and improved propulsion efficiency in the HM7 engine;*
- *Modification of the volume within the fairing.*

To allow maximum flexibility in assigning launchers to missions, Ariane-2 and 3 will be identical in construction, and in particular the elements that have been modified with a view to mounting boosters will be standard for both versions, the

Figure 3 – Booster mounted on the first stage/*Montage du propulseur d'appoint sur le premier étage*



comparable a donc été préférée. Un dernier exemple de solution envisagée et rejetée est l'introduction d'un cinquième moteur sur le premier étage, modification très favorable à l'augmentation de la performance, mais qui exigerait une requalification importante de l'ensemble propulsif.

La configuration générale retenue pour le lanceur Ariane-3 se distingue d'Ariane-1 par:

- l'adjonction de deux propulseurs d'appoint à poudre sur le premier étage;
- l'augmentation du niveau de poussée des moteurs Viking des premier et deuxième étages;
- l'augmentation de la masse d'ergols du troisième étage et l'amélioration du rendement propulsif du moteur HM7;
- une modification du volume sous coiffe.

Afin de disposer d'un maximum de souplesse dans l'affectation des lanceurs aux missions à effectuer, la réalisation des lanceurs 2 et 3 est identique, en particulier les éléments modifiés en vue de l'adaptation des propulseurs d'appoint seront standard pour les deux versions, la configuration 2 étant obtenue par simple suppression des propulseurs d'appoint prévus pour Ariane-3.

Ces deux versions remplaceront la configuration initiale Ariane-1 (Fig. 1).

Modifications apportées au lanceur

Propulseurs d'appoint
Le premier étage est muni de deux propulseurs d'appoint d'environ 7.4 t de poudre chacun (Figs. 2 – 3). Le choix des caractéristiques de ces propulseurs résulte de plusieurs contraintes:

- l'expérience acquise et les moyens disponibles chez SNIA-Viscosa;
- la recherche d'une efficacité maximum, obtenue par un temps de fonctionnement relativement court (28 s);

Ariane-2 configuration being obtained simply by omitting the boosters with which Ariane-3 will be equipped.

These two versions will replace the initial configuration, Ariane-1 (Fig. 1).

Modifications to the launcher

Boosters

The first stage is fitted with two boosters, each containing some 7.4 t of solid propellant (Figs. 2 and 3). Their characteristics were determined by several factors, namely:

- *The experience acquired and facilities available at SNIA-Viscosa;*
- *The desire for maximum efficiency, to be achieved by a relatively short burn time (28 s);*
- *The jettisoning of the spent boosters at subsonic velocity ($z \simeq 250$ m/s).*

The forces exerted by these boosters are transmitted through the thrust frame and the inter-tank skirt, which entails structural strengthening of these elements and some modifications in order to mount the attachment and separation system. Three jettison systems were considered: retro-rockets, pyrotechnic actuators and spring actuators. Because of their ease of development and low production cost, spring actuators were chosen.

Viking engines

In the light of the Viking-V engine tests carried out under the development programme, a combustion-chamber pressure of 58 bar has been chosen for Ariane-2 and 3 instead of the nominal 54.3 bar for Ariane-1. It is achieved by increasing the flow rate.

The numerous tests carried out since the L02 failure have shown that the

Table 1 — Main characteristics of boosters

Nominal total impulse along nozzle axis (at 21°C)	*16.8 × 10⁶ Ns*
Nozzle offset angle	*12° ± 3°*
Total mass	*8700 kg*
Mass of envelope	*950 kg*
Mass of propellant	*7370 kg*
Burn time	*28.3 s*
Total impulse	*17.1 × 10⁶ Ns*
Maximum thrust (at 21°C)	*770 kN*
Maximum pressure (at 21°C)	*57.4 bar*
Envelope diameter	*1070 mm*
Overall length	*7600 mm*
Envelope material	*AISI 4130*
Propellant	*Flexadyne powder*

Figure 4 – Comparison of the fairings of Ariane-1 and 3/*Comparaison des coiffes Ariane-1 et Ariane-3*

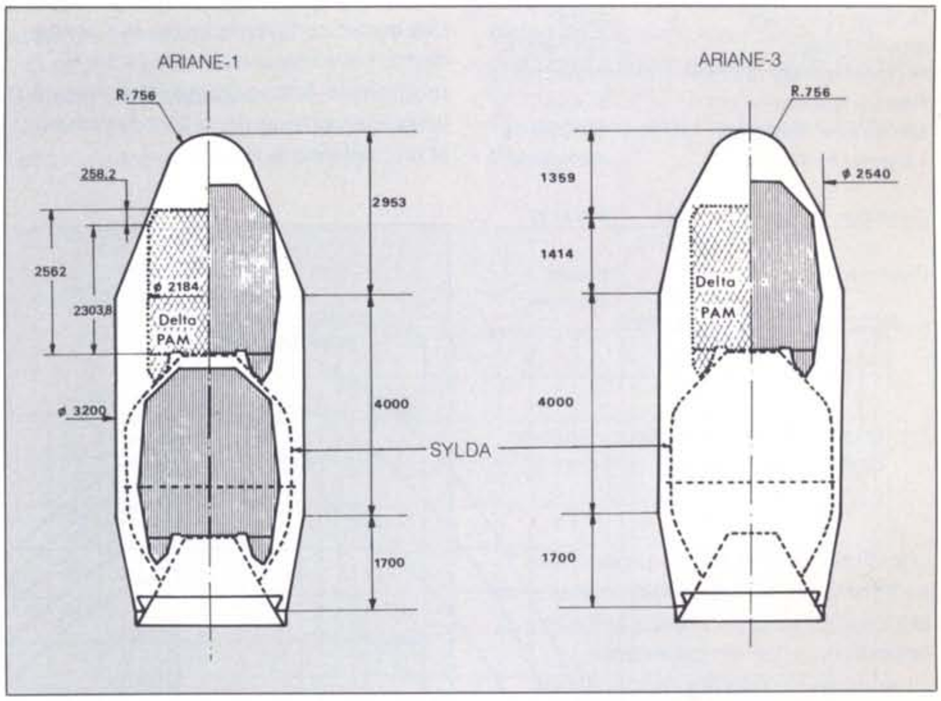


Figure 5 – Comparison of the fairings of Ariane-3 and 4/*Comparaison des coiffes Ariane-3 et Ariane-4*

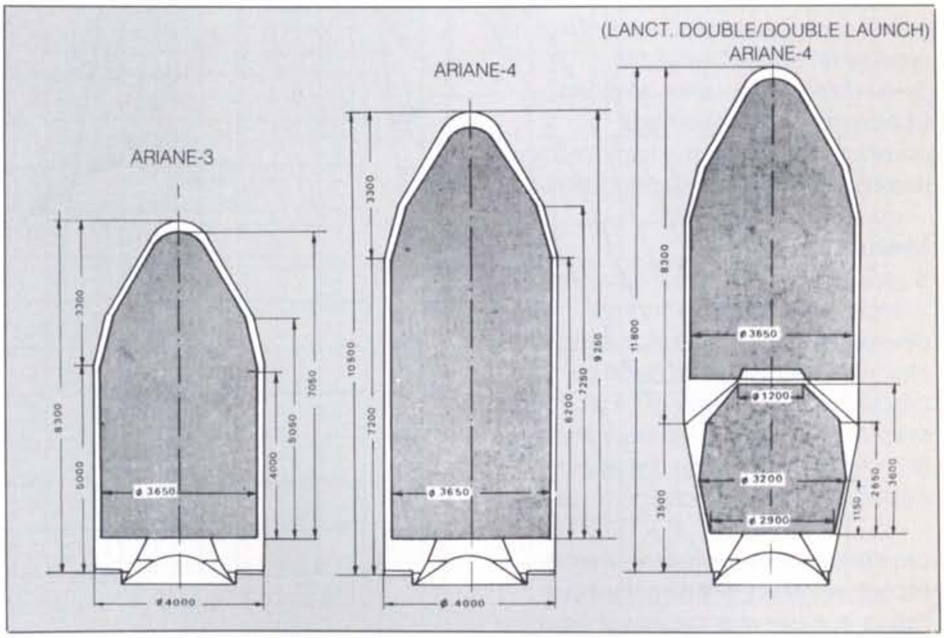


Figure 6 – Performance of Ariane-2 (launched from Kourou)/*Performances Ariane-2 (lancement à partir de Kourou)*

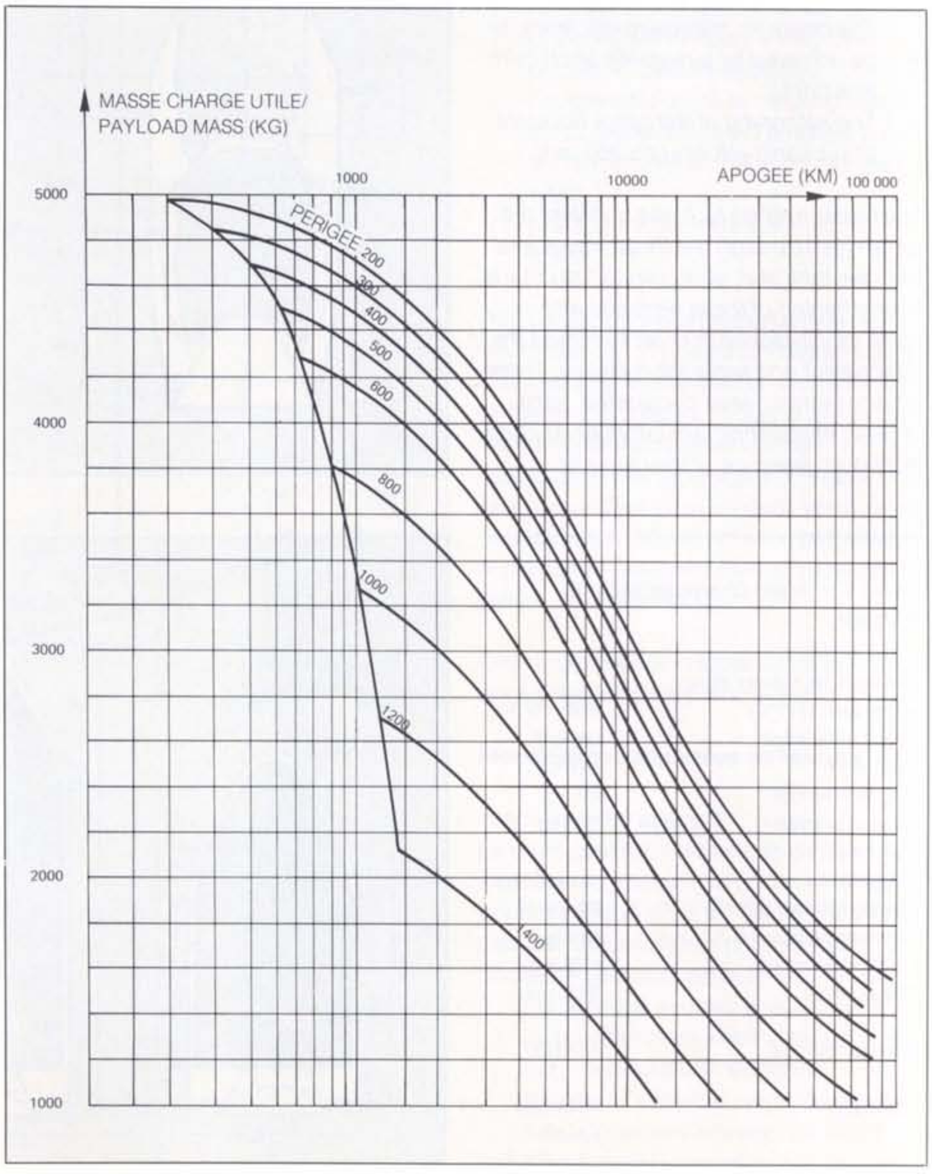


Tableau 1 – Caractéristiques essentielles des propulseurs d'appoint

Impulsion totale nominale suivant l'axe tuyère (à 21°C)	$16{,}8 \cdot 10^6$ N s
Angle de calage de la tuyère	$12° \pm 3°$
Masse totale du propulseur	8700 kg
Masse de l'enveloppe	950 kg
Masse du propergol	7370 kg
Durée de combustion	28,3 s
Impulsion totale	$17{,}1 \cdot 10^6$ N s
Poussée maximale (à 21°C)	770 kN
Pression maximale (à 21°C)	57,4 bar
Diamètre de l'enveloppe	1070 mm
Longueur hors tout	7600 mm
Enveloppe	AISI 4130
Propergol	poudre flexadyne

– le largage des propulseurs vides en régime subsonique ($z \simeq 4$ km, $v \simeq 250$ m/s).

Les efforts exercés par les propulseurs sont repris au niveau du bâti moteur et de la jupe inter-réservoir, ce qui entraîne sur ces éléments des renforcements structuraux et certaines modifications permettant de placer les systèmes d'attache et de séparation. Trois solutions étaient envisageables pour le largage: un système retrofusées, les vérins pyrotechniques, les vérins à ressort. Compte tenu de sa facilité de développement et de son faible coût de production, le vérin à ressort a été retenu.

Moteurs Viking

S'appuyant sur des essais du moteur Viking-V accomplis au cours du développement, une pression de la chambre de combustion de 58 bar (réglage nominal d'Ariane-1 à 54,3 bar) a été proposée pour les lanceurs Ariane-2 et 3, cette augmentation de pression s'obtenant par augmentation de débit.

Les nombreux essais réalisés depuis l'échec de vol L02 ont démontré que l'apparition des phénomènes d'instabilité de combustion constatés sur ce vol est, entre autres paramètres, liée au niveau de la pression. Les mesures envisagées dans le cadre du développement d'Ariane-1 doivent permettre d'élargir les marges de stabilité autour de la pression nominale de fonctionnement afin de s'affranchir de ce phénomène.

Des essais complémentaires aux limites devront être réalisés dans le cadre du programme Ariane-3 pour démontrer la faisabilité de l'augmentation de pression et en confirmer le niveau.

Troisième étage

La capacité du troisième étage est portée de 8 à 10 t d'ergols cryogéniques par un allongement des parties cylindriques des réservoirs. Cette masse d'ergols correspond à la limite de ce qui était possible, compte tenu des moyens de production installés à l'Air Liquide et de la hauteur disponible sous la tour de lancement.

Certains renforcements structuraux sont nécessaires. La pression chambre du moteur HM7 est portée de 30 à 35 bar et *combustion-instability phenomena that occurred on that flight are linked, inter alia, to the pressure level. The corrective measures planned under the Ariane-1 development programme should enable these phenomena to be eliminated by increasing the stability margins around the nominal operating pressure.*

Further limit testing will need to be conducted under the Ariane-3 programme in order to demonstrate the feasibility of operating at higher pressures and to determine the requisite pressure value.

Third stage

The third-stage cryogenic-propellant capacity is increased from 8 to 10 t by lengthening the cylindrical parts of the tanks. This figure is a limit imposed by the production facilities at Air Liquide and the height available beneath the servicing tower.

Some structural reinforcement is necessary. The chamber pressure of the HM7 engine is increased from 30 to 35 bar and the nozzle is extended by a 150-mm ring; these two modifications increase the expansion ratio from 60 to 80 and improve the specific impulse by 4 s.

Fairing

In parallel with these measures leading to improved performance, the volume within the fairing is increased.

The basic version of the Ariane-3 fairing is derived from Ariane-1. It will retain the same diameter and overall height, but the forward cone will be biconic with the cap radius remaining unaltered (Fig. 4). This modified fairing will be available in late 1982 or early 1983.

Development work has started on a large-diameter fairing (external diameter 4 m instead of 3.2 m). The configuration of any such fairing must be optimised with a view to using it both on Ariane-3 and on its successor, Ariane-4. The design envisaged is based on a number of modules arranged lengthwise. Ariane-3 may be fitted with a first, short version. This same short version could be mounted on a structure bearing an upper passenger and enclosing a lower passenger for an Ariane-4 dual launch. For single launches, Ariane-4 will be fitted with a long version (Fig. 5). The short, large-diameter fairing is expected to be available some time in 1984.

General performances

The general performance data quoted constitute a minimum guaranteed performance of:

- *2000 kg in geostationary transfer orbit for Ariane-2 (Fig. 6);*
- *2420 kg for Ariane-3 (Fig. 7).*

It should be noted, however, that for payloads greater than 2500 kg it may be necessary to reinforce the upper part of the structure. These performances are based on the same assumptions that produced a figure of 1700 kg for Ariane-1.

Figure 8 compares the Ariane-1, 2 and 3 trajectories.

Figure 7 – Performance of Ariane-3 (launched from Kourou)/*Performances Ariane-3 (lancement à partir de Kourou)*

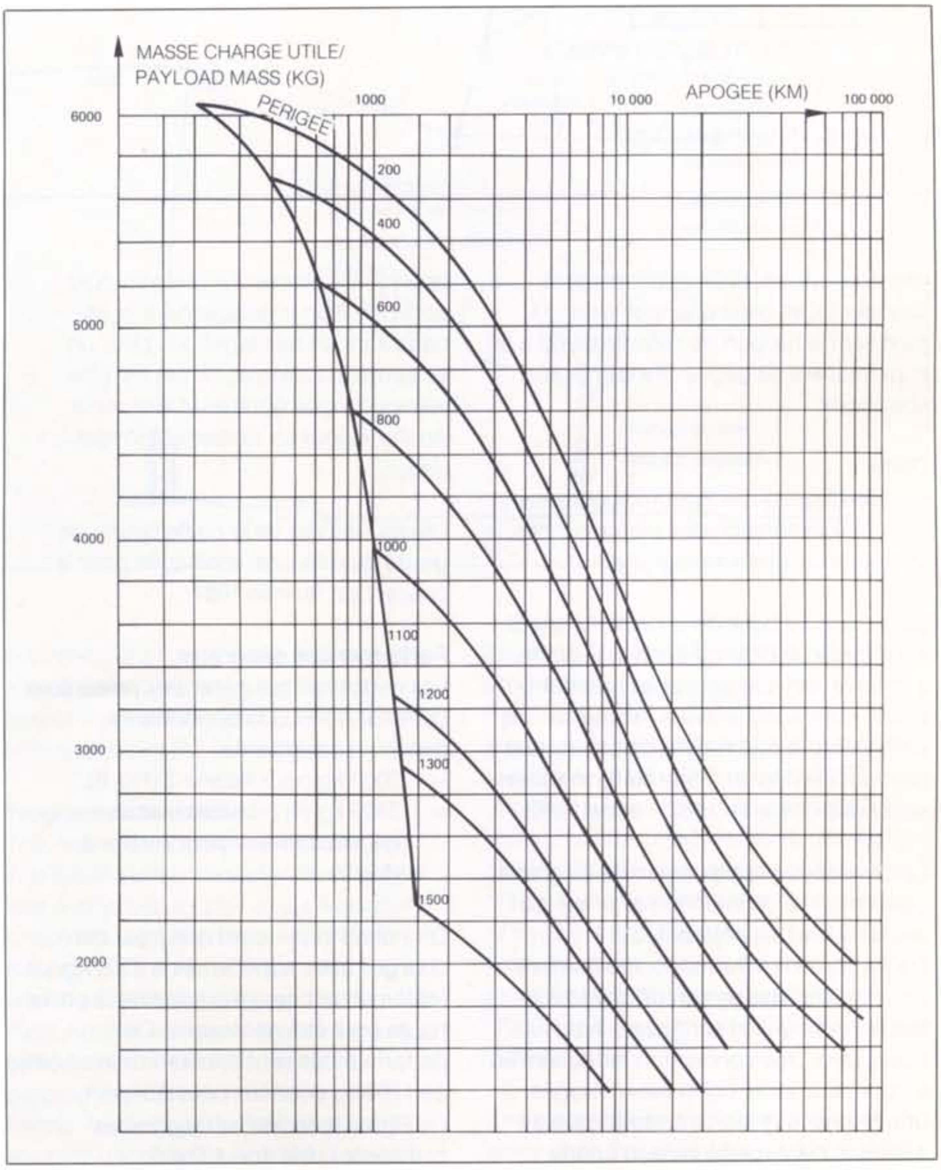
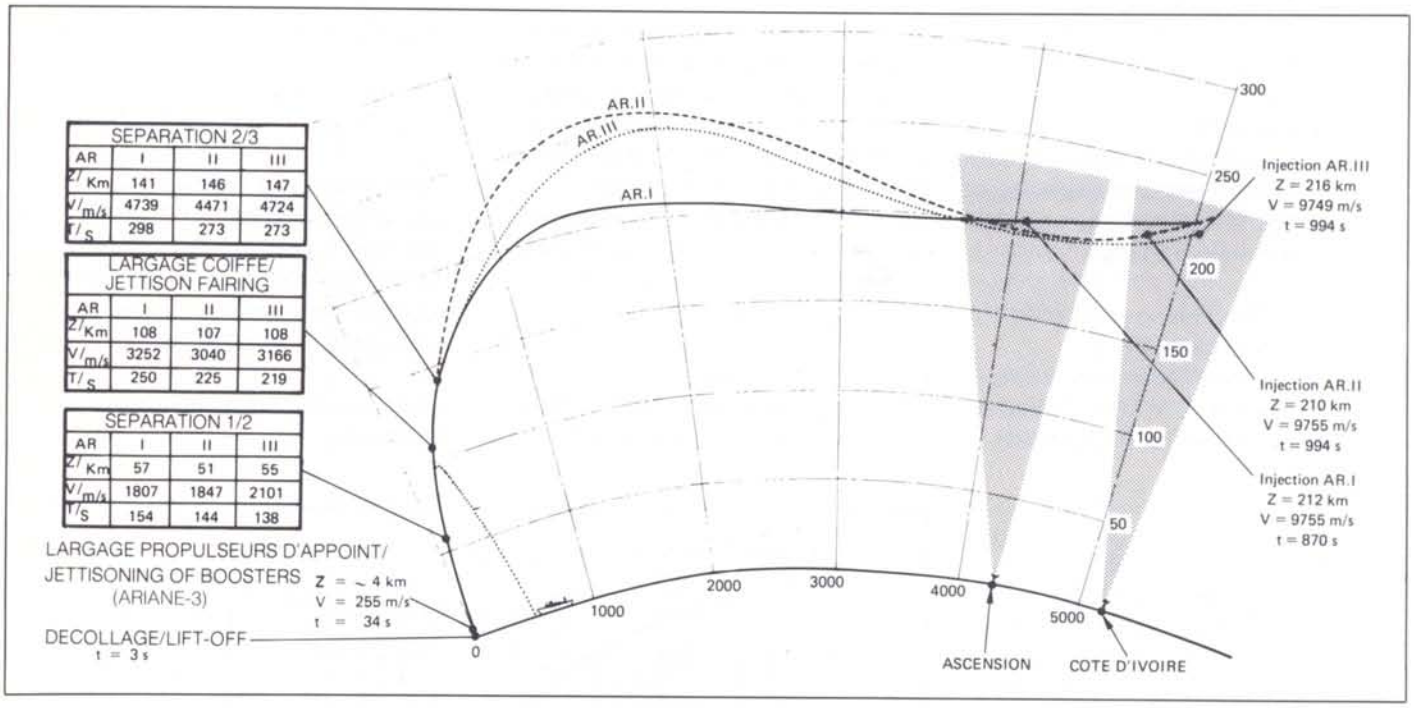


Figure 8 – Trajectories of Ariane-1, 2 and 3/*Trajectoires comparées Ariane-1, 2 et 3*



une colerette de 150 mm prolonge le divergent. Ces deux changements modifient le rapport de détente de 60 à 80 et permettent de gagner 4 s d'impulsion spécifique.

Coiffe
Parallèlement à ces mesures conduisant à une augmentation des performances, le volume sous coiffe est agrandi.

La version de base de la coiffe Ariane-3 est dérivée de celle d'Ariane-1, la coiffe conserve son diamètre et sa hauteur totale, mais le cône avant est transformé en bi-cône, le rayon de la calotte n'étant pas modifié (Fig. 4). Cette coiffe modifiée serait disponible fin 1982 – début 1983.

Le développement d'une coiffe de grand diamètre (4 m de diamètre extérieur au lieu de 3,2 m) est entrepris. La configuration d'une telle coiffe doit être optimisée en vue de son utilisation à la fois sur Ariane-3 et sur Ariane-4 qui lui succèdera. Une conception modulaire en longueur de cette coiffe est envisagée; une première version courte équiperait Ariane-3; cette même version courte pourra être placée sur une structure porteuse d'un passager haut et en-capsulant un passager bas pour un lancement double sur Ariane-4. Une version longue équiperait le lanceur Ariane-4 pour un lancement simple (Fig. 5).

La disponibilité de la coiffe courte de grand diamètre est envisagée pour le courant de l'année 1984.

Performances générales
Les performances générales présentées correspondent à la performance minimum garantie de
- 2000 kg pour Ariane-2 (Fig. 6);
- 2420 kg en orbite de transfert géostationnaire pour Ariane-3 (Fig. 7).

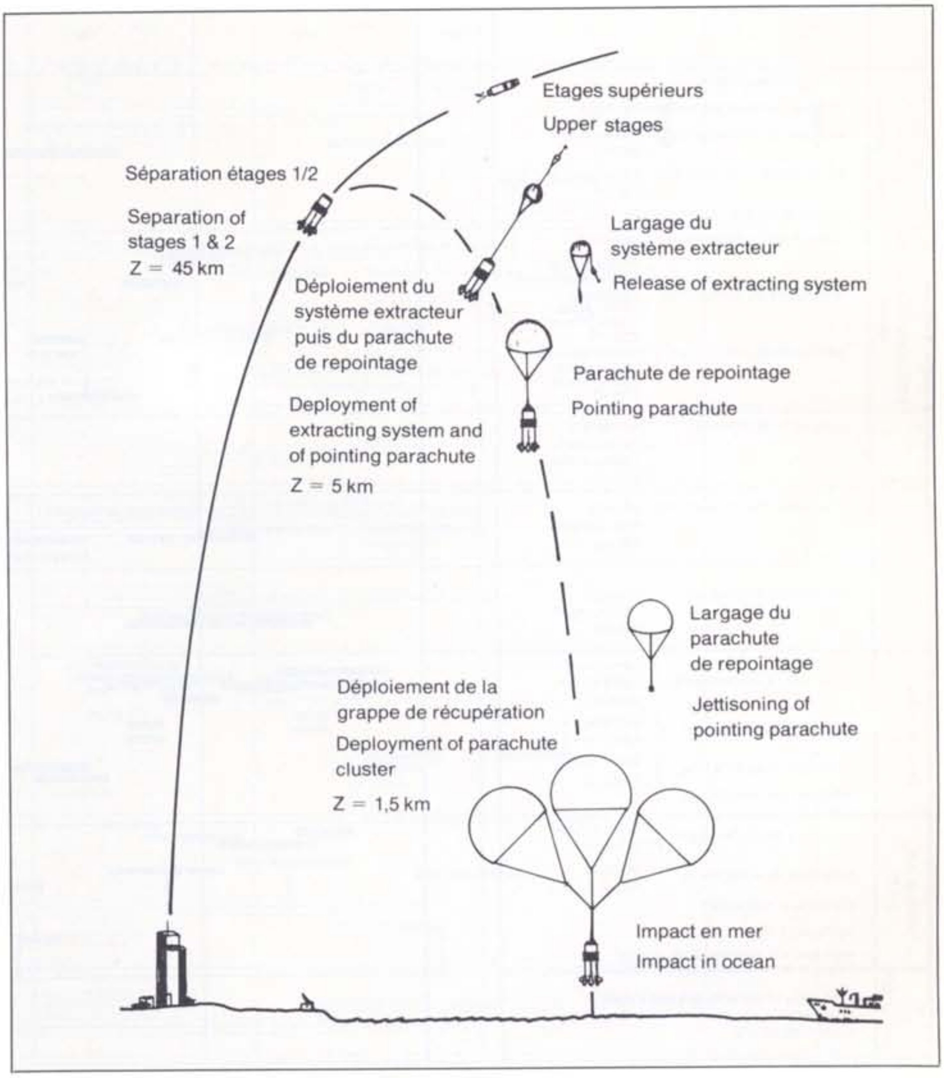
On notera cependant que pour des charges utiles supérieures à 2500 kg, un renforcement des structures de la partie haute peut être nécessaire. Ces performances sont cohérentes avec celles de 1700 kg données pour Ariane-1.
La Figure 8 donne les trajectoires comparées d'Ariane-1, 2 et 3.

Récupération du premier étage
Le premier étage d'Ariane-3 se sépare à 53 km d'altitude environ à la vitesse de 2100 m/s. Il culmine à 87 km et retombe en phase balistique en mer à 340 km environ du site de lancement.

L'opération de récupération consiste à munir le premier étage d'une grappe de parachutes placés dans l'inter-étage 1/2 dont le premier (parachute extracteur et voilure de repointage) s'ouvrirait à une altitude de 5000 m pour un premier freinage; l'ensemble de la voilure (2600 m²) s'ouvrant à 1500 m d'altitude freinerait le premier étage jusqu'à une vitesse d'impact en mer comprise entre 10 et 15 m/s selon la voilure considérée. La possibilité d'équiper l'étage de retrofusées assurant un freinage supplémentaire à celui des parachutes pourrait être envisagée, mais ne semble pas devoir être retenue au stade actuel (Fig. 9).

L'étage doit être muni d'une balise afin d'aider à sa localisation et permettre une récupération rapide. Une remise en pression des réservoirs pourrait être nécessaire pour assurer la tenue de

Figure 9 – Recovery of first stage/*Récupération du premier étage*



Recovery of the first stage

The first stage of Ariane-3 separates at an altitude of about 53 km and a velocity of 2100 m/s. It continues its coasting flight up to an altitude of 87 km, after which it falls back into the sea, some 340 km from the launch site.

Recovery is achieved by equipping the first stage with a cluster of parachutes stowed in the 1/2 interstage. The first canopy, whose primary role is extraction and pointing, would open at 5000 m and produce initial braking. The remaining canopies (2600 m²) would open at 1500 m and slow the first stage down so that it enters the sea at between 10 and 15 m/s, depending on the canopy area. The possibility of fitting the stage with retro-rockets to provide additional braking might be envisaged, but is not felt to be desirable at this point (Fig. 9).

The stage will need to be fitted with a beacon to facilitate tracking and allow rapid recovery. It might be necessary to repressurise the tanks in order to ensure that the stage remains afloat after impact. The stage would be decontaminated at the Guiana Space Centre before being returned to Europe for complete dismantling and refurbishing of all recoverable hardware.

The cost-effectiveness of the operation would depend on the amount of recoverable stage hardware, the number of times that the same item could be recovered, the refurbishment costs compared with recurring costs, and the cost of the logistical operations necessary for the recovery. The current objective is a reduction of some 2 MAU per launch.

The feasibility and cost-effectiveness of this measure can only be determined after carrying out a major programme of studies and tests. In particular, it will be necessary to carry out impact tests — both reduced and full-scale — corrosion tests, towing tests, and hardware-refurbishment tests.

It is intended to carry out a real recovery exercise after one launcher flight, to assess the feasibility and cost-effectiveness of the operation.

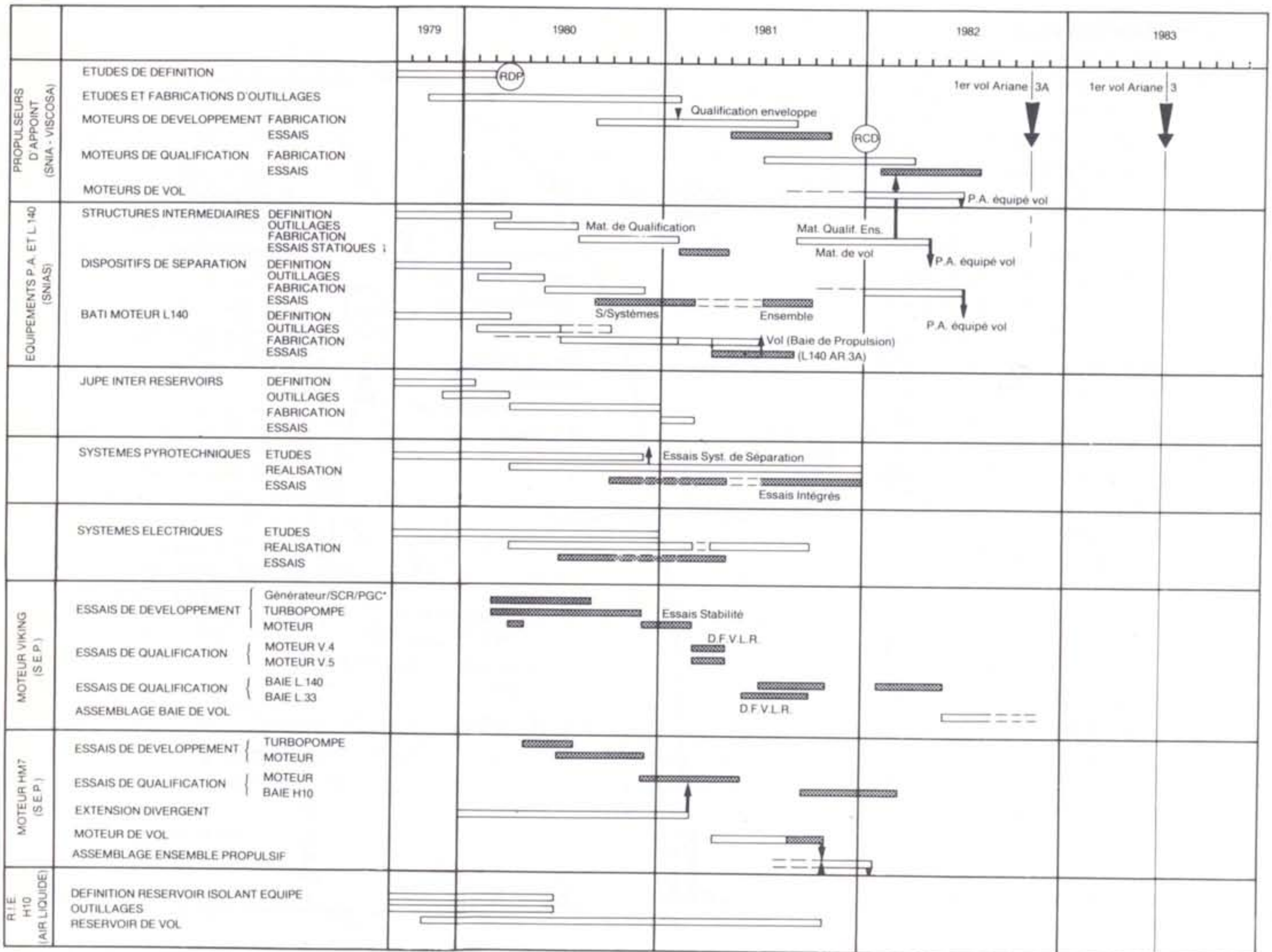
Programme timetable

The Ariane-3 programme is under way. The initial work on booster development was authorised as part of a preparatory phase decided upon in June 1979. A decision on the various tasks leading to improved performance was taken in July 1980. Further decisions are on the way concerning the other slices of the programme: development of a new fairing, recovery of the first stage, and study of a second launch site. This last aspect will be the subject of a separate programme.

A first launching of Ariane-2 or 3 should take place in late 1982 or early 1983. A detailed review of on-going activities shows that the time needed to develop the modifications to the Viking engine is a critical factor. Nevertheless, the mounting of boosters and the greater capacity and propulsion efficiency of the third stage will increase performance appreciably (2300 kg) for launches taking place in late 1982 (Fig. 10).

The biconic fairing will be available by the same date, but more time will be needed

Figure 10 – Calendrier de développement



* Système de contrôle roulis / pressurisation gaz chaud

l'étage après l'impact. L'étage subira au CSG des opérations de décontamination avant d'être réexpédié en Europe pour un démontage complet et une remise à niveau des équipements susceptibles d'être récupérés.

L'intérêt économique de l'opération dépend de la quantité de matériels de l'étage pouvant être récupérés, du nombre de récupérations possibles d'un même matériel, des coûts de réhabilitation à comparer aux coûts récurrents, des coûts des opérations logistiques entraînés par la récupération. L'objectif fixé actuellement est d'atteindre une réduction de l'ordre de 2 MUC par lancement.

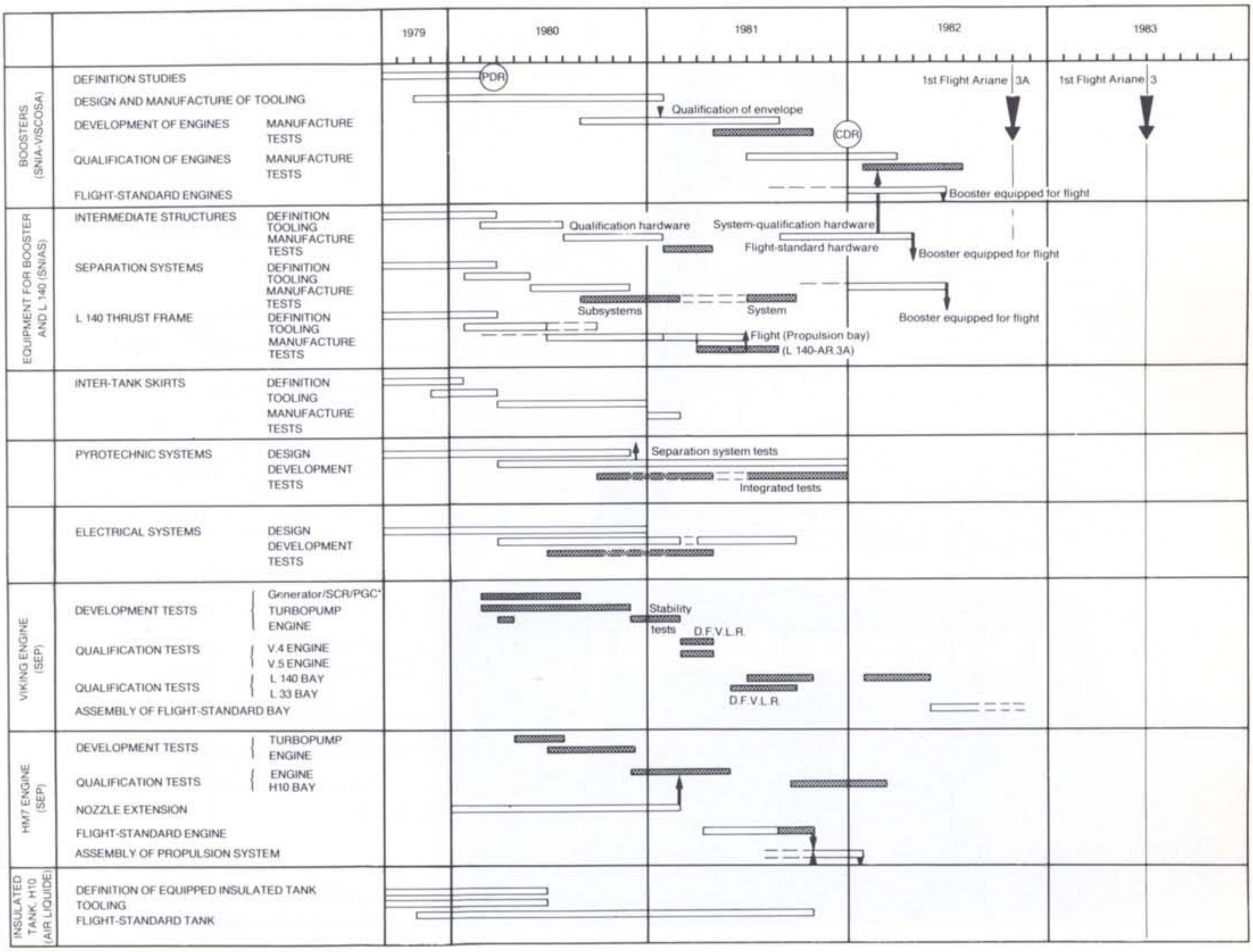
La faisabilité de cette mesure, de même que sa rentabilité, ne pourront être établies qu'après la réalisation d'un programme d'études et d'essais importants. En particulier, il faudra réaliser des essais d'impact à échelle réduite mais aussi à échelle réelle, des essais de corrosion, des essais de remorquage en mer, des essais de réhabilitation de matériels.

La méthode retenue consiste à réaliser une véritable opération de récupération lors d'un vol du lanceur afin de pouvoir se prononcer sur la faisabilité de l'opération et sur son intérêt économique.

Calendrier du programme

Le programme Ariane-3 est en cours. Les premiers travaux sur le développement des propulseurs d'appoint ont été autorisés dans le cadre d'une phase préparatoire décidée en juin 1979. La décision relative à l'ensemble des développements sur l'accroissement des performances a été acquise en juillet 1980. D'autres sont en cours sur les autres tranches du programme – développement d'une nouvelle coiffe, récupération du premier étage, étude d'un second ensemble de lancement (la construction de ce dernier fera l'objet d'un programme distinct).

Figure 10 — Development timetable



* Roll-control system / Hot-gas pressurisation

for the large-diameter fairing, planned for mid-1984.

The feasibility of first-stage recovery will be assessed on the results of an exercise to be carried out late in 1981 or very early in 1982. The aim is to introduce this operation for the first Ariane-2 and 3 vehicles produced.

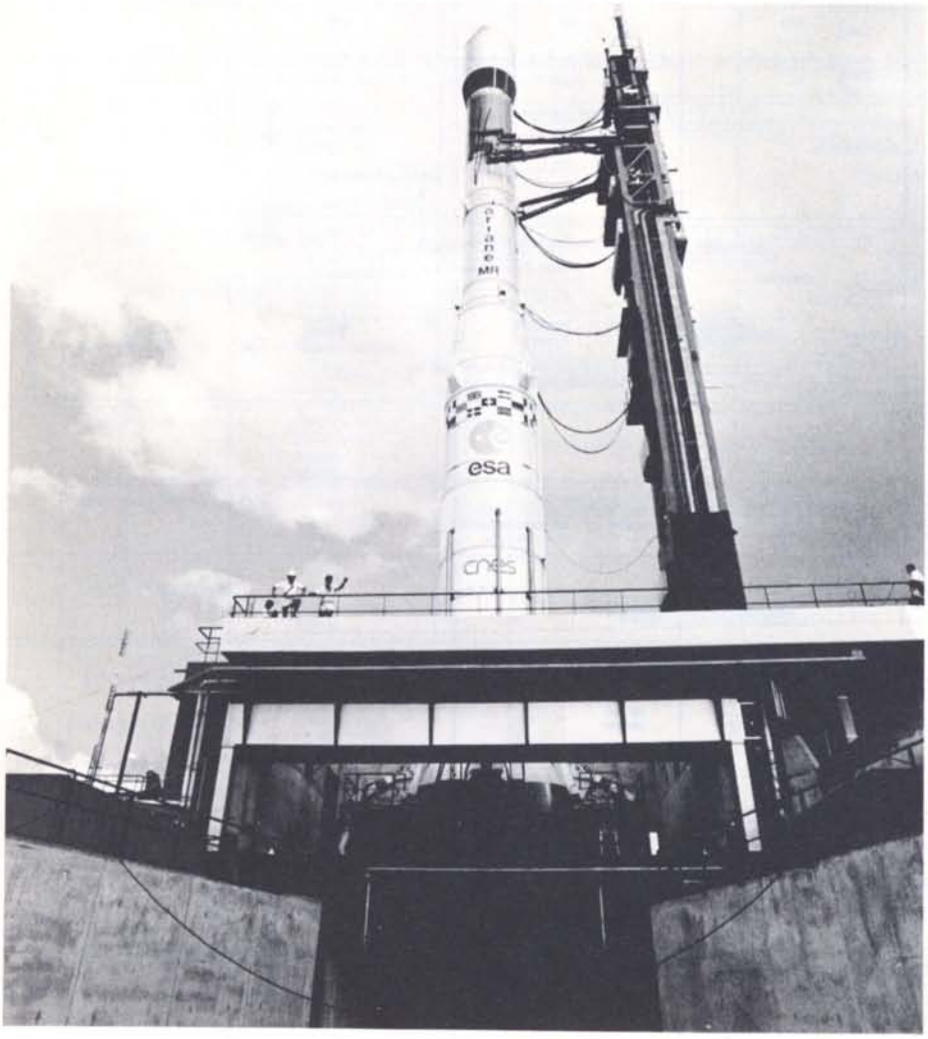
Longer-term prospects

When the modifications needed for the Ariane-2 and 3 launchers have been carried out, performance may be further uprated by increasing the first-stage capacity from 140 to 200 or even 220 t of propellant, the tanks being lengthened by some 2.8 to 3 m. Performance could be further enhanced by mounting four boosters similar to the two used on Ariane-3. The large-diameter fairing would accommodate a dual or a single payload. These could be the main characteristics of the Ariane-4 configuration.

With these modifications, the minimum guaranteed performance for Ariane-4 could be about 3500 kg, or about twice that of Ariane-1, for a slightly greater launch cost. The aim is to reduce the cost per kilo in transfer orbit by 40% compared with Ariane-1, the corresponding reduction for Ariane-3 being 25%.

Construction of a second launch site is justified in part by the need to guard against accident damage to the existing facilities and to achieve greater operational flexibility.

The efforts expended by Europe between 1973 and 1981 on the development of Ariane must be followed up if the launcher and its associated facilities are to match users' requirements and the market situation. If Ariane is to thrive and be used in the 1980s, those who promote it must adopt a dynamic approach; only in this way can an independent European launch capability be preserved.



Un premier lancement d'Ariane-2 ou 3 devrait avoir lieu fin 1982 ou début 1983. Une analyse fine des activités met en évidence l'aspect critique des délais de développement des modifications du moteur Viking. Néanmoins, l'adjonction des propulseurs d'appoint, l'accroissement de la capacité et du rendement propulsif du troisième étage accroîtront sensiblement les performances (2300 kg) pour des lancements intervenant fin 1982 (Fig. 10).

La coiffe bi-conique sera disponible à cette même date, mais un délai supplémentaire est nécessaire pour la coiffe de grand diamètre prévue à la mi-84.

La faisabilité de l'opération de récupération du premier étage sera déterminée au vue des résultats d'une tentative menée lors d'un des lancements réalisés à la fin de l'année 1981 ou au tout début de 1982. L'objectif est de rendre effective cette mesure sur les premiers exemplaires produits des lanceurs Ariane-2 et 3.

Perspectives d'avenir

Les modifications prévues pour Ariane-2 et 3 étant réalisées, une augmentation ultérieure des performances du lanceur peut être obtenue par accroissement de la capacité du premier étage de 140 à 200 et même 220 t d'ergols, les réservoirs étant allongés de 2,8 à 3 m au total.

Contribuant également à l'augmentation des performances, le lanceur est équipé de quatre propulseurs d'appoint semblables aux deux propulseurs d'Ariane-2. La coiffe de grand diamètre abrite une charge utile double ou simple. Ceci pourrait constituer les principales caractéristiques de la configuration Ariane-4.

Avec ces modifications, la performance minimum garantie d'Ariane-4 pourrait se situer autour de 3500 kg, soit sensiblement le double de la capacité d'Ariane-1 pour un coût de lancement très légèrement supérieur. L'objectif est de réduire le coût du kilogramme en orbite de transfert de 40% par rapport à celui d'Ariane-1 (la réduction correspondante pour Ariane-3 est de 25% par rapport à Ariane-1).

Les modifications qui ont été citées font l'objet d'études de définition détaillées. Toute évolution importante des performances au-delà d'Ariane-4 nécessite une transformation profonde du lanceur, en particulier de son deuxième étage.

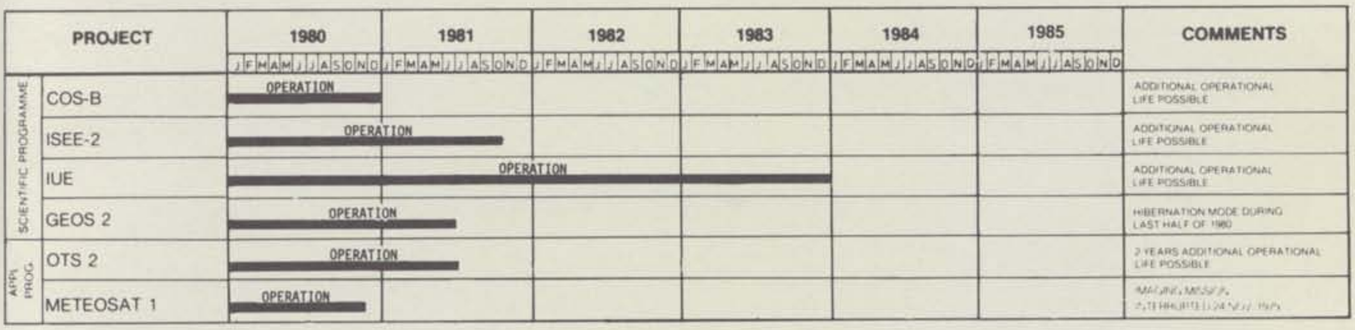
La réalisation d'un second ensemble de lancement se justifie par ailleurs par la nécessité de se prémunir contre tout dommage accidentel des installations actuelles et le besoin d'obtenir une souplesse opérationnelle accrue.

L'effort consenti par les Européens entre 1973 et 1981 pour le développement d'Ariane doit être poursuivi afin d'adapter le lanceur et les moyens qui lui sont associés à la demande des utilisateurs et à la situation du marché. L'existence d'Ariane et son utilisation dans les années 80 exigent une attitude dynamique de ses promoteurs; c'est à ce prix qu'une indépendence européenne en matière de moyens de lancement pourra être préservée.

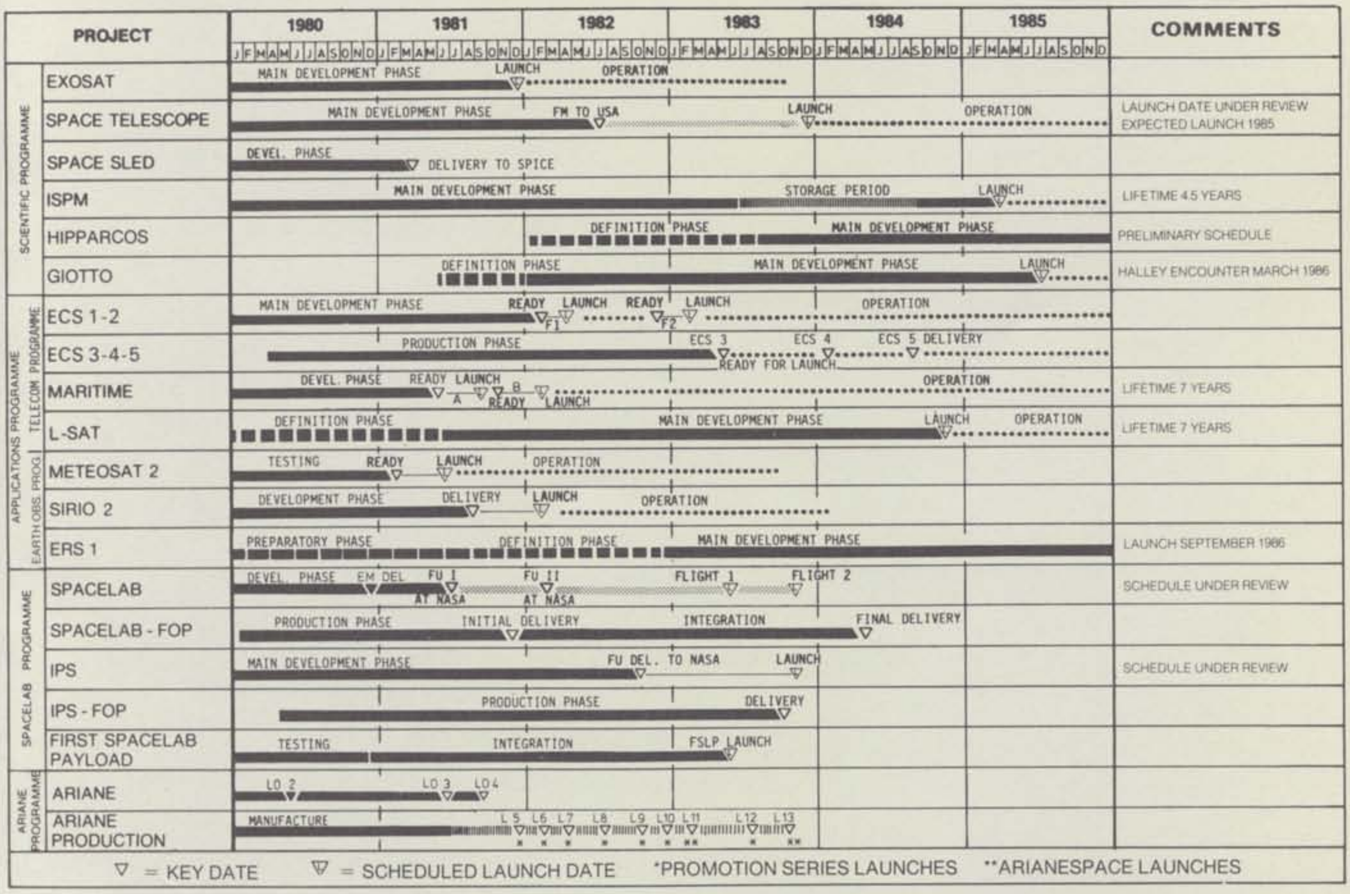
Programmes under Development and Operations*

Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status as per end November 1980/Bar chart valid end December 1980 *Situation des projets décrits fin novembre 1980/Planning fin décembre 1980*

Météosat

Secteur spatial

Le 23 novembre 1980 a marqué le troisième anniversaire de la mise en orbite de Météosat-1 (vie nominale), mais, depuis environ un an, le satellite n'assure plus que la mission de collecte des données en raison d'une défaillance du dispositif de protection contre les surtensions.

Météosat-2 est maintenant prêt à être lancé sur Ariane L03, mais la date de ce lancement n'est toujours pas fixée du fait de l'analyse des causes de la défaillance d'Ariane L02. Un problème vient de se poser: les rétrofusées du deuxième étage d'Ariane produisent des flux thermiques et contaminants, d'un niveau supérieur aux prévisions, à l'interface de Météosat. L'équipe Ariane envisage de ramener la durée de fonctionnement de ces fusées de 0,9 à 0,5 s et prépare des essais sous vide qui serviront à étudier le problème en détail et à rechercher d'éventuelles solutions.

Exploitation

La mission de collecte des données dessert actuellement 29 plates-formes.

La préparation du traitement des images de Météosat-2 se poursuit, l'objectif visé étant d'améliorer la qualité des produits météorologiques et de raccourcir leurs délais de livraison.

Programme opérationnel

L'Agence recevra les 28 et 29 janvier une conférence intergouvernementale réunissant 19 pays en vue de discuter le programme Météosat opérationnel et, espère-t-on, d'adopter un plan d'action pour son démarrage.

Sirio-2

Les essais électriques de l'élément plate-forme de maintenance du modèle d'intégration du satellite ont été achevés. Les quelques anomalies techniques mineures rencontrées au cours de ces essais ont été analysées et l'accord s'est fait sur les remèdes à y apporter.

La prochaine phase du programme concerne l'intégration et l'essai des charges utiles MDD et Lasso qui ont déjà été qualifiées au niveau composants ou sous-systèmes. La vérification finale du modèle d'intégration du satellite porte sur la compatibilité électromagnétique et sera suivie d'un examen final de la conception (au printemps 1981).

Une proposition relative à l'exploitation de Sirio-2, comportant les activités avant lancement déjà approuvées (préfinancées par l'Italie), sera soumise au Conseil directeur de programme en décembre 1980.

Télédétection

La plupart des activités du programme préparatoire de télédétection (RSPP) ont été mises en route. La demande de participation au RSPP présentée par la Norvège sera soumise à l'approbation des autres participants. Une extension du RSPP, axée sur ERS-1 et couvrant la période mars-décembre 1981, a été préparée et devrait être approuvée prochainement.

Un programme préliminaire de la campagne SAR-580 a été envoyé aux expérimentateurs pour commentaires. Ces derniers organisent actuellement différents ateliers destinés à aider l'ESA et le JRC à arrêter définitivement le contenu de ce programme.

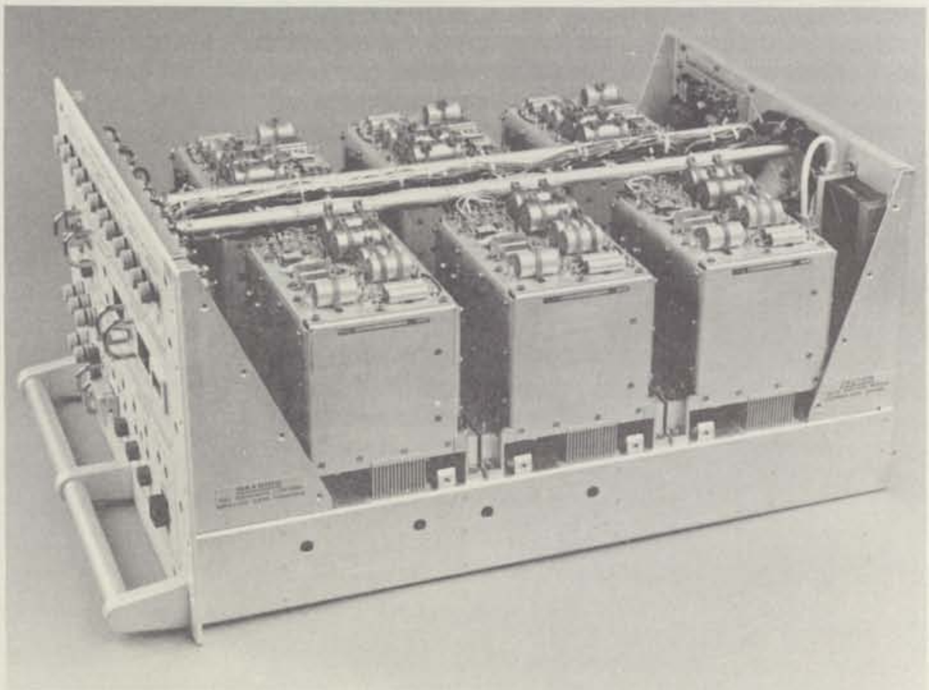
En ce qui concerne les études de systèmes et de charges utiles, l'étude de définition de l'imageur 'couleurs des océans' (OCM) de ERS-1 est achevée, deux études de définition de l'altimètre radar ont été mises en route en septembre et deux versions du diffusiomètre sont à l'étude. Pour les deux configurations de cet instrument qui se dessinent, les résultats définitifs seront prêts en décembre.

Mars 1981 est la date objectif pour la sélection de la configuration de la charge utile de base de ERS-1 et l'approbation des phases B/C/D du même programme.

En ce qui concerne le secteur sol et les activités opérationnelles, le Conseil a approuvé à sa session d'octobre l'actualisation d'Earthnet en vue du soutien des satellites Landsat D/D'.

Traîneau spatial

Le modèle de sous-système électrique du traîneau spatial destiné à la formation de l'équipage a été livré à l'ESTEC fin novembre 1980. La phase d'assemblage, d'intégration et d'essai au niveau système commencera à l'ESTEC en décembre, dès que les essais de propreté électromagnétique qui se déroulent actuellement seront terminés. Le second modèle de sous-système électrique, ou modèle de vol, est entièrement monté et subit actuellement les essais de recette chez le contractant. La livraison de ce



The Space Sled Electronics Unit (SEU), built by Bell Telephone Manufacturing Co. (Belgium)

L'ensemble 'électronique' du Traîneau spatial, construit par Bell Telephone Manufacturing Co. (Belgique)

Meteosat

Space segment
On 23 November 1980 Meteosat-1 had been in orbit for three years (nominal lifetime), although for about a year the satellite has only been supporting the data-collection mission because of a failure in the undervoltage protection unit.

Meteosat-2 is now ready for launch on Ariane L03, but the launch date is still tentative as a result of the analysis of the causes of the Ariane L02 failure. A problem has recently come to light in that the retro-rockets on the launcher's second stage are generating unexpectedly high thermal and contamination fluxes at the Meteosat interface. It is planned to reduce the firing time of these rockets from 0.9 s to 0.5 s, and vacuum tests are planned to examine the problem in detail and evaluate possible solutions.

Exploitation
The data-collection mission is now supporting 29 platforms.

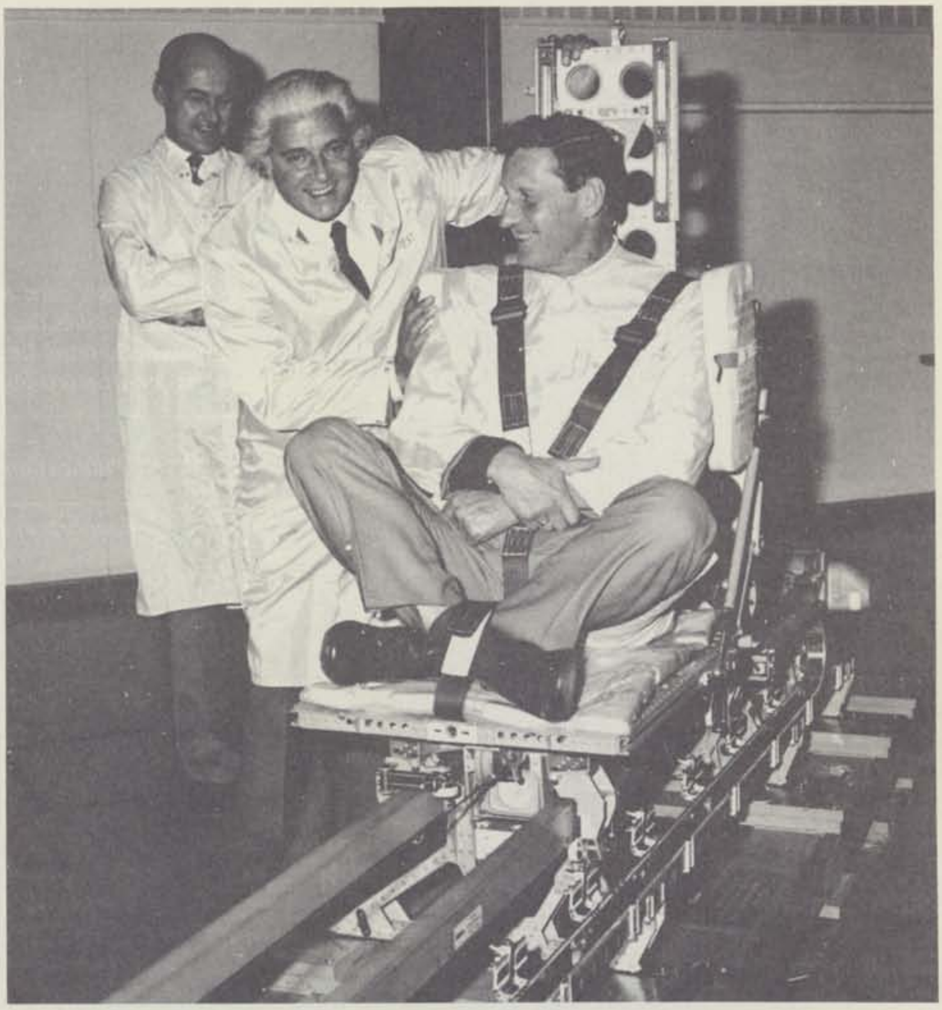
Preparation for Meteosat-2 image processing continues, with the aims of improving quality and faster delivery of meteorological products.

Operational programme
The Agency will be hosting an Intergovernmental Conference of 19 countries on 28 and 29 January in Paris to discuss the Operational Meteosat Programme, and hopefully to agree on a plan of action for starting this programme.

Sirio-2

Electrical testing of the housekeeping platform part of the satellite integration model has been completed. Some minor technical anomalies encountered during the tests have been analysed, and corrective actions have been agreed. The next phase in the programme includes integration and testing of the MDD and Lasso payloads, which have already been qualified at unit or subsystem level. The final checkout activity on the satellite integration model is concerned with electromagnetic compatibility, and will be followed by a Final Design Review (in Spring 1981).

A proposal for Sirio-2's exploitation, including the already-approved pre-launch activities (pre-financed by Italy), will be submitted to the Programme Board in December 1980.



Space Sled protoflight model on the test floor at ESTEC. Seated Mr. Erik Quistgaard, ESA's Director General and standing (centre), Prof. Massimo Trella, ESA Technical Director.

Le prototype modèle de vol du Traîneau spatial dans le hall d'essai à l'ESTEC. On reconnait sur la photo M. Erik Quistgaard, Directeur général (assis) et le Professeur Massimo Trella, Directeur technique (debout)

Remote Sensing

Most activities involved in the Remote Sensing Preparatory Programme (RSPP) have now been commenced. Norway's request for participation in the RSPP will be submitted for approval to the other participants. An extension of the RSPP oriented towards ERS-1 and covering the period from March 1981 until December 1981 has been prepared and is expected to be approved soon.

Within the framework of the SAR-580 campaign, a preliminary campaign schedule has been sent to the experimenters for comment. Various experimenters' workshops are presently being organised to assist ESA and the JRC in the finalisation of the experimental programme.

As far as the system and payload studies are concerned, the definition study of the ocean colour monitor (OCM) for ERS-1 is complete; two radar-altimeter definition studies were initiated in September and two versions of the scatterometer are being studied. Two configurations for the instrument have been identified and the final results will be available in December.

March 1981 is the target date for the selection of the basic payload configuration for ERS-1 and approval of the ERS-1 definition and development phases (Phases B and C/D).

With respect to ground-segment and operations activities, the Council, at its meeting in October, approved the updating of Earthnet and Landsat-D/D'.

modèle est prévue pour décembre 1980. La date fixée pour l'achèvement du programme de développement du traîneau spatial est reportée à fin mars 1981. Ces deux mois de retard proviennent de plusieurs petits problèmes de développement qui ont contraint à apporter des modifications mineures à 14 modules d'amplificateurs d'attaque. Depuis août, le programme se déroule conformément aux prévisions du calendrier révisé mis au point à cette date.

Lors de sa session des 22 et 23 octobre le Conseil de l'Agence a examiné les futures possibilités de vol du Traîneau spatial et a déclaré qu'il se prononcerait avant fin 1980 pour la mission D-1 ou pour la mission SL-4 du Spacelab.

Giotto

Le projet Giotto a été inscrit au programme scientifique de l'Agence dès son approbation par le Comité du Programme scientifique de l'ESA à sa réunion du 8 et 9 juillet 1980. Giotto sera la première mission dans l'espace lointain à utiliser la fusée Ariane. Le lancement du satellite est prévu pour juillet 1985 et sa rencontre avec la Comète Halley aura lieu en mars 1986. (Un article complet sur la mission a été publié dans le Bulletin no. 24, pages 6 à 11.)

Le Comité de la Politique industrielle de l'Agence (IPC) a approuvé la poursuite de négociations directes avec British Aerospace (BAe) pour la fourniture du satellite Giotto. Cette décision est motivée par le fait que la période de développement dont on dispose est limitée en raison de l'impératif d'un lancement en 1985 et par le fait également que la conception du satellite est dérivée de celle de Geos.

A l'ESTEC les activités se déroulent actuellement en fonction d'une mise en route de la phase de définition du projet (Phase-B) à la mi-1981. Par ailleurs les 17 expériences scientifiques proposées par des instituts européens pour inclusion dans la charge utile de Giotto font actuellement l'objet d'une évaluation technique en vue de déterminer si elles sont compatibles avec le satellite et de définir leurs besoins en ressources (masse, énergie, etc.).

La sélection des expériences est effectuée par un comité composé de membres du

ESA Spacelab payload specialists in training at SPICE, Porz-Wahn Right (standing on right), Ulf Merbold; below left, Wubbo Ockels; below right, Claude Nicollier

Les spécialistes mission Spacelab de l'ESA en cours de formation au SPICE, à Porz-Wahn: Ulf Merbold (debout à droite), Wubbo Ockels (en bas à gauche) et Claude Nicollier (en bas à droite)

groupe de travail 'Système solaire' de l'Agence.

Etapes de la sélection des expériences
15 octobre 1980 — Date limite de soumission des propositions d'expériences
11 novembre 1980 — Réunion de mise en route des travaux du Comité de sélection
15/16 décembre 1980 — Recommandation du Comité de sélection
17 décembre 1980 — Recommandation du Comité consultatif scientifique (SAC)
15/16 janvier 1981 – Décision du Comité du Programme scientifique (SPC).

Télescope spatial

Réseau solaire

L'intégration du modèle de développement du mécanisme de déploiement secondaire s'est poursuivie; elle atteindra sa phase finale avec l'intégration de la nappe. L'essai du système commencera ensuite à l'aide de ce modèle.

Les examens critiques de la conception des sous-systèmes (électronique de commande du déploiement et nappes du réseau solaire) se sont achevés. Des examens similaires sont en cours pour les autres sous-systèmes. Le problème de la stabilité du mécanisme de déploiement primaire va être résolu par l'introduction d'un autre jeu de pignons. En outre, certaines modifications de conception sont apparues nécessaires dans l'accouplement du moteur du mécanisme d'actionnement du bi-stem.

Une grande incertitude continue de régner sur les différents modes de mission du Télescope spatial en ce qui concerne le déploiement et la maintenance. Ceci pourrait avoir des effets sur la conception thermique du réseau solaire.

Chambre pour objets de faible luminosité (FOC)

L'intégration de l'ensemble du compartiment électronique du système de traitement de données et de calculateur de bord a pris fin; les travaux se

Sled

The Sled electrical-subsystem training model was delivered to ESTEC at the end of November 1980. The system assembly, integration and test phase at ESTEC will start in December when electromagnetic-cleanliness tests now in progress have been completed. The second electrical-subsystem model, the flight model, is fully assembled and is being acceptance tested at the contractor's facilities. Delivery of the flight model is planned for December 1980.

The predicted end-date for the Sled development programme has slipped to the end of March 1981. This two-month delay is the result of several small development problems which required minor circuit changes to be made in 14 drive amplifier modules. Progress since August has been exactly in accordance with the revised schedule established at that time.

The ESA Council discussed future flight opportunities for the Sled at its meeting on 22/23 October, and the choice of either the Spacelab D-1 or SL-4 mission should be taken by the end of 1980.

Giotto

The Giotto project was included in the Agency's scientific programme immediately after the positive decision of ESA's Science Programme Committee on 8/9 July 1980. Giotto will be the first deep-space mission using Ariane. The launch is planned for July 1985, and the encounter with Comet Halley will take place in March 1986. (A comprehensive article on the mission was published in ESA Bulletin No. 24, pp 6 – 11.)

The Agency's Industrial Policy Committee (IPC) has approved the proposal to pursue a direct negotiation with British Aerospace (BAe) for the Giotto spacecraft procurement. The reasons for this approach are the constrained development period, stemming from the unique 1985 launch requirement, and the fact that the spacecraft design is a derivative of the Geos concept.

Present activities at ESTEC are directed towards initiation of the project definition phase (Phase B) in mid-1981. In addition, the 17 scientific experiments proposed by European institutes for inclusion in the Giotto payload are being technically evaluated, with a view to assessing spacecraft compatibility and experiment-resource requirements (mass, power, etc.).

The experiment selection is being performed by a committee drawn from the members of the Agency's Solar System Working Group.

Milestones for experiment selection

15 October 1980 – Experiment proposal deadline
11 November 1980 – Kick-off meeting of Selection Committee
15/16 December 1980 – Recommendation of the Selection Committee
17 December 1980 – Recommendation of the Science Advisory Committee (SAC)
15/16 January 1981 – Decision by the Science Programme Committee (SPC).

Space Telescope

Solar array

Integration of the development-model secondary deployment mechanism has continued during the reporting period and is reaching a final stage with integration of the development blanket. The system testing with this model will then start.

Critical Design Reviews have been completed for the deployment control electronics and the blanket subsystems. Similar reviews for the other subsystems are in progress. The stability problem with the primary deployment mechanism is being resolved by the introduction of another gear. Also some design changes in the bi-stem actuator motor-gear arrangement are becoming necessary.

Considerable uncertainty still remains concerning the various Space Telescope mission modes for deployment and maintenance, and this could eventually have an effect on the thermal design of the solar array.

Faint-object camera

Integration of the electronic-bay assembly has been finalised for the data-handling and on-board computer system, and is now continuing with integration of the dedicated electronics.

The opto-mechanical flight hardware is being manufactured with the exception of the refocusing mechanism, where some redesign still has to be incorporated.

The Critical Design Review is in progress.

Photon detector assembly

Integration of the PDA engineering model continued on schedule, until a high-voltage-induced malfunction occurred in the intensifier section after 200 hours of operation. This is under investigation.

Analysis of failures encountered in the camera section has revealed that some problems exist in both the thermal/mechanical and high-voltage designs and some development tests are required for their solution. These difficulties introduce a further delay in the deliveries of the PDA units for integration into the FOC.

NASA activities

As a result of fiscal-year funding limitations, NASA has reduced the manpower levels with all contractors. This will lead to a delay in the Space Telescope launch date, although the precise extent of this delay has not yet been announced by NASA.

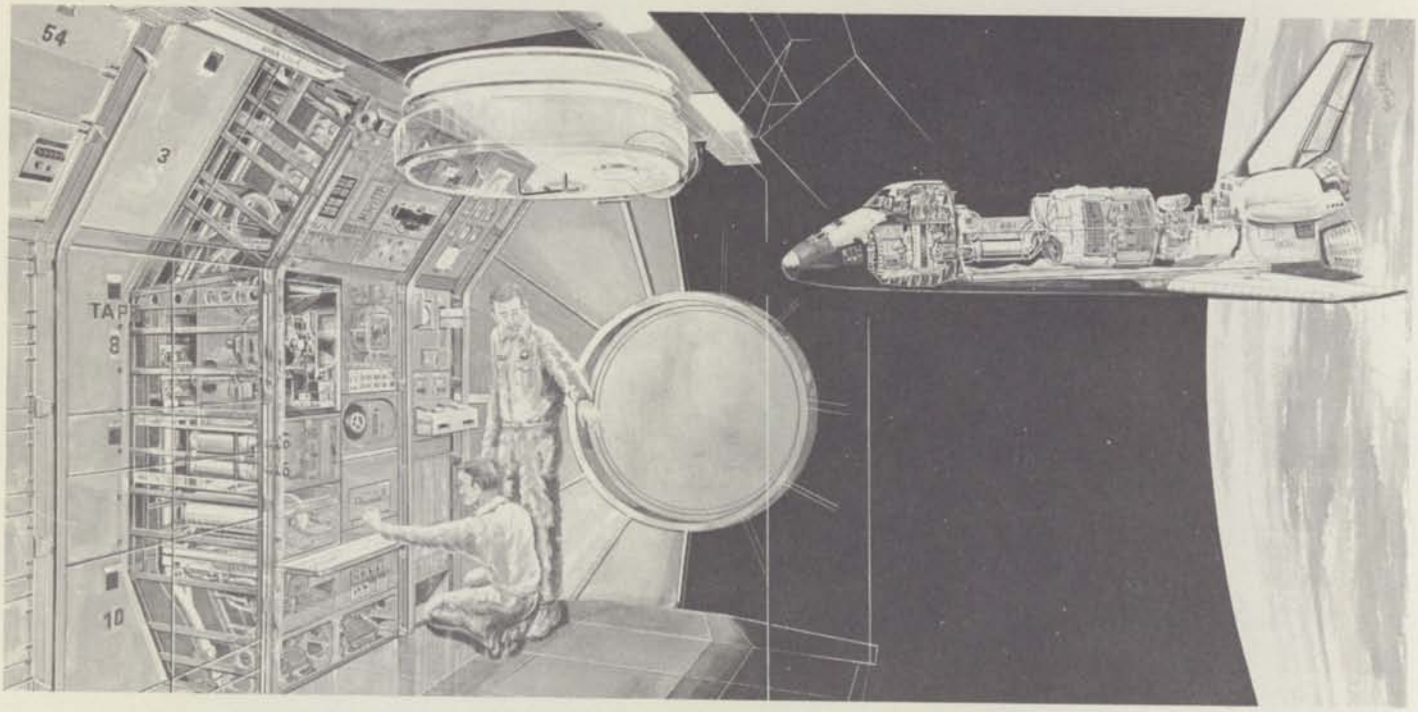
Spacelab

Spacelab engineering model delivered

A milestone in European/US space co-operation was celebrated on 28 November 1980 when the engineering model of Spacelab was delivered from ERNO to ESA and from ESA to NASA. Acceptance of the Spacelab was conducted jointly by ESA, NASA and ERNO after six and a half years of development and manufacture. In early December, the engineering model was transported by wide-bodied aircraft to the Kennedy Space Center.

In his speech during the hand-over ceremony on 28 November, the Agency's Director General, Mr. E. Quistgaard, congratulated the European industrial firms for the fine performance and stated that the final evaluation of the success of Spacelab would have to wait for the first Spacelab mission. He considered the achievement of the milestone of the engineering-model delivery to be an important encouragement for the next phases of the Spacelab Programme.

The engineering model is a prototype of the Spacelab flight unit, but is itself not intended for flight. It will be used by NASA to prepare for processing the Spacelab flight unit, including verification of the



Artist's impression of the material-sciences facility for the first Spacelab mission

Installation d'expérience sur les sciences des matériaux pour le première mission Spacelab (vue conceptuelle)

poursuivent par l'intégration de l'électronique spécialisée.

Le matériel opto-mécanique de vol est en cours de fabrication, à l'exception du mécanisme de mise au point pour lequel il reste encore à appliquer certaines modifications de conception. L'examen critique de la conception est d'ailleurs en cours.

Détecteur de photons (PDA)
L'intégration du modèle d'identification du PDA se déroule selon le calendrier; toutefois, après 200 heures de marche, la section 'intensificateur' a été victime d'un dérangement provoqué par une haute tension. Les recherches sur cet incident sont en cours. L'analyse des défaillances de la partie 'chambre' a révélé qu'il y a encore des difficultés en ce qui concerne la conception tant des aspects thermique/mécanique que haute tension. Certains essais de développement sont nécessaires pour résoudre ces questions. Les difficultés rencontrées introduisent un nouveau retard dans la livraison des organes du PDA pour intégration dans la FOC.

Activités NASA
A la suite des restrictions financières de l'exercise courant, la NASA a réduit les niveaux de personnel pour tous ses contractants. Ceci va retarder la date de lancement du Télescope bien que l'importance exacte de ce retard n'ait pas encore été fixée.

Spacelab

Livraison du modèle d'identification à la NASA
C'est une importante étape de la coopération spatiale entre l'Europe et les Etats-Unis qu'a marquée, le 28 novembre 1980, la cérémonie organisée à l'occasion de la remise par ERNO à l'ESA, puis par l'ESA à la NASA, du modèle d'identification du Spacelab. Les essais de recette ont été conduits conjointement par l'ESA, la NASA et ERNO après six ans et demi de travaux de développement et de fabrication. Début décembre, le modèle d'identification a été transporté par avions gros-porteurs au Centre spatial Kennedy.

Dans l'allocution qu'il a prononcée au cours de la cérémonie, le Directeur général de l'ESA, M.E. Quistgaard, a félicité les firmes européennes de l'excellent résultat obtenu, indiquant qu'il faudrait attendre la première mission du Spacelab pour pouvoir se prononcer de façon définitive sur sa réussite. Il a déclaré qu'à son avis le fait d'avoir franchi l'étape de la livraison du modèle d'identification est un important encouragement pour les phases suivantes du programme.

Le modèle d'identification du Spacelab est un prototype de l'unité de vol mais il n'est pas destiné à voler. La NASA l'utilisera pour préparer la mise en place de l'unité de vol, notamment pour vérifier les interfaces du Spacelab avec les équipements sol au site de lancement de la Navette et pour former et entraîner les équipages.

Recette des premiers éléments du modèle de vol
Avant que le modèle d'identification ait été présenté et remis à la NASA, les premiers éléments du modèle de vol du Spacelab étaient achevés à Brême. Après des essais qui ont duré quatre jours, les représentants de l'ESA et de la NASA ont délivré les certificats de recette pour certains matériels de vol, à savoir les bâtis d'expériences standard à intégrer dans le laboratoire. Outre les trois bâtis totalement équipés, d'autres bâtis standard destinés à recevoir les équipements nécessaires à la régulation thermique et à l'acquisition des données des expériences sur porte-instruments ont été jugés recevables et le feu vert a été donné pour l'intégration des expériences.

Cette recette anticipée était devenue nécessaire, l'intégration des expériences européennes de la première mission Spacelab devant commencer à Brême dès la fin de l'année 1980. C'est ERNO qui, au titre d'un contrat qui lui a été confié par l'ESA, est chargé de cette tâche pour toutes les expériences européennes destinées à cette première interfaces between Spacelab and the ground equipment at the Shuttle launch site, and for training purposes.

First Spacelab flight elements accepted by ESA/NASA
Prior to the presentation of the Spacelab engineering model and its delivery to NASA, the first Spacelab flight elements were completed in Bremen. After acceptance tests lasting four days, ESA and NASA representatives issued certificates for certain items of flight hardware, such as the standard experiment racks to be integrated into the laboratory area. Aside from the three completely equipped racks, other standard racks designed for pallet-experiment temperature control and data acquisition have been accepted and released for experiment integration.

This 'premature acceptance' became necessary because the integration activities for the European experiments for the first Spacelab mission were to start in Bremen at the end of 1980. Under contract to ESA, ERNO is integrating all European experiments for flight within the framework of this first Spacelab mission (the so-called First Spacelab Payload, FSLP).

Spacelab post-delivery change-control agreement signed
On 3 November the ESA/NASA Spacelab Programme Directors signed a document which defines the policy for configuration management of Spacelab items after their delivery to NASA. The agreement applies to the ESA-developed Spacelab items from the time of their delivery until completion of the second Spacelab flight (currently scheduled by NASA for November 1983). Under the agreement, ESA will retain the design responsibility for Spacelab and will make all make-work changes which are not time-critical. NASA will be responsible for all changes that are time-critical. The as-designed configuration will be maintained in Europe whereas the as-built configuration will be under NASA responsibility following delivery of the Spacelab items. NASA will fund any new-requirements changes to the Spacelab baseline as established in September 1979.

ISEE

The mission is now into its third year and although data recovery has dropped a little recently, for at least 60% of the time data is simultaneously available from all three spacecraft. All spacecraft systems continue to work well and sufficient control gas is available for several more years of operations. Although there have been some failures within experiments, these have not been sufficient to destroy the basic mission goals and it is planned to continue operations until the start of NASA's Open (Origin of Plasmas in the Earth's Neighbourhood) project.

The condition of the main twinned experiments on the ISEE-1 and 2 spacecraft can be summarised as follows:

	ISEE-1	ISEE-2
Magnetometer	good	good
Plasma wave instruments	good	good
Electron density	good	good
Fast plasma, high time resolution	partial loss	total loss
Fast plasma, high angular resolution	good	partial loss
Medium energy particles high time resolution	partial loss	good
Medium energy particles high angular resolution	total loss	good
Solar wind	good	good

The most important experiments are still working well after nearly three years in space.

IUE

During the third year of operation, 269 different scientists were involved as guest observers in accepted ESA programmes. The corresponding figure for UK Science Research Council programmes which also use the ESA Vilspa station was 115. At the time of writing, proposals for the fourth year are flowing in and a similar total to last year (170) is anticipated.

Recent highlights of IUE observations include:

- an experiment to measure the reflectivities of the outer planets Jupiter, Saturn and Uranus in hydrogen Lyman Alpha by observing with delays such that the travel times of the light from Sun to planet and back to Earth are compensated for and any effects of solar variability are removed. This is relevant to the chemistry in the outer atmospheres of these planets. It was found that the reflectivity of Uranus was significantly higher than that of Jupiter or Saturn;
- absolute spectro-photometry for a sequence of spiral galaxies of different hubble type has been performed by combining data from IUE and a small ground telescope fitted with a 'replica' of the IUE large aperture and measuring at longer wavelengths. The results show changes in the stellar populations of galactic nuclei with more hot stars in 'later' type (more open spiral) galaxies. This suggests that faint galaxy surveys will be dominated by the strong UV emission of late-type spiral galaxies.

Recent analyses of the power output from the solar panels suggest (barring catastrophic failure) a technical capability to continue the present style of operations until 1984 or 1985. Power may still be available, with the spacecraft at the most favourable angle, until 1989. Ways of continuing operations without relying on the on-board batteries are under study in case they should fail earlier. (See also IUE item on page 72.)

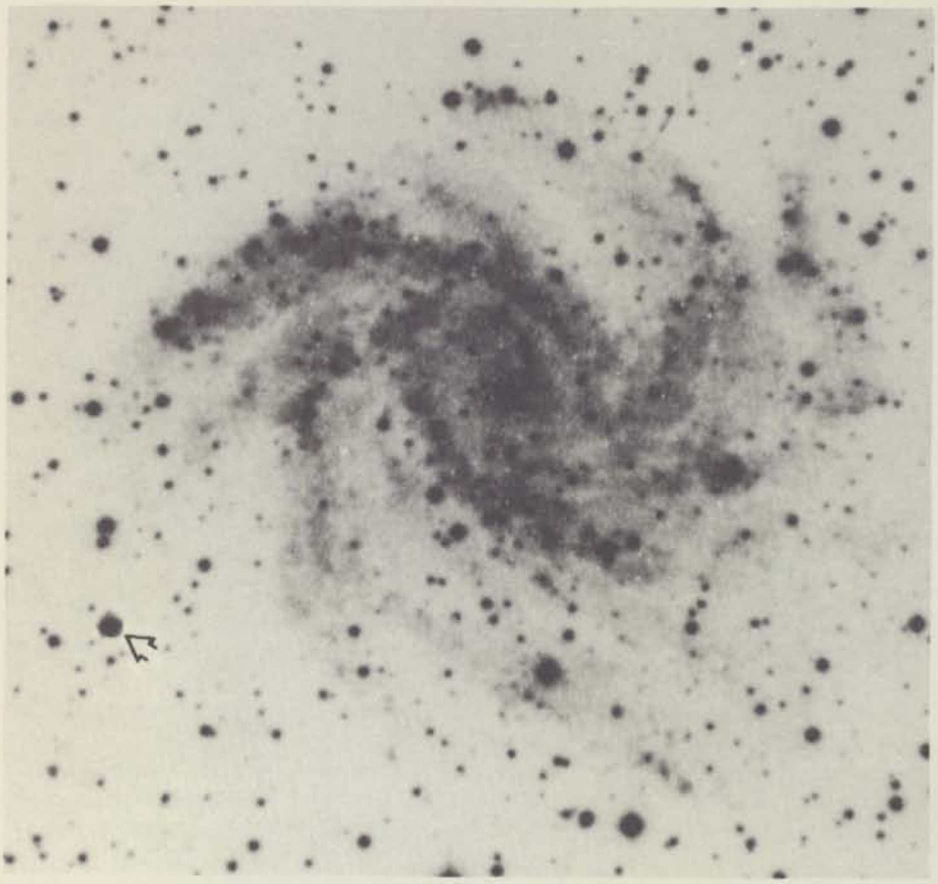
Geos-2

Operations continued on a 24 h per day basis until switch-off at the end of July 1980. On 1 August the satellite entered its hibernation phase. At the start of the eclipse season, towards the end of August, it was discovered that the on-board battery that provides power during eclipses was no longer functioning. Consequently there will be a loss of data during all future eclipse periods, this loss lasting for about 1 h in every 24 h for approximately 20 days around each equinox. The total loss averaged over a year will be of the order of 1%, and is therefore negligible.

At a recent meeting between the Geos experimenters and the Eiscat community, it was agreed to reactivate Geos-2 on 1 February 1981.

Cos-B

The results of Cos-B were a major topic at a discussion meeting on Gamma-Ray



Palomar ground observatory photograph showing the new supernova in spiral galaxy NGC 6946, studied recently with IUE (see page 72)

Cette photographie, prise par l'Observatoire du Mont Palomar, montre une nouvelle supernova dans la galaxie spirale NGC 6946, qui a été observée récemment par IUE (voir page 72)

mission du Spacelab (intitulée FSLP – First Spacelab Payload).

Signature d'un accord sur le contrôle des modifications apportées au Spacelab après sa livraison

Les Directeurs du Programme Spacelab de la NASA et de l'ESA ont signé le 3 novembre un document définissant la politique qui sera suivie pour le contrôle de configuration des éléments du Spacelab après leur livraison à la NASA. Il s'agit d'un accord applicable aux éléments développés par l'ESA, depuis le moment de leur livraison jusqu'à l'achèvement du second vol du Spacelab (actuellement prévu par la NASA pour novembre 1983). Aux termes de cet accord, l'ESA conservera la responsabilité de la conception du Spacelab et réalisera toutes les modifications nécessaires à son bon fonctionnement qui ne présentent pas un caractère critique sur le plan des délais, la NASA assumant pour sa part la responsabilité de toutes les modifications critiques à cet égard. Le contrôle de la configuration sera assuré, au niveau de la conception, par l'Europe et, au niveau de la construction, par la NASA, après livraison des éléments Spacelab. C'est la NASA qui financera les modifications résultant d'impératifs nouveaux qui seraient apportés à la conception de référence telle qu'elle a été définie en septembre 1979.

ISEE

La mission est entrée dans sa troisième année et, bien que la récupération des données ait légèrement baissé ces temps derniers pendant au moins 60% du temps, on dispose simultanément de données provenant des trois satellites. Tous les systèmes des satellites continuent de bien fonctionner et la quantité de gaz disponible pour les commandes d'orientation est suffisante pour encore plusieurs années d'opérations. Quelques défaillances ont affecté les expériences mais elles n'étaient pas de nature à s'opposer à la réalisation des objectifs fondamentaux de la mission et la NASA a l'intention de poursuivre les opérations jusqu'à la mise en route de son projet OPEN ('Origine des plasmas au voisinage de la Terre').

En ce qui concerne les principales expériences jumelées sur ISEE-1 et 2, la situation peut se résumer comme suit:

Etat de fonctionnement	ISEE-1	ISEE-2
Magnétomètre	bon	bon
Mesure des ondes plasmiques	bon	bon
Densité électronique	bon	bon
Plasma rapide, haute résolution temporelle	perte partielle	perte totale
Plasma rapide, haute résolution angulaire	bon	perte partielle
Particules moyenne énergie, haute résolution temporelle	perte partielle	bon
Particules moyenne énergie, haute résolution angulaire	perte totale	bon
Vent solaire	bon	bon

Les investigations les plus importantes continuent de fournir de bons résultats après quelque trois années dans l'espace.

IUE

Pour la troisième année d'exploitation, 269 scientifiques de différentes disciplines participent à titre d'observateurs hôtes à des programmes ESA approuvés. Pour les programmes du Science Research Council du Royaume-Uni, qui utilisent également la station ESA de Vilspa, le chiffre est de 115. Actuellement, les propositions pour la quatrième année affluent et on pense qu'elles seront en nombre sensiblement égal à celui de l'année dernière (170).

Signalons parmi les principaux faits récents:

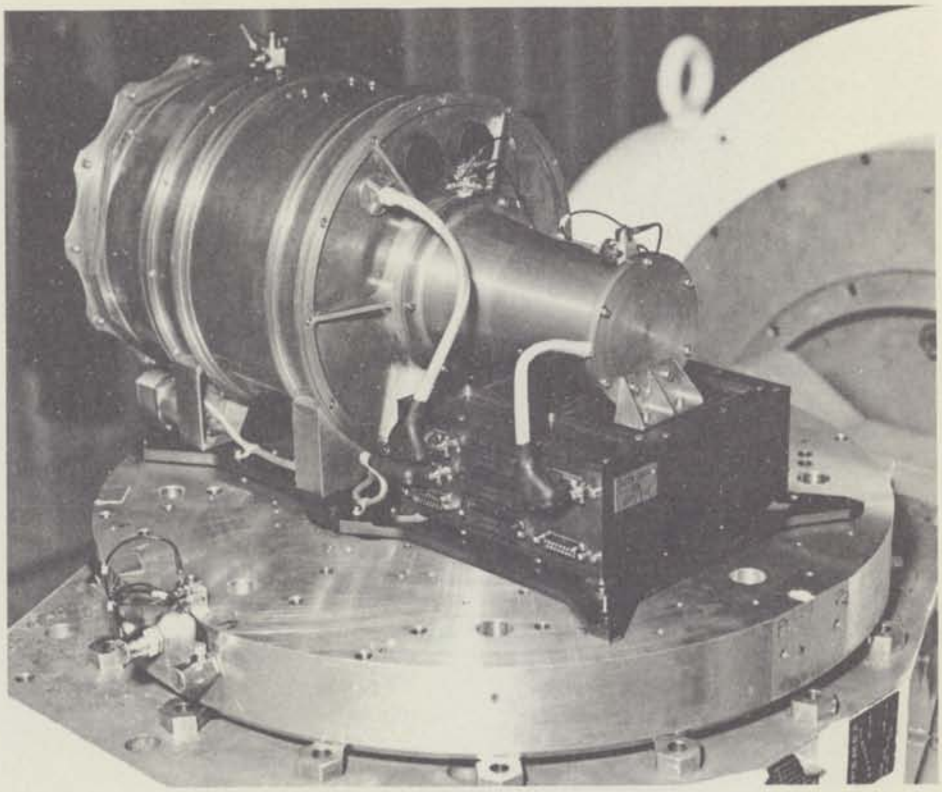
- *Une expérience pour la mesure des réflectivités des planètes supérieures Jupiter, Saturne et Uranus dans la raie Lyman alpha de l'hydrogène grâce à des observations effectuées avec des retards calculés de façon à compenser la durée du trajet de la lumière du Soleil à ces planètes et de là à la Terre et à éliminer toute incidence de la variabilité solaire. Il s'agit de mesures relevant de la*

Astronomy arranged by the Royal Society and the British National Committee on Space Research and held in London on 27–28 November 1980. One such result, presented for the first time, was a measured change in the relative strengths of the two pulses in the gamma-ray light curve of the Crab pulsar PSR0531+21 between observations in 1975 and in 1979. A new observation of this source was made in September 1980 to obtain additional information on this phenomenon. This followed an observation of a part of Gould's Belt that had not been previously investigated by Cos-B. A strong correlation has been found to exist between the distribution of the diffuse gamma radiation measured at galactic latitudes up to 20° and this belt of gas, dust and stars that surrounds the solar system at distances up to about 2000 light years.

Following the announcement of the discovery at the end of October of a supernova in the galaxy NGC6946, Cos-B was reoriented to bring that galaxy into its field of view. Data will need to be accumulated for several weeks before it is possible to say whether high-energy gamma rays are included in the radiations from this outburst, but even an upper limit on the gamma-ray flux will place a useful constraint on models of supernova development.

Since the low gas consumption of the attitude-control subsystem and the longevity of the solar cells and batteries have been established, it has become understood that the overriding technical constraint on continued operations of Cos-B is the availability of neon gas for the occasional replenishment of the experiment's spark chamber. There still remains sufficient gas for one more such operation, but the experimenters have no immediate plans for its use. Although the efficiency of the spark-chamber itself is now generally lower than at the beginning of the mission, it does not have a proportional impact on the overall efficiency of the experiment and has not changed significantly during most of the eight months that have elapsed since the spark chamber was last refilled.

The past successes of the mission and the technical feasibility of its continuation for at least another six months have prompted the Caravane Collaboration to remind ESA of the potential for new science that still exists and the Science Programme Committee has recommended the extension of operations beyond the end of 1980.



The Exosat payload's gas-scintillation proportional counter (GSPC)

Le compteur proportionnel à scintillation dans le gaz du satellite Exosat

Exosat

Satellite

Following completion of the thermal-vacuum tests on the engineering-model (EM) spacecraft, malfunctions have been investigated and in some cases units removed and returned to the manufacturer for more detailed testing.

Acoustic testing of the EM spacecraft proved to be satisfactory, with no major problems being reported. Following these tests the EM spacecraft was delivered to ESTEC and subjected to static and dynamic balancing in both air and vacuum. The conclusion reached following such tests is that the flight-model (FM) spacecraft will need to be balanced under vacuum conditions.

Deployment of antenna booms, various flaps, release of solar-array clamp and spacecraft separation tests using live pyros were, with two exceptions, successful. The failure of the Medium-Energy Experiment flap and one antenna boom to deploy is currently under investigation.

Preparations are currently being made for the final integrated system test (IST), in the first half of December, which should lead to a completion of the formal EM test programme by the end of the year.

Following repair of the test facility, vibration tests on the mechanical model (MM) were completed, demonstrating that the dynamic behaviour of the model was satisfactory.

The structure of the FM spacecraft is currently located at MSDS where the reaction-control equipment, propane and hydrazine, is being integrated. Delivery to MBB, the prime contractor, is expected to occur before the end of the year.

Late delivery to the prime contractor of other flight hardware, notably attitude and orbit control and data-handling subsystems and also payload units, is leading to an extremely tight assembly, integration and test (AIT) programme. Extra effort will clearly be necessary during the system-level test phase if a launch within the currently planned window at the end of 1981 is to be maintained.

chimie des atmosphères extérieures de ces planètes. On a constaté que la réflectivité d'Uranus est sensiblement supérieure à celle de Jupiter ou de Saturne.

- *On a soumis une série de galaxies spirales de différents types Hubble à une spectrophotométrie absolue en combinant les données provenant d'IUE à celles d'un petit télescope au sol équipé d'une 'réplique' de l'instrument à grande ouverture d'IUE et en effectuant des mesures à de plus grandes longueurs d'onde. Les résultats font apparaître des modifications dans les populations stellaires de noyaux galactiques avec un plus grand nombre d'étoiles chaudes dans les galaxies du type 'tardif' (spirale plus ouverte). Ceci semble indiquer que les observations de galaxies faibles seront dominées par la forte émission UV des galaxies spirales du type tardif.*

Des analyses récentes de la production électrique des panneaux solaires indiquent que, sauf défaillance catastrophique, le type actuel d'opérations pourrait, techniquement parlant, être poursuivi jusqu'en 1984 ou 1985. Il se pourrait même qu'à l'angle le plus favorable on puisse disposer encore d'énergie électrique jusqu'en 1989. On étudie actuellement des moyens de poursuivre les opérations sans batteries au cas où celles-ci cesseraient de fonctionner d'ici là. (Voir également la rubrique IUE, p. 72).

Geos-2

Les opérations du satellite se sont poursuivies 24 heures sur 24 jusqu'à sa mise hors circuit à la fin de juillet 1980. Le 1er août, Geos-2 est entré dans sa phase d'hibernation. Au début de la saison d'éclipses, vers la fin du mois d'août, on a découvert que la batterie embarquée, qui fournit l'énergie électrique pendant les éclipses, ne fonctionnait plus. Il en résultera une perte de données pendant toutes les périodes d'éclipses à venir, soit environ une heure sur 24 pendant une vingtaine de jours aux alentours de chaque équinoxe. La perte totale moyenne calculée sur un an est de l'ordre de 1% et est donc négligeable.

Lors d'une récente réunion entre les expérimentateurs de Geos et la communauté Eiscat, il a été décidé de remettre Geos-2 en activité le 1er février 1981.

Cos-B

Les résultats fournis par Cos-B ont été l'un des sujets principaux qui ont été discutés au cours d'une réunion organisée par la Royal Society et le Comité britannique de la recherche spatiale, sur l'astronomie du rayonnement gamma, qui s'est tenue à Londres les 27 et 28 novembre 1980. L'un de ces résultats, présentés pour la première fois, a été l'observation d'une modification notable de la puissance relative des deux impulsions de la courbe du rayonnement gamma du pulsar du Crabe PSR0531 + 21, entre les observations qui ont été faites en 1975 et en 1979. Une nouvelle observation de cette source a été effectuée en septembre 1980 pour obtenir des renseignements supplémentaires sur ce phénomène. Elle faisait suite à une observation de la ceinture de Gould qui n'avait pas été examinée précédemment par Cos-B. On a trouvé qu'il existait une corrélation étroite entre la distribution du rayonnement gamma diffus mesuré aux latitudes galactiques jusqu'à 20° et cette ceinture de gaz, poussières et étoiles qui entoure le système solaire à des distances allant jusqu'à environ 2000 années-lumière.

A la suite de l'annonce, à la fin d'octobre, de la découverte d'une supernova dans la galaxie NGC6946, Cos-B a été réorienté pour amener cette galaxie dans son champ de vision. Il faudra accumuler des données pendant plusieurs semaines avant qu'il soit possible de dire si des rayons gamma de haute énergie sont compris dans le rayonnement émis à la suite de cette explosion mais, même s'il y a une limite supérieure au flux de rayons gamma, celle-ci imposera une contrainte utile aux modèles de développement de supernova.

La faible consommation de gaz du sous-système de commande d'orientation et la longévité des photopiles et des batteries étant désormais établies, on sait maintenant que la contrainte technique déterminante pour la poursuite des opérations de Cos-B est la disponibilité de néon pour le remplissage occasionnel de la chambre à étincelles de l'expérience. Il reste encore suffisamment de gaz pour une opération de remplissage mais les expérimentateurs n'en prévoient pas l'utilisation dans l'immédiat. Bien que le rendement de la chambre à étincelles proprement dite soit dans l'ensemble plus faible maintenant qu'il ne l'était en début de mission, ce fait n'a pas une incidence directement proportionnelle sur le rendement global de l'expérience et il n'a pas varié sensiblement durant la majeure partie des six mois écoulés depuis le dernier remplissage de la chambre.

Les succès déjà enregistrés par la mission et le fait qu'il soit techniquement possible de la poursuivre pendant au moins six mois encore ont incité la Collaboration Caravane à rappeler à l'ESA le potentiel qu'elle représente encore pour l'obtention de nouveaux résultats scientifiques et à demander la poursuite des opérations après fin 1980.

Exosat

Satellite

Après l'achèvement des essais thermiques sous vide effectués sur le modèle d'identification du satellite, les défauts de fonctionnement ont été étudiés; dans certains cas, des équipements ont été démontés et renvoyés au fabricant en vue d'essais plus poussés.

Les essais acoustiques du modèle d'identification se sont révélés satisfaisants, aucun problème majeur n'ayant été signalé. A la suite de ces essais, le modèle d'identification a été livré à l'ESTEC et soumis à des essais d'équilibrage statique et dynamique dans l'atmosphère normale et dans le vide. Ceux-ci ont amené à la conclusion que le modèle d'identification aura besoin d'être équilibré dans les conditions du vide.

A deux exceptions près, les essais de déploiement des mâts d'antenne, d'ouverture des différents volets, de largage des sangles du réseau solaire et de séparation du satellite, essais effectués avec des dispositifs pyrotechniques actifs, ont été couronnés de succès. Les échecs, qui concernent le volet de l'expérience 'moyenne énergie' et un mât d'antenne, sont en cours d'investigation.

Les préparatifs de l'essai final du système intégré, prévu pour la première quinzaine de décembre, sont en cours; cet essai devrait conduire à l'achèvement du programme officiel d'essais du modèle d'identification pour la fin de l'année.

Payload
Failures that occurred on the gas-scintillation proportional counter (GSPC) and Low-Energy Experiments during thermal vacuum testing of the EM spacecraft have been identified and repairs effected where appropriate. A scientific model of the GSPC was recently flown on a sounding-rocket experiment in the USA and provided excellent results.

Manufacture of flight hardware is, in general, proceeding satisfactorily, with the first LEIT experiment fully integrated and passing its first functional test.

Two flight-model detectors for the Medium-Energy Experiment have also been delivered, but manufacture of the remaining detectors has been interrupted because of problems associated with the thin beryllium window.

Launcher
Discussions between the launcher authority and the Exosat project on the subject of compatibility tests, have led to an agreed time slot for implementing such tests and a draft procedure has been drawn up.

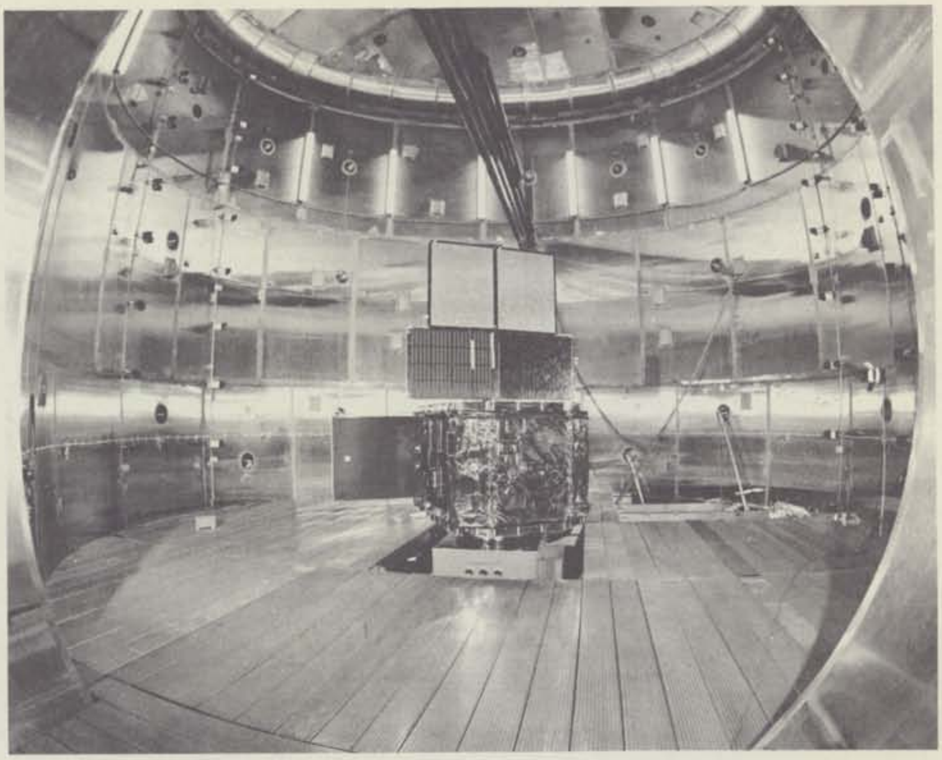
Repercussions from the Ariane L02 test-flight failure and subsequent failure investigations have led to the requirement for a new launch schedule for the remaining development flights.

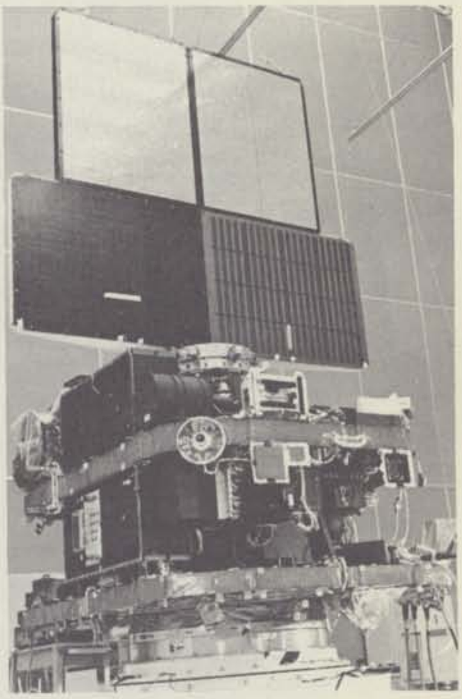
ESOC activities
Procurement of the Exosat ground-station equipment is critical, particularly for the ranging equipment, which is required in April 1981 for initial compatibility tests with the satellite. There is also concern about the marginal performance of the ground transmitter, which further emphasises the urgency of implementing compatibility tests as early as possible.

Progress on development of operational software is satisfactory and will be further supported by holding a number of workshop sessions with the project up to the end of 1980.

Ariane

APEX programme
In recent months the APEX programme – which allows payloads to be flown on the Ariane programme test flights – has passed two major milestones.





Exosat engineering model under test at ESTEC (above) and earlier (right) during integration at MBB (Ottobrunn)

Modèle d'identification d'Exosat en cours d'essais à l'ESTEC (en haut) et en cours d'intégration chez MBB, Ottobrunn (à droite)

After preparatory work in Europe had been completed without incident, the L02 composite payload was shipped to Guiana in early April for the final preparation of the launch. It consisted of the Ariane technological capsule (CAT), the scientific satellite Firewheel, and the radio-amateur satellite Amsat (Oscar-9). Despite the disappointment of the unsuccessful launch, the five-week payload preparation exercise nonetheless proved that the teams and facilities at the Guiana Space Centre serving the payloads enable a complex launch campaign to be satisfactorily carried out.

The second recent milestone was the final preparation in Europe of the Ariane L03 composite payload, consisting of the CAT, the Indian satellite Apple, and Meteosat-2, which is designed to take over from its predecessor Meteosat-1.

The Indian satellite Apple, which has been designed, built and integrated by the Indian Space Research Organisation (ISRO), is the precursor of the Indian communication satellites of the Insat family. Its mission, which is mainly technological, has the following objectives: to familiarise the Indian space agency with the construction of a three-axis stabilised satellite placed in geostationary orbit by an Indian-built apogee motor; to acquire experience with the subsystems constituting the L- and C-band telecommunications platform; to train its tracking network (ISTRAC) in tracking a satellite from its injection point into transfer orbit to its final station, and in subsequent stationkeeping; and to

Après réparation de l'installation d'essais, les essais en vibrations effectués sur le modèle mécanique ont pu être achevés; ils montrent que le comportement dynamique de ce modèle est satisfaisant.

La structure du modèle de vol, qui a subi chez MSDS l'intégration des circuits de propane et d'hydrazine de l'équipement de commande par réaction, a été livrée au contractant principal, MBB, à la fin de l'année.

Les retards survenus dans la livraison au contractant principal d'autres matériels de vol, notamment du sous-système de commande d'orientation et de correction d'orbite, du sous-système de traitement des données et aussi de certains éléments de la charge utile, rendent extrêmement serré le programme d'assemblage, d'intégration et d'essais. Des efforts supplémentaires devront manifestement être fournis au cours de la phase d'essais au niveau du système si l'on veut maintenir le lancement dans le créneau actuellement prévu pour la fin de l'année 1981.

Charge utile
Les défaillances qui se sont produites sur l'expérience 'compteur proportionnel à scintillation dans le gaz' (GSPC) et l'expérience 'faible énergie' pendant les essais thermiques sous vide du modèle d'identification ont été identifiées et les réparations nécessaires ont été effectuées. Un modèle scientifique du GSPC récemment embarqué dans une fusée-sonde pour un vol expérimental aux Etats-Unis a donné d'excellents résultats.

La fabrication des matériels de vol progresse en général de façon satisfaisante; la première expérience LEIT (Télescope imageur faible énergie) a été entièrement intégrée et a subi avec succès son premier essai fonctionnel.

Deux détecteurs 'modèle de vol' pour l'expérience 'moyenne énergie' ont également été livrés, mais la fabrication des détecteurs restants a été interrompue en raison de problèmes liés à la fenêtre mince en béryllium.

Lanceur
Les discussions entre l'autorité de lancement et les responsables du projet Exosat au sujet des essais de compatibilité ont abouti à la fixation d'un créneau pour l'exécution de ces essais, et un projet de procédure a été établi.

Les répercussions de l'échec du vol L02 et l'enquête à laquelle celui-ci a donné lieu ont rendu nécessaire l'établissement d'un nouveau calendrier de lancements pour les vols de développement restant à effectuer.

Activités ESOC
L'approvisionnement des équipements de la station sol Exosat présente un caractère critique, particulièrement en ce qui concerne l'équipement de télémétrie qui doit être disponible en avril 1981 pour les premiers essais de compatibilité avec le satellite. La performance marginale de l'émetteur au sol est également une source de préoccupation et fait ressortir la nécessité de procéder le plus tôt possible aux essais de compatibilité.

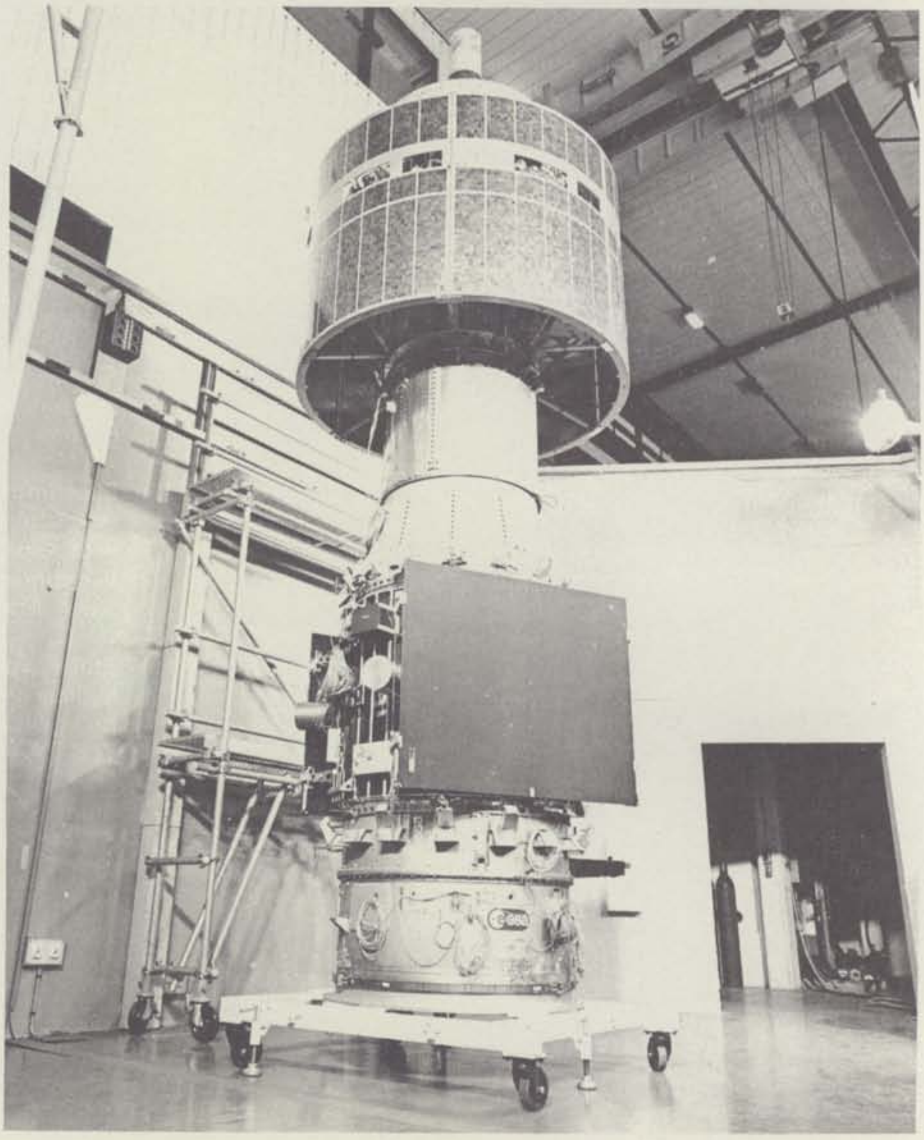
Le développement du logiciel opérationnel progresse de façon satisfaisante et bénéficiera du soutien d'un certain nombre de réunions de travail tenues avec les responsables du projet jusqu'à la fin de l'année.

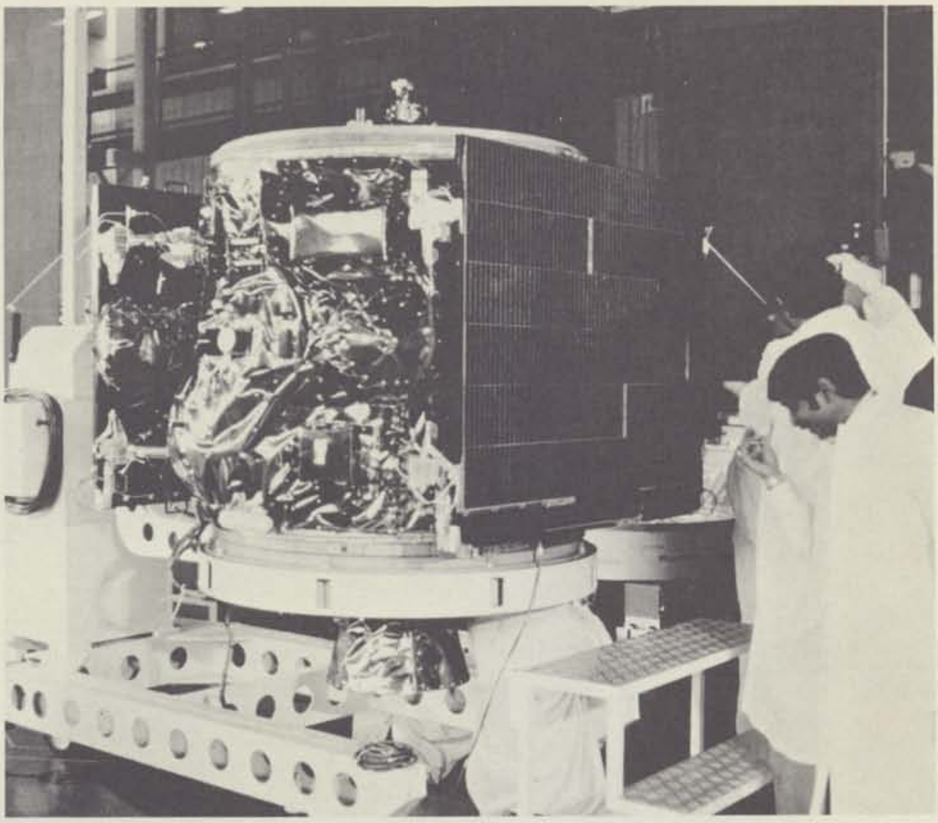
Ariane

Programme APEX
Au cours de ces derniers mois le programme APEX – qui doit permettre l'emport de charges utiles sur les vols d'essais d'Ariane – a franchi deux étapes importantes. Après une préparation menée sans surprise en Europe, le composite L02 était envoyé début avril en Guyane pour la préparation finale au lancement. La charge utile comprenait la capsule technologique Ariane (CAT), le satellite scientifique Firewheel et le satellite

Meteosat-2 + Apple + CAT composite to be launched on the third Ariane test flight (L03)

Composite Météosat-2 + Apple + CAT destiné à être lancé au tir de développement d'Ariane L03





The Indian satellite Apple to be launched together with Meteosat-2 on the third Ariane test flight (L03)

Le satellite indien Apple destiné à être lancé en tandem avec Météosat-2 à bord d'Ariane L03

familiarise personnel with satellite communications, local and long distance, and with the transmission, acquisition and processing of the data.

The L03 composite is a major European 'first' because of its weight (1635 kg) and dimensions (height of 6.525 m measured from the separation plane with the launch vehicle). The Meteosat and Apple satellites having separately and successfully completed their acceptance tests, the assembled flight model of the L03 composite successfully passed its acceptance tests in October and November. The flight-readiness reviews for the two satellites will take place successively in December and January.

In parallel with this work, the integration of the Ariane L04 composite payload, consisting of the CAT and the maritime communications satellite Marecs-A, has been proceeding satisfactorily and the qualification tests are scheduled for January at CNES's Toulouse space centre.

L-Sat

'Preliminary Phase-B2' of the L-Sat project-definition phase was completed in mid-November after finalisation of key system-level design trade-offs affecting both platform and payload. The competitions to choose the contractors responsible for platform subsystems were also conducted.

An industrial offer for main Phase-B2 was provided to the Agency in mid-October and negotiated to form the basis, together with the platform-subsystem-contractor recommendations, of a proposal to the Member States.

The Member States approved in principle the start of the main Phase-B2 at their Industrial Policy Committee meeting in mid-November, subject to satisfactory completion of some residual activities, the negotiation of which is expected to be concluded in time for the Phase-B2 contract to be released in December. Phase-B2 will cover the completion of the satellite definition, down to equipment level, including competitive selection of equipment suppliers by the subsystem contractors.

The Phase-C/D proposal is scheduled to be submitted by the prime contractor (British Aerospace) towards the end of Phase-B2 in April/May 1981.

ECS

Implementation of an improved Eurobeam antenna and the capability to operate nine channels in eclipse at end-of-life has been initiated with industry during the months of September and October.

In addition, proposals have been obtained and negotiated for enhancement of the ECS mission by the addition of a European Specialised Services (ESS) payload comprising two dedicated channels with capacity for high-speed data transmission between small earth terminals. This modification of the ECS baseline has been defined in response to a EUTELSAT requirement to look into the possibility of accommodating commercial communications services, such as transmission of voice, video and high-speed computer data between business and other organisations, within the ECS coverage. EUTELSAT is expected to reach a final decision on whether to go ahead with ESS before the end of the year.

The AEG-Telefunken repeater of the ECS-1 payload is being integrated at the company's plant at Backnang, Germany, with a view to completing subsystem testing during February.

The majority of the platform electrical system units are now being delivered to MATRA's integration facility at Toulouse, pending start of first flight-satellite assembly and integration scheduled for March 1981.

de Radio-amateurs Amsat (Oscar-9). Après une préparation de cinq semaines conduite selon le calendrier prévu, la charge utile était lancée sans succès, le 23 mai. Si décevant que soit l'événement, cet exercice a cependant permis de prouver que les équipes et moyens du CSG mis à la disposition des charges utiles permettaient d'effectuer une campagne de lancement dans de bonnes conditions.

Une autre étape qui a été franchie récemment était la préparation finale en Europe de la charge utile L03, composée de la CAT, du satellite indien Apple et du satellite Météosat-2 destiné à prendre la relève de son prédécesseur Météosat-1. Le satellite indien Apple, qui a été conçu, construit et intégré par l'Indian Space Research Organisation, est le précurseur des satellites de télécommunications indiens de la famille Insat. Sa mission, essentiellement technologique, couvre les objectifs suivants: familiariser l'Agence spatiale indienne avec la construction d'un satellite géostationnaire stabilisé trois axes et mis en orbite par un moteur d'apogée de fabrication nationale; acquérir l'expérience des sous-systèmes constituant la plate-forme de télécommunications en bandes L et C; préparer le réseau de poursuite indien (ISTRAC) à prendre en compte un satellite de son point d'injection en orbite de transfert jusqu'à sa mise à poste fixe et son maintien à ce poste; familiariser le personnel aux communications locales ou à longue distance par satellite et enfin, à la transmission, à l'acquisition et au traitement des données.

Le composite L03 constitue une grande première européenne par son poids (1635 kg) et ses dimensions (hauteur 6,525 m au plan de séparation avec le lanceur). Les satellites Météosat et Apple ayant subi séparément avec succès leurs essais de recette, le modèle de vol assemblé du composite L03 a également subi, avec les mêmes succès, les essais de recette au cours des mois d'octobre et novembre. Les examens d'aptitude au vol des deux satellites doivent avoir en décembre et janvier. Parallèlement à ces activités, l'intégration de la charge utile composite L04 comprenant la CAT et le satellite de télécommunications maritime Marecs-A s'est poursuivie de façon satisfaisante et les essais de qualification sont prévus au CNES (Centre Spatial de Toulouse) dans le courant du mois de janvier.

L-Sat

La phase B2 préliminaire de la phase de définition du projet s'est achevée à la mi-novembre, après la mise au point définitive des principaux compromis concernant la conception au niveau des systèmes et intéressant aussi bien la plate-forme que la charge utile. Les appels d'offres concurrentiels pour le choix des contractants chargés des sous-systèmes de la plate-forme ont également été organisés.

L'Agence a reçu à la mi-octobre, pour la phase B2 principale, une offre industrielle qui a fait l'objet de négociations et constitue, avec les recommandations relatives aux contractants des sous-systèmes de la plate-forme, la base d'une proposition soumise aux Etats membres.

Ces derniers ont approuvé en principe, lors de la réunion tenue à la mi-novembre par le Comité de la Politique industrielle, le démarrage de la phase B2 principale sous réserve de l'achèvement satisfaisant de certaines activités résiduelles en cours de négociation; celle-ci sera probablement terminée à temps pour permettre la passation en décembre du contrat relatif à la phase B2. Cette phase portera sur l'achèvement de la définition du satellite, jusqu'au niveau des équipements, et comprendra le choix des fournisseurs des équipements par les contractants des sous-systèmes, qui les sélectionneront après mise en concurrence.

Il est prévu que la proposition concernant la phase C/D sera soumise par le contractant principal (British Aerospace) vers la fin de la phase B2, en avril-mai 1981.

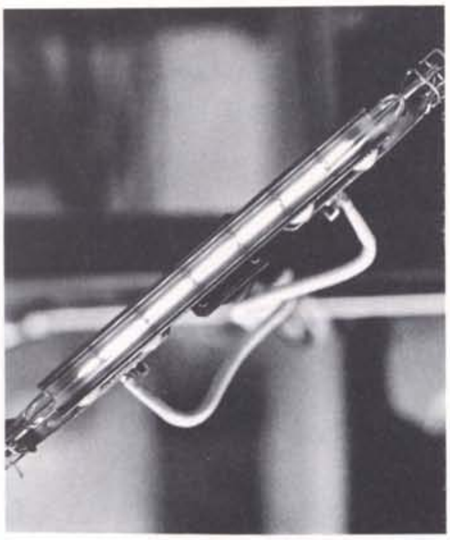
ECS

Au cours des mois de septembre et d'octobre, des dispositions ont été prises avec l'industrie en vue d'introduire une antenne Eurobeam améliorée et une capacité de fonctionnement en éclipse de neuf canaux en fin de vie.

Par ailleurs, l'Agence a reçu et négocié des propositions portant sur l'amélioration de la mission ECS par l'adjonction d'une charge utile de services européens spécialisés (ESS) comprenant deux canaux spécialisés permettant des transmissions de données à grande vitesse entre petites stations terriennes. Cette modification de la formule de référence d'ECS a été définie en réponse à une demande d'EUTELSAT visant à étudier la possibilité d'introduire, dans la zône de couverture d'ECS, des services de communications commerciaux tels que transmissions en phonie, en vidéo et transmissions de données d'ordinateurs à grande vitesse entre organismes commerciaux et autres. On pense qu'EUTELSAT prendra vraisemblablement d'ici la fin de l'année une décision définitive sur les services européens spécialisés.

Le répéteur de la charge utile d'ECS-1 construit par AEG-Telefunken, est en cours d'intégration dans l'usine de cette firme à Backnang (Allemagne) pour que les essais de sous-systèmes puissent être achevés en février.

La plupart des ensembles du système électrique de la plate-forme sont en cours de livraison chez MATRA à Toulouse, en attendant le démarrage des premières activités d'assemblage et d'intégration du modèle de vol du satellite prévu pour le mois de mars.



Development of Infrared Techniques for Testing Spacecraft

J.B. Walker, Test Services Division, ESA Technical Directorate, ESTEC, Noordwijk, Netherlands

As part of the qualification of a particular spacecraft type prior to launch, environmental testing is a prerequisite in the verification of the spacecraft's thermal design. The thermal-balance test has become the accepted tool for this purpose and in the late 1960s a number of European testing facilities were built. These facilities are still satisfying the testing requirements for medium-sized spacecraft today. A continuing programme of development and adaptation of the facilities ensures viable, correct testing of current spacecraft and also of the subsystems of larger applications spacecraft, such as those designed to exploit the full potential of the Ariane launcher. The thermal testing of these large spacecraft presents a problem, however, in that they are physically too large for the available European solar-simulator beam (Fig. 1).

Space/solar simulators

The present-day, classical solar-simulation facility used for thermal-balance testing may be considered to consist of three significant hardware items, with three separate functions:

- A basic vacuum-chamber shell, complete with pumping system for evacuation to reproduce the negligible-convection environment of space,
- A low-temperature, black absorbing inner wall which the spacecraft 'sees' and which simulates the energy loss by radiation in a space environment,
- A solar simulator, which reproduces the solar-energy input to a near-Earth spacecraft. To achieve its full potential, the solar simulator requires a sophisticated spacecraft orientation or motion system that allows the effect of variations in solar aspect angle on the spacecraft to be reproduced.

The solar simulator is a complex item requiring the generation of a pseudo-solar beam. With its sophisticated optical elements and well-controlled high electrical power, it requires a significant capital investment and has high operating costs. Such a facility with a 5.5 m diameter beam is estimated to cost 35 MAU*, and 450 kW of controlled electrical power would be required to drive the solar simulator alone.

When considering the testing of the larger Ariane-launched spacecraft, there are in existence in Europe facilities that can provide the first two functions of the above list, the basic vacuum chamber and the low-temperature wall. Only the USA, however, has facilities fitted with a sufficiently large solar-simulator beam (Fig. 2).

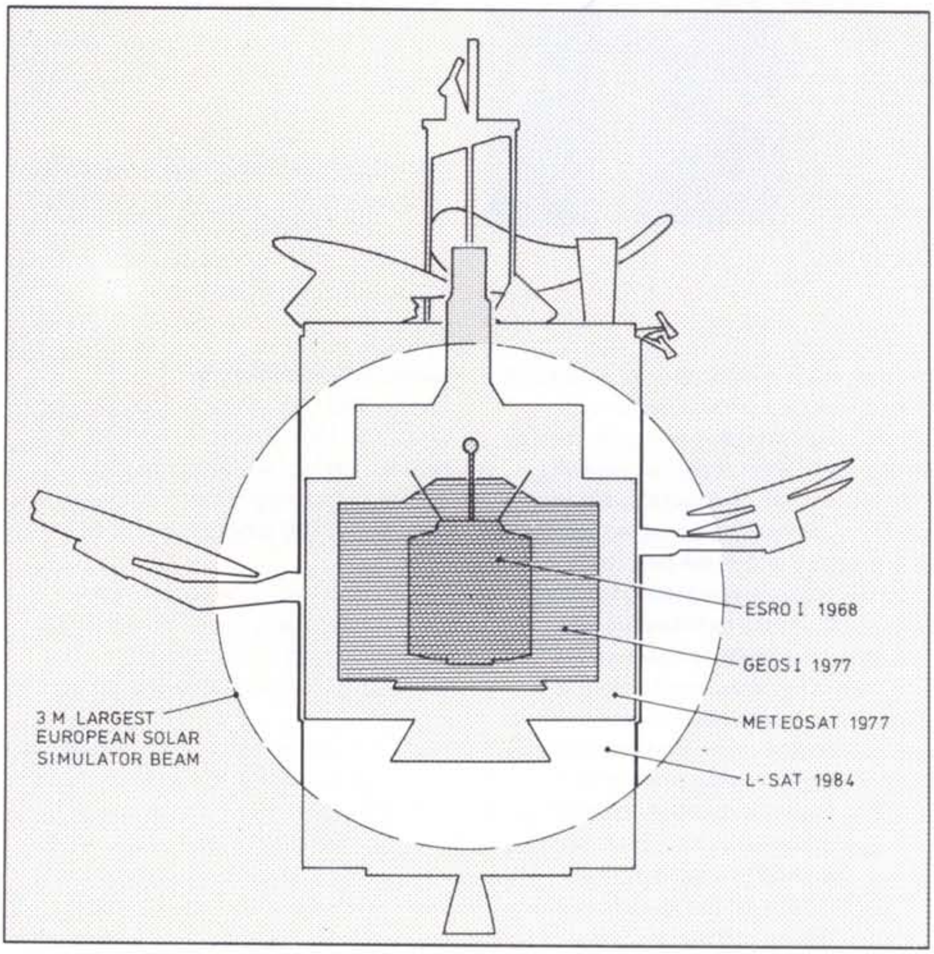
Why infrared?

From the foregoing it should have become apparent that means of reproducing the effect of the energy input from the Sun to the spacecraft on test other than the conventional solar simulator merit consideration, both from the point of view of containing capital expenditure and as a means of circumventing the logistic and scheduling problems associated with solar-simulation-testing a European spacecraft outside Europe. Moreover, a thermal-balance test is normally carried out only once on an early model of a spacecraft type in order to confirm and refine the thermal mathematical model. Thereafter, since the temperature excursions are known, the testing for acceptance of workmanship of flight models of the same type of spacecraft can be effected by reproducing suitable boundary conditions and temperature gradients.

This last goal can be achieved more economically than by using a conventional solar simulator, a fact that influences the choice of testing methods of many firms in the USA, where infrared techniques are extensively used. The provision of heat sources, i.e. IR sources, local to the spacecraft inside the vacuum chamber, offers a much more efficient approach in terms of the controlled electrical power required.

* 1 accounting unit (AU) ≃ 1,2 US $

Figure 1 – The increasing size of ESA spacecraft over the years



What are the infrared alternatives?
The well-established solar-simulation technique relies on a knowledge of the level and character of the flux radiated to the spacecraft surface. With this knowledge and knowledge of its counterpart in the orbital case, i.e. under real space conditions, it is possible to ensure that the design of the typical spacecraft thermal subsystem can be checked. Consideration of the absorptance characteristics of the spacecraft surface is necessary and allowance must be made for the difference in character between real solar radiation and the best solar beam that can be provided in a test facility. It may be concluded that the further away from the reproduction of true space conditions one strays, the lower the confidence level in the veracity of the test. Many solar simulators that have been built compare poorly with the Sun in, for example, intensity, homogeneity and wavelength. A balance is normally struck between accuracy of simulation and costs when procuring a solar simulator.

To be in a position to make a similar trade-off when considering infrared as a source, it is necessary to examine a number of possible methods in detail. The following is a list of techniques that have been used in spacecraft thermal-vacuum and thermal-balance testing.

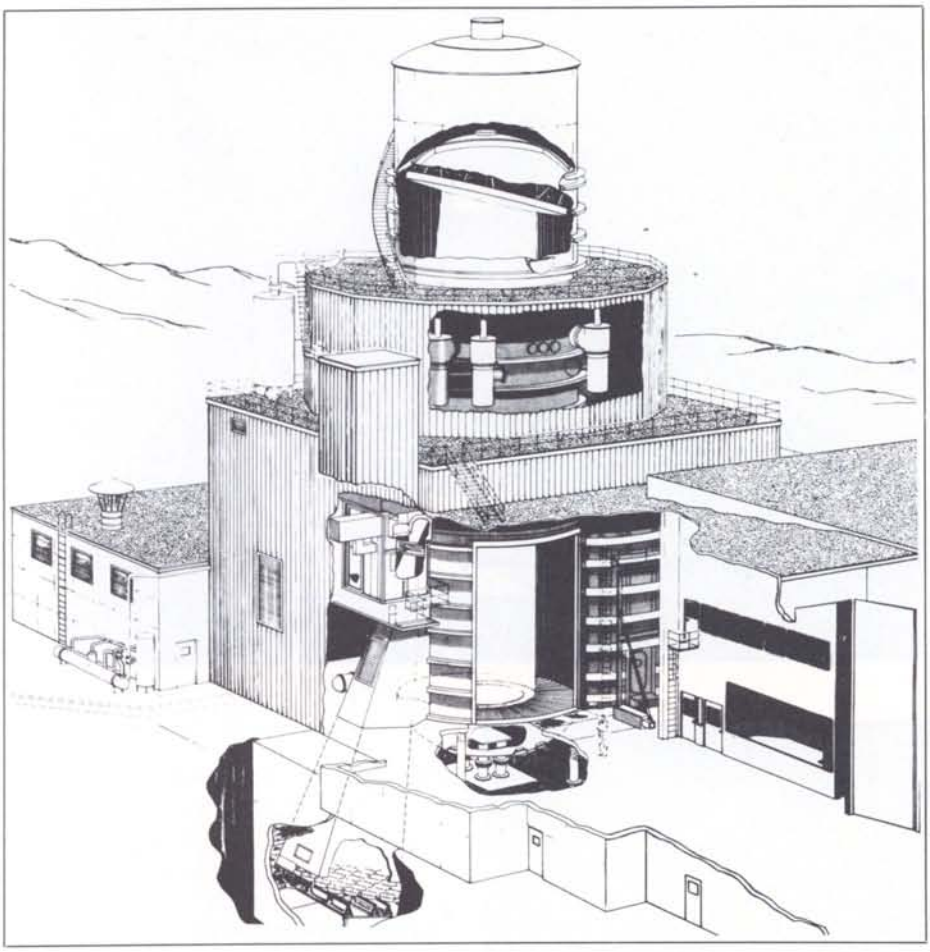
Skin heaters
In this method the absorbed incident flux is generated at the spacecraft surface by means of thin, sheet electrical heaters. The heater surface is finished with the appropriate spacecraft coating. Heaters are stripped off prior to flight or, under certain circumstances, are actually flown and are redundant in orbit. This technique is suitable for the simple insulated surface of say the main body of a spacecraft, but not for any heat-rejection or solar panels.

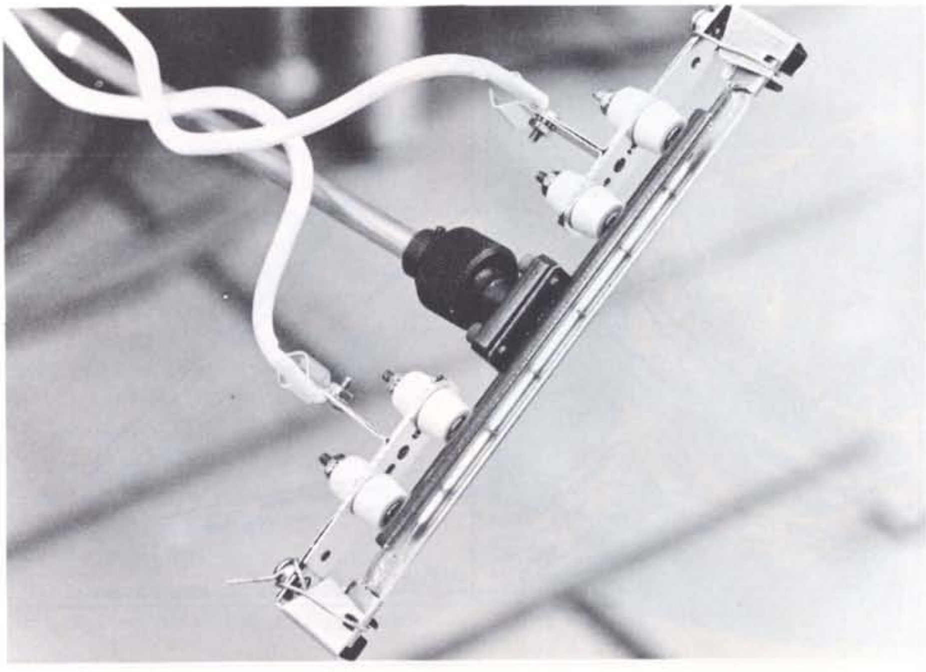
Plate heaters
The spacecraft thermal environment may be simulated by positioning a plate or local shroud adjacent to the surface and controlling the plate temperature by means of electrical heaters, such that the surface receives an energy input equivalent to that received from the Sun, less that normally emitted to cold space. Again, the technique is suitable in certain cases, but is less flexible than other methods. Where a spacecraft surface consists of areas of differing absorptivities and emissivities for example, quite small changes which may be made late in a spacecraft's design can have a strong impact on the test set-up.

Rod and wire heaters
The placing of electrically heated rods or wires arrayed around the spacecraft is an often used technique which is more flexible than the completely shrouded approach with plate heaters. Here the wires are not so significant in size as to affect importantly the heat loss of the spacecraft to its surroundings. The equivalent solar-energy input can be obtained by adjusting for differences in surface absorptance between solar radiation and the longer IR wavelength of the wire heater. An important feature of this technique is that the higher the temperature of the wire heater, the more efficient the method is as a heat-transfer source. This means in broad terms that, for a given energy input to the spacecraft surface, the higher the source temperature the less will be the interference or 'blockage' by the source of the energy radiated by the spacecraft to its surroundings. This advantageous state of affairs is, however, limited by the onset of sublimation of the heater-wire material in the vacuum environment at high

Figure 2 – The 5.6 m solar-beam space simulator at Jet Propulsion Laboratories, Pasadena (drawing courtesy of JPL)

Figure 3 – The tungsten-filament quartz lamp and reflector to be used as a source in spacecraft thermal-balance testing





temperatures, with the risk of spacecraft contamination. In practice wires are usually limited to 400°C.

Tungsten-filament quartz lamps

The enclosure of the heated wire by a sealed quartz tube overcomes the limitation imposed on the wire-heater approach (Fig. 3). Wire temperatures of 3000°C are now possible. The use of a small reflector which, by taking energy that is normally radiated away from the spacecraft and redirecting and distributing it in a beam of known characteristic, increases the efficiency of the method. The disadvantage accompanying this increase in efficiency is that the reflector quality and any physical changes under test conditions result in uncertainty regarding the intensity presented to the surface. The precise knowledge of the intensity distribution is a prerequisite of any thermal-balance testing technique which is to be used to verify spacecraft surface temperatures. For this reason a programme of work has been carried out with the aim of establishing the characteristic intensity distribution of the reflector–lamp assembly.

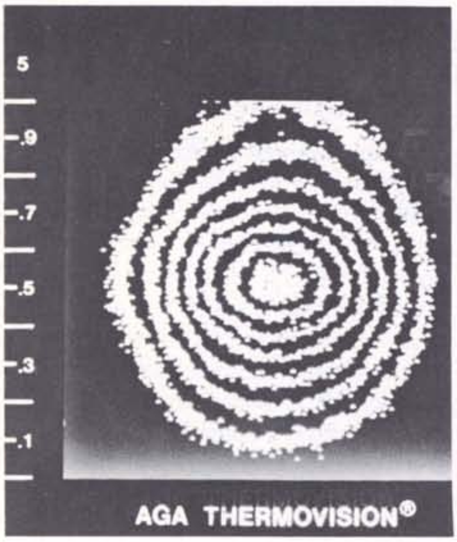
Preliminary work to determine lamp characteristic intensity distributions was carried out in ESTEC's thermal control laboratory. Isotherms generated in a thin sheet irradiated by a lamp were photographed using an infrared camera (Fig. 4). The use of this technique minimised the more expensive vacuum-environment test work which was required in order to avoid the results being disturbed by convection currents.

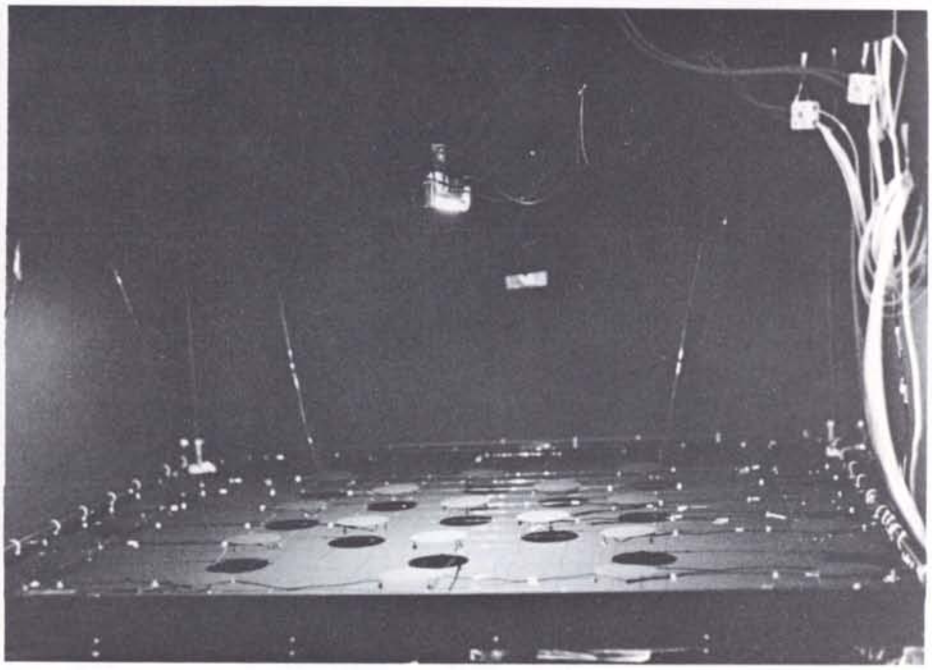
Figure 5 shows the set-up for the vacuum environment tests. This consisted of an array of disc sensors receiving radiation from a lamp and surrounded by a liquid-nitrogen-cooled, absorbing, cubical shroud. The whole assembly was placed within a vacuum chamber. Many tests were carried out with different lamps and reflectors until sufficient information had been gathered to produce a family of

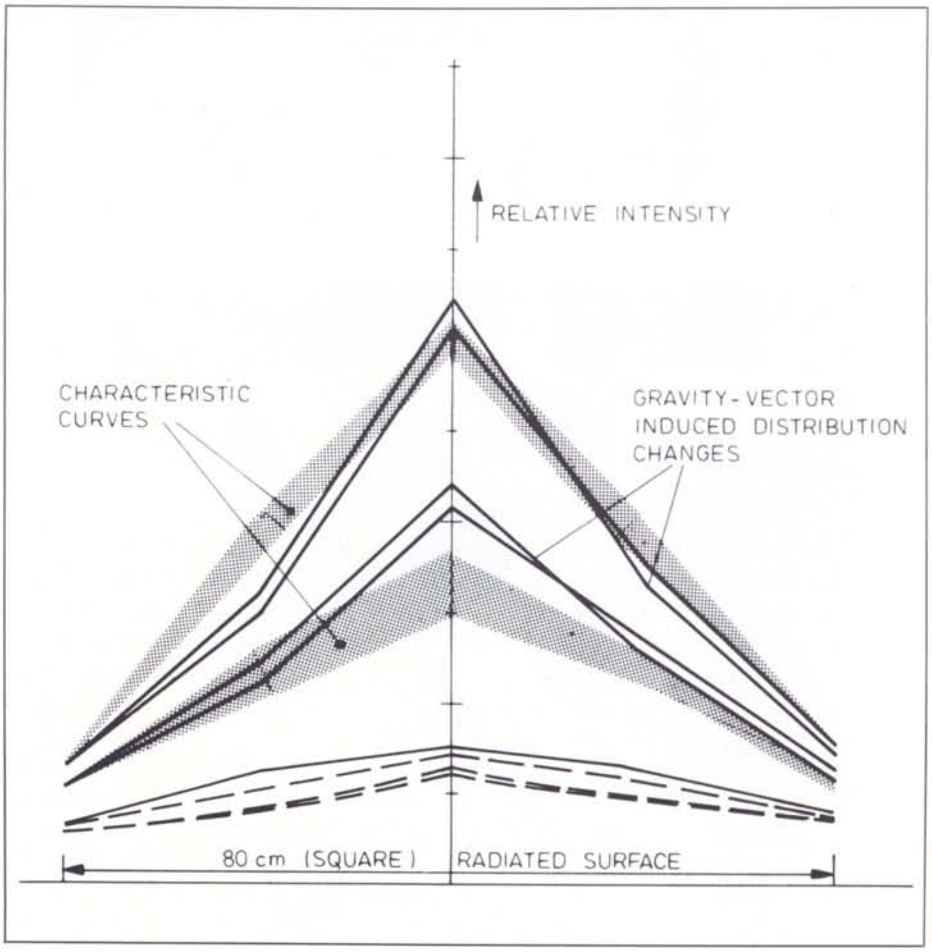
Figure 4 – Isotherms generated in a thin sheet irradiated by a lamp, photographed using an infrared camera, indicate the distribution of intensity

Figure 5 – Vacuum environment tests to determine the characteristic intensity distribution from the lamp–reflector assembly

Figure 6 – Results of the infrared lamp – reflector tests reveal variations from the characteristic intensity distribution due to manufacturing differences and gravity-vector effects upon the 3000°C tungsten filament







curves and to establish a characteristic curve with known variations. By changing the orientation of the lamp assembly, the effects of gravity on the delicate tungsten filament at high temperatures could also be observed (Fig. 6).

Armed with the characteristic distribution of the lamp, it should be possible, by developing computer software, to determine the intensity distribution on a complex spacecraft geometry from arrays of lamps quickly and economically. Optimum lamp arrangements with known intensity distributions could then be produced with minimal changes in the actual physical test set-up. This work, carried out at Liège University, has shown that although this approach is a useful aid when setting up lamp arrays, it has certain limitations. Prior to use on a real spacecraft final adjustments to the lamp arrays and intensity-distribution measurements have to be made using a spacecraft mock-up with the same external geometry as the flight spacecraft.

The successful thermal-balance testing of any particular spacecraft using the IR approach is heavily dependent upon the selection of the correct technique or combination of techniques from those presented above. This selection process must be applied early in the spacecraft

Figure 7 – Accurate power control to the heaters is provided by a DC 18-channel unit commanded by a desk-top calculator

Figure 8 – An infrared lamp array used during model tests in ESTEC's heat-balance facility (HBF3)

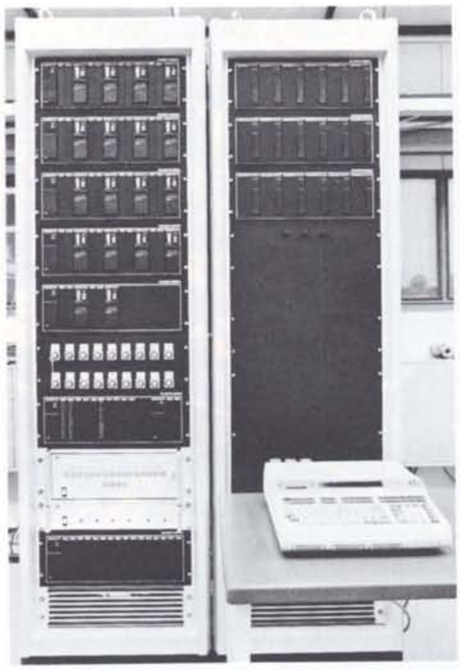
design programme and calls for close cooperation between the thermal analyst and the thermal tester.

Instrumentation and power control
In parallel with the work on sources, two other avenues have been pursued.

Flux measurements
Flux measurements are made in order to determine the energy radiated to the spacecraft on test. The accuracy of this measurement is a key factor in the overall accuracy of the testing method. Since the IR approach, by definition, uses a longer wavelength source, flux measurement requires suitable sensors. ESTEC is currently pursuing a procurement and development programme for such sensors, which will be used in three ways:

- to obtain the intensity distribution over the irradiated spacecraft surface in air
- to monitor the energy delivered by the array of lamps at the spacecraft surface inside the vacuum chamber
- as a sensor allowing the closing of the control loop in terms of energy presented at the spacecraft surface.

Power control
Accurate control of the electrical power dissipated at the source supplying energy to the spacecraft on test is mandatory. Moreover this energy has to be presented in such a way as to minimise disturbance of the spacecraft's, often highly sensitive, internal electronics. For this reason DC power supplies with outputs capable of smoothly controlled demand changes have been procured (Fig. 7). An 18-channel system is presently available and each channel is capable of supplying 8.5 A at 120 V DC. The system is commanded from a desk calculator where power demands are translated to voltage controls at each of the sources. The desk calculator provides a voltage, current and power monitoring function and also an alarm capability in the event of a channel power exceeding defined limits.



Model tests
To study the problems of full-scale testing using IR techniques, a test was made on a simple black-plate model of a spacecraft (this work was a cooperative effort by ESTEC's Thermal Analysis and Thermal Test Groups). This model was manufactured during ESTEC's early solar-simulation development work and consists of black-painted, thin copper sheets of various geometric shapes with low-conduction connections. Minor refurbishing, including the addition of some thermocouples in order to gather temperature information from 150 points, was carried out. Supporting analysis work produced a mathematical model. Two solar-aspect-angle cases were investigated, first using solar simulation and then the IR lamp-array approach.

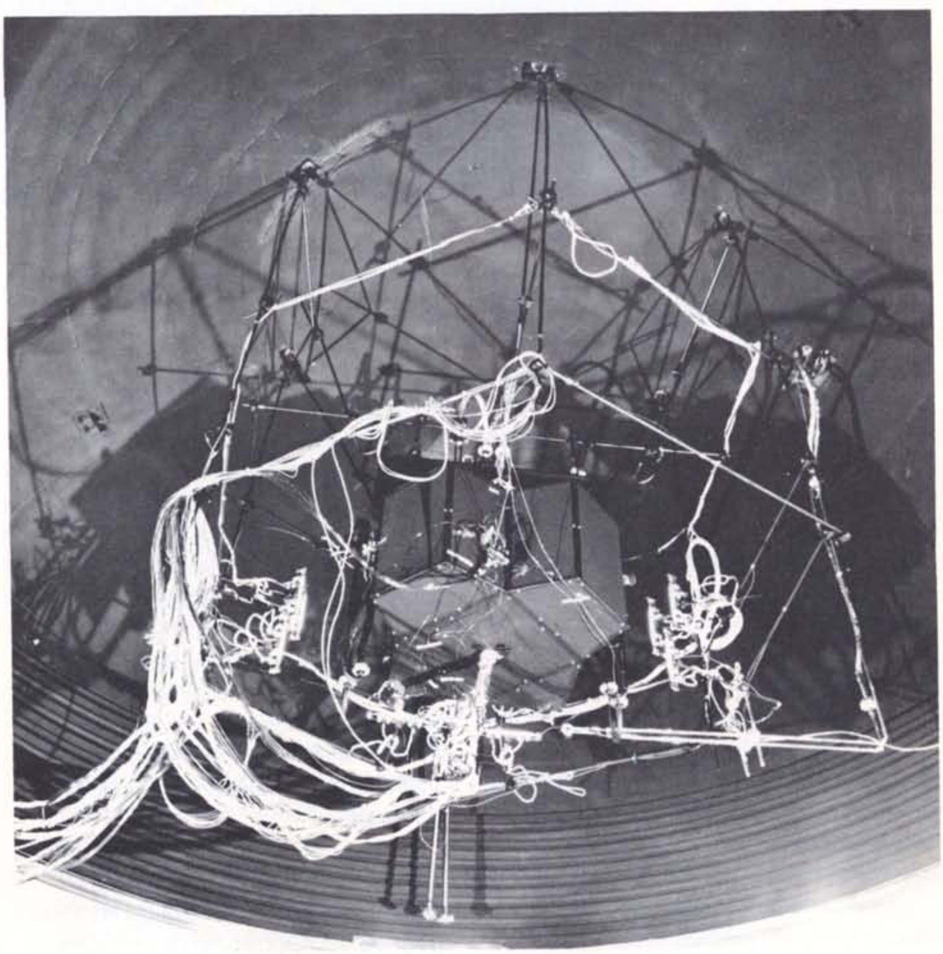
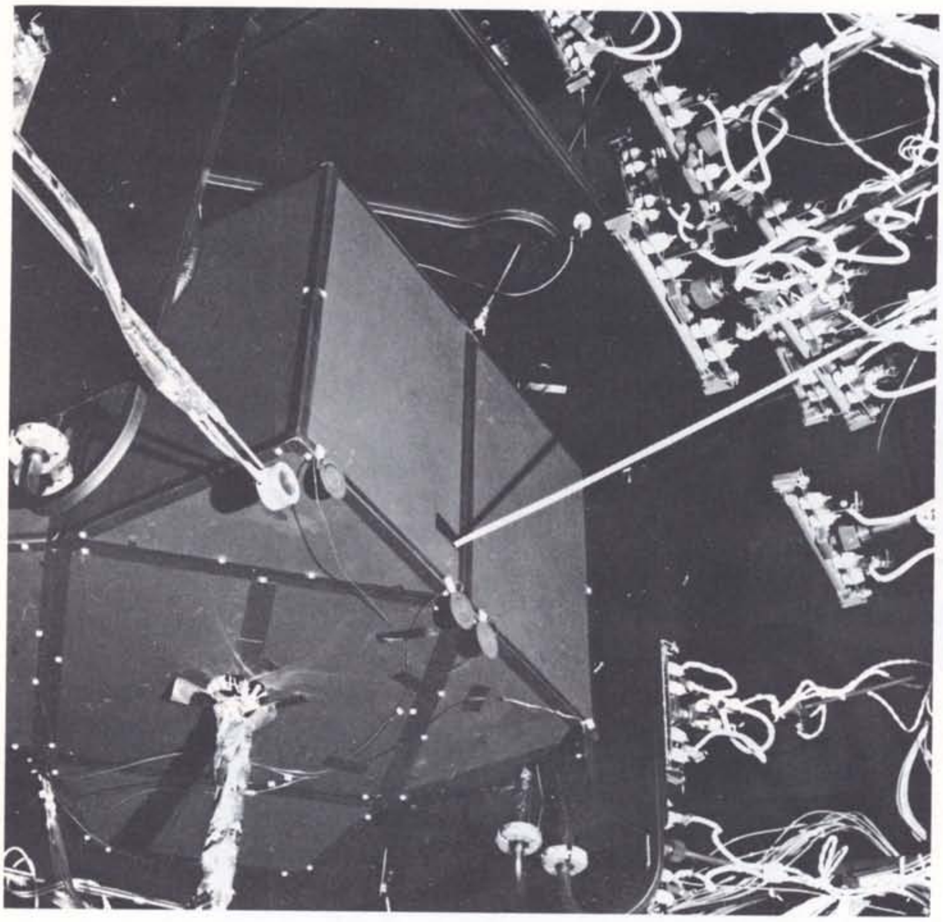


Figure 9 – Detail of a lamp array used in reproducing a further solar-aspect-angle case in a model test



The object of the tests was to compare the two different test approaches with the in-orbit case. Figures for the degree of prediction uncertainty could be obtained and possible areas where development work could be expected to improve the IR approach were identified. The tests were conducted in the HBF3 heat-balance facility at ESTEC (Fig. 8). Figures 8 and 9 show the lamp arrays used to reproduce the two solar-aspect-angle cases studied.

Present situation

Analysis of the test data obtained from the model tests is still in progress at the time of writing. Explanations for differences between the two testing methods are being sought and comparisons with the thermal mathematical model are being made. An overall figure of accuracy for the IR simulation method used on this simple spacecraft model is being determined.

Tests on a more complex spacecraft model are in the planning stage. This model should have surface characteristics typical of today's spacecraft, representative internal conduction paths, and some internal heat dissipation. The provision of representative spacecraft surface characteristics is a particularly important feature. Information regarding absorptivity in the IR is not as readily available as that for the Sun's and solar-simulator radiation and a procurement programme for IR absorptivity measuring equipment is underway.

Power-control equipment is currently being procured which will allow 80, 1 kW channels of DC power to be controlled. This equipment will be a thermal vacuum testing facility, but its design will be the same as the 18-channel prototype and it will therefore be suitable for thermal-balance testing also. The individual channel outputs can be either manually or computer controlled. Extensive software and some computer hardware is being procured which will allow control, monitoring, and the simplification of calibration procedures.

The Dynamic Test Chamber (DTC)

In parallel with the work of providing an IR-source simulation facility, work is proceeding on the provision of liquid-nitrogen-cooled shrouds in ESTEC's largest vacuum facility, the DTC. This is a 10 m diameter, 15 m high chamber used for mechanical test work and, more recently, thermal vacuum testing. The new shrouds are modular in design to ensure the necessary flexibility for optimum economy in testing. The provision of liquid-nitrogen shrouds and the IR facility will significantly upgrade the DTC, making possible the thermal vacuum testing of large spacecraft. This upgrading is planned for completion by the end of 1981.

It is expected that the evaluation work being carried out on the infrared method of testing will allow further upgrading of the facility with a view to achieving the most economic thermal-balance testing of ESA's future large spacecraft.

Acknowledgement

The programme described in this article involves the cooperation and support of a number of ESTEC Divisions. This cooperation is gratefully acknowledged together with that of collaborators from the following organisations who have provided inputs as a result of study contracts: Dornier System (A. Braig); Institute d'Astrophysique, Liège University (A. Cucchiaro); and ERNO Raumfahrttechnik (B. Schwarz).

Satellite Power Systems under Consideration by the United Nations*

D. Kassing, Systems Engineering Department, ESA Technical Directorate, ESTEC, Noordwijk, Netherlands

The eleventh World Energy Conference in Munich last September reconfirmed that there are a very limited number of options that could make substantial contributions towards meeting our electrical energy needs in the long term. Two of them are fast-breeder and thermal-fusion reactors. A third option could be the Satellite Power System (SPS) now under study.

The SPS assessment activities conducted so far in the United States and, on a smaller scale, in Europe, have shown that the SPS could generate electrical energy on a large scale. There are, however, a number of technical, environmental and socio-economic uncertainties that require further study before any decision regarding SPS implementation can be envisaged in the late 1980s or early 1990s. A number of the issues associated with the SPS that require international cooperation are already being addressed by committees and specialised agencies within the United Nations, and ESA has been invited to assist in the assessment.

Since the 1973 Arab oil embargo and the subsequent more than tenfold increase in international crude-oil prices, no issue has generated more sustained discussion, debate, and controversy than energy. Indeed, many people have come to view the energy issue as a crisis that is going to affect their economic, social, political, institutional, and environmental well-being for a long time to come.

International in scope, the crisis cuts across national and regional boundaries, political philosophies, and economic persuasions. The present energy situation in the world, the most likely trends in energy demand, the transition to new sources, and also policy decisions that have to be taken jointly to overcome the more serious problems, were traced out and discussed by delegations from more than 80 countries at the 11th World Energy Conference held in Munich last September.

The delegations consented to a number of conclusions, the more important of which, as far as the future of space-based energy systems are concerned can be summarised as follows:

- energy demand will continue to grow to a significant extent, particularly in developing countries (Fig. 1);
- to meet this demand, it will be necessary to maximise the contribution of all present and future energy sources, while at the same time taking advantage of every opportunity to save energy;
- in view of the anticipated long-term decline in the share of oil and gas, with new energy sources assuming increased significance only in the more distant future, most of the growing demand in the industrialised countries in the foreseeable future (up to the year 2000) can only be covered by coal and nuclear energy;
- in view of the long lead time required to develop and implement new energy sources (typically two to four decades), it is imperative to take all the necessary measures well in advance;
- for such measures to be taken without delay and successfully implemented by the industrial community in the energy sector, a political framework that can be trusted in the long term will be absolutely essential.

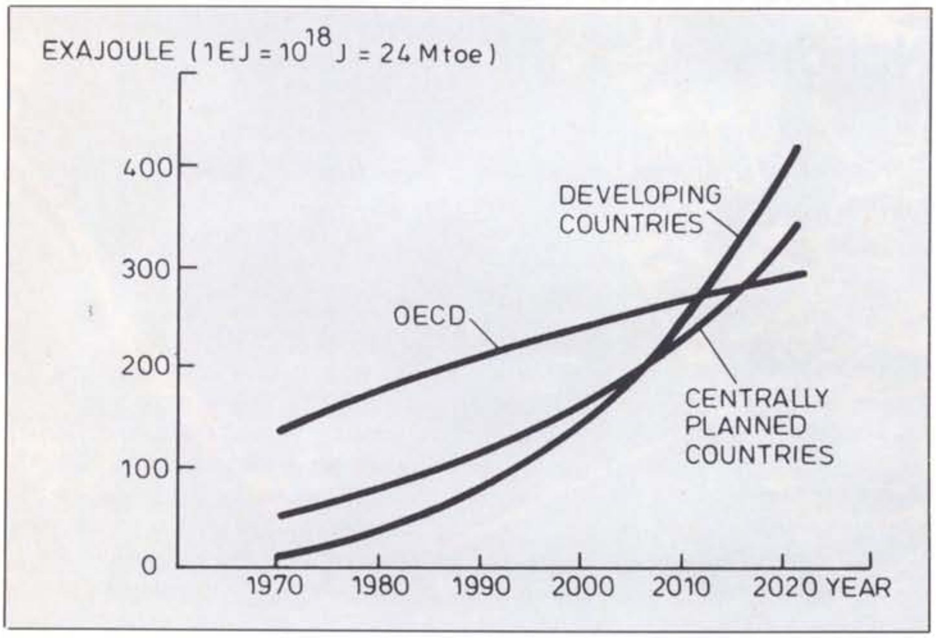
What does this mean for Europe's long-term energy future? For the next 10 to 30 yr it is expected that the greatly expanded and combined use of nuclear energy and coal could ease the situation in the industrialised countries and move Europe away from its present heavy reliance upon imported oil and gas. To overcome the dependence on uranium and coal, which are also scarce in Europe, and to transit smoothly into the so-called 'post-oil society', will require the development and commercialisation of new energy sources and related technologies.

Space energy systems – an alternative energy option

The Satellite Power System (SPS) concept promises to provide a new and inexhaustible energy source. As currently conceived, it consists of a number of large

* The author has participated in a number of the relevant UN meetings and this article recounts the present deliberations by the various bodies of the UN on the SPS concept. It is intended to be a supplement to the two articles contained in ESA Bulletin No. 21, February 1980 (pp 8–21).

Figure 1 – Energy-demand projections prepared by the Conservation Committee for the World Energy Conference



satellites sited in outer space to collect and convert the almost continuously available solar energy into microwaves for transmission to receiving antennas on Earth (Fig. 2), which in turn convert the microwaves into electrical energy, as in a base-load power plant (as discussed in ESA Bulletin No. 21).

There are only two other new concepts in sight at present that have the potential to produce larger quantities of electricity (i.e. 20% or more of the electricity demand in the industrialised countries of Europe) in the very long term, and whose operation does not depend on exhaustible fossil resources or minerals, on imports of which the European countries are presently so seriously dependent. These two concepts are the fast-breeder reactor and the thermonuclear-fusion reactor. The former is facing a number of environmental and political concerns, whereas the latter has still to demonstrate its scientific feasibility, as was reported at the World Energy Conference.

The concerns associated with the SPS are different from, though little smaller than, those facing nuclear breeder and fusion reactors. However, the studies conducted to date – mostly in the United States under the direction of the Department of Energy and NASA – have not identified any insurmountable obstacles as far as the technical feasibility, economic practicality, and social and environmental acceptability of the SPS concept are concerned, although large uncertainties do still exist, all of which require careful investigation in the years ahead.

Meanwhile, a number of United Nations committees and specialised agencies have started to look at the potential benefits and problems associated with the SPS concept, and this it is hoped will lead to international agreement and cooperation in the future. Some of the more significant areas of investigation touched upon in this article are:

- the potential contribution of the SPS as an alternative to supply electrical energy to the utility grids of the UN's member states in the long term, both industrialised and developing countries;
- the availability of the geostationary orbit, which is the most convenient site from which to transmit the collected and converted solar energy to Earth;
- allocation of microwave frequencies for purposes of power transmission, with a view to optimising efficiency in the use of the electromagnetic spectrum and minimising harmful interference;
- definition and adoption of internationally acceptable occupational and public standards for permissible exposure to microwaves.

Space energy systems discussed within the United Nations

At its 33rd General Assembly in 1978, the United Nations decided to convene, under its own auspices, an International Conference in 1981 on new and renewable sources of energy. In this, the General Assembly followed the recommendation of the Economic and Social Council of the UN, which recognised the importance of developing these energy sources in order to meet requirements for continued economic and social development, particularly in the developing countries, which depend so heavily on an increase in industrial capacity.

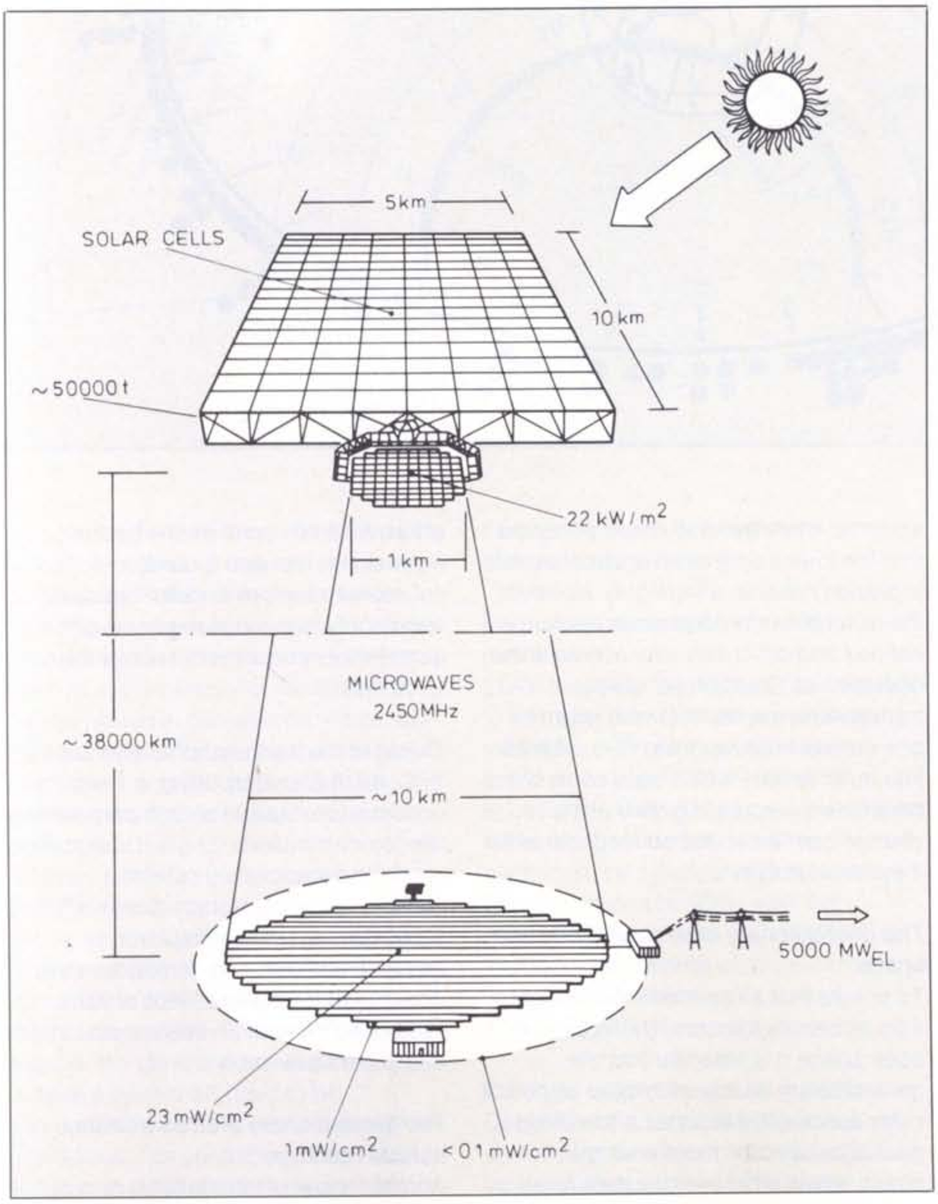
The Conference should help to elaborate measures for concerted action designed to promote the development and utilisation of the various new and renewable sources of energy, including solar energy (terrestrial and space-based), geothermal and wind power, tidal power, wave power, thermal gradients in the sea, biomass conversion, fuel-wood, charcoal, peat energy from draught animals, oil shale, tar sands and hydro power.

Growing interest in the Conference is apparent in many countries; the work of the preparatory committee is now being supported by more than 70 countries (including ESA Member States), and a number of technical panels and groups of experts are evaluating the technical, environmental, economic and social aspects of all the energy options that have been identified.

Figure 2 – The concept of the Satellite Power System (SPS)

At the invitation of the Secretary General of the Conference, ESA is participating in the preparatory effort. Based on its considerable experience in the design and development of photovoltaic solar arrays, power-conditioning electronics, batteries and other high-technology items for a broad range of space applications, and its broad understanding of the full range of subjects involved in the SPS assessment, the Agency has been able to provide worthwhile contributions to the preparatory committee. The reports of this committee will serve, inter alia, as a technical basis for the comparative assessment of the various energy sources at the Conference, which will be held in Nairobi in August this year.

In parallel, the UN Economic Commission for Europe (ECE) (which covers not only European countries, but also the United States, Canada and the USSR), is holding seminars on technologies related to new energy sources. In a comparative economic assessment of decentralised and centralised solar energy conversion technologies, prepared for an ECE seminar in 1980, the attraction of the satellite in geostationary orbit concept was seen to lie in the fact that the solar energy harnessed is available independently of the day/night cycle and of weather perturbations.



Space energy and UNCOPUOS
Although the scenario for constructing large power satellites stretches far into the future, several associated and complex international problems already call for attention.

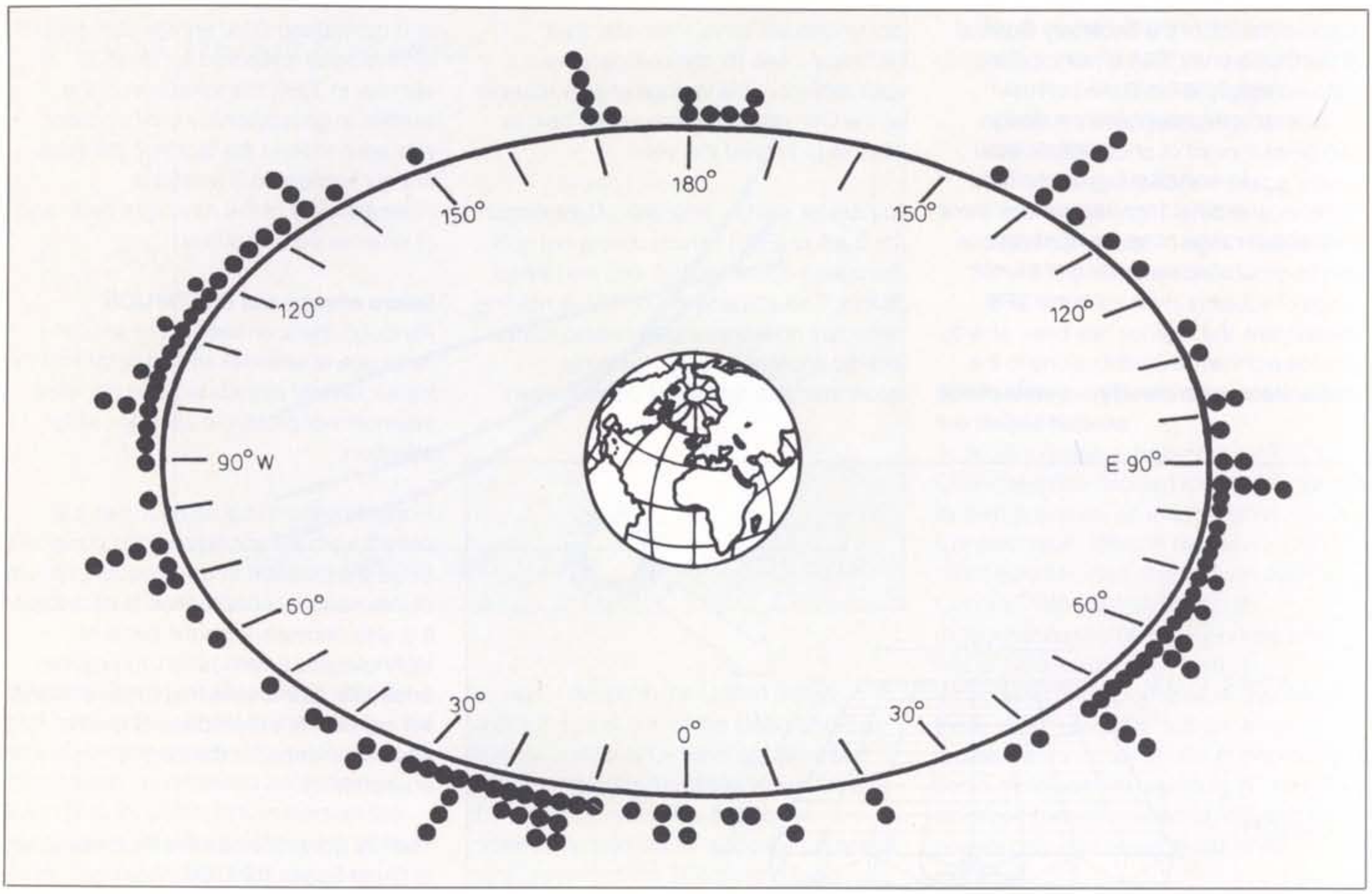
Firstly, to ensure that all countries can benefit from the access to solar power via SPSs, the creation of an adequate system of international cooperation is necessary. It is also necessary, on the basis of technological investigation, to provide adequate guarantees that these activities will not pollute outer space or create adverse changes in the Earth's environment.

The UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) has addressed these problems at its 19th Session and the UN Secretary General has requested information from nations and international organisations as to their plans and appropriate recommendations.

In a response to the UNCOPUOS background report ('Solar Power Stations in Space') in 1976, ESA described its activities in the various technical fields in which it was active and affirmed its willingness to share its accumulated experience to the benefit of the United Nations. The Agency also suggested means for possible cooperation with other organisations.

The applicability of the Outer Space Treaty to SPS
Activities conducted in the domain of space-based energy systems, like any activities in outer space, are bound by both international and outer-space laws, and in particular by the principles

Figure 3 – An approximate distribution diagram for satellites in geostationary orbit – both those already launched and those planned



contained in the Outer Space Treaty of 1976 and the Charter of the United Nations.

The Treaty defines general guidelines for activities in outer space, to ensure its peaceful use for the benefit of all mankind, without discrimination or national appropriation, and to prohibit harmful contamination and also adverse changes in the Earth's environment. Although the Treaty is drafted in a very general, largely uncontroversial manner, there is still controversy regarding the interpretation of certain terms used.

Some of the problems in the interpretation of the Treaty, which are relevant to the SPS project, are discussed below.

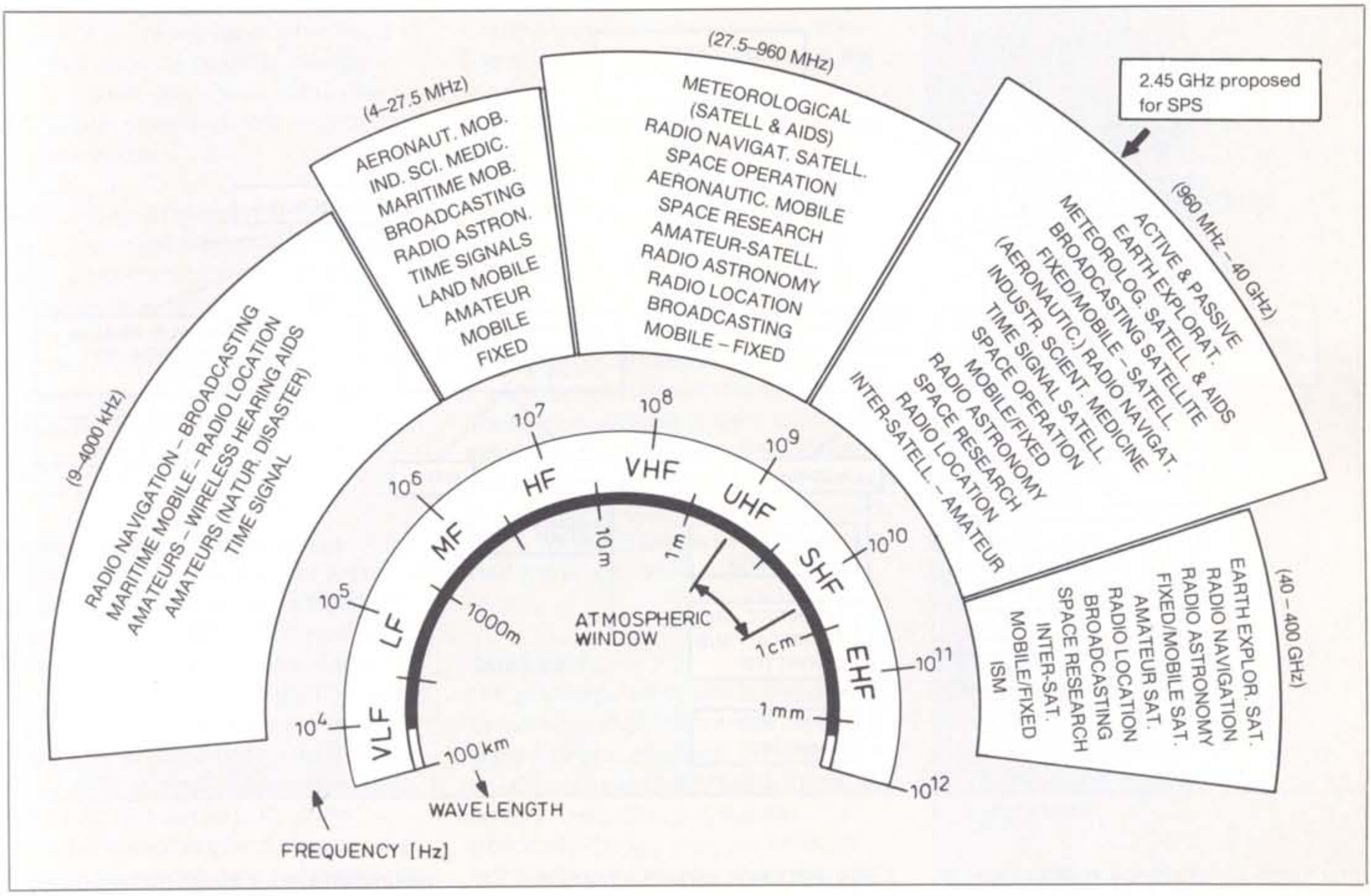
Definition of outer space
From the commencement of space activities, it has generally been accepted that the lowest orbit of an artificial satellite is outside national sovereignty. However, the exact boundary has never been defined and difficulties may arise with the operation of 'Shuttle-type' space transportation systems (which might be one means of transporting SPS material into outer space), which have some of the attributes of aircraft, e.g. their ability to change path within the atmosphere when they return to Earth.

The geostationary orbit as part of outer space
To ensure that all countries can benefit from access to solar energy via SPSs in outer space, it is essential that the geostationary orbit be accepted as part of outer space. (The fact that a satellite in geostationary orbit has the unique characteristic of appearing stationary above a certain point on the Earth's equator has induced a number of equatorial countries to claim national sovereignty over those segments of the geostationary orbit that lie above their territories).

Owing to the particular characteristics of this orbit, it is already being and will continue to be used for such purposes as telecommunications (of great importance for direct broadcasting satellites), remote sensing, and meteorology. Some SPS subsystem-technology exploratory research activities and demonstrations anticipated for the late 1980s or early 1990s also depend on free access to parts of this particular orbit.

The geostationary orbit as a limited natural resource
Another issue for international negotiation

Figure 4 – Primary services for region 1 (Europe/Africa) and the position of the frequency band suggested for SPS use in the radio-spectrum



and of extreme importance for SPSs is the utilisation of (limited) natural resources in outer space. Satellites in geostationary orbit require a certain separation in order to avoid harmful interference. Opinions differ as to the number of satellites that can be placed in geostationary orbit, but the possibility of saturating the orbit is not questioned, and it must therefore be considered a limited natural resource of outer space.

There are presently about 90 geostationary satellites either in operation or planned (Fig. 3), and it is estimated that about 150 further satellites will be placed in this orbit by 1990. For the SPS to be feasible, the geostationary requirements of such a system will need to be compatible with future orbital separation regulations. The combining of several services on large platforms is one step that can be taken to ease future overcrowding problems.

Permanent occupation of orbital positions

ESA's satellites in orbit have lifetimes of up to 7 yr, and 10 yr lifetimes are envisaged for the future. Power satellites are assumed to have a 30 yr lifetime. The issue for the United Nations in this respect will be the harmonisation of this effectively permanent occupation of geostationary orbital positions by SPSs, with the principles of 'equitable access', the 'benefits and interests of all countries' and the 'efficient and economic use' of preferred parts of outer space.

Damage caused by space objects

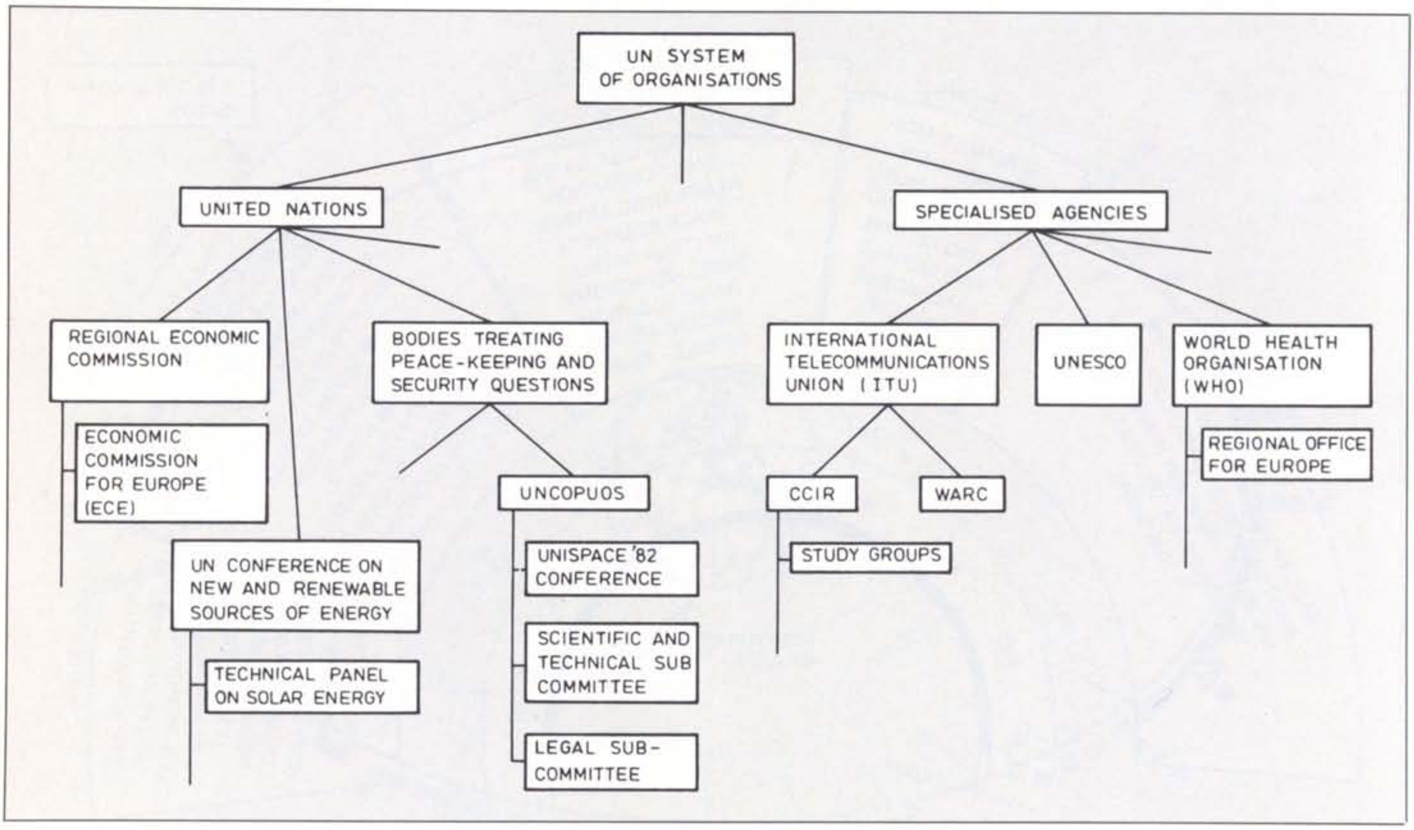
Debates of the Legal Subcommittee concerning the placing of very large space objects such as SPSs in the geostationary orbit have started to take into account the potential danger of a collision, and the liability for damages that could follow any such collision.

The technical problem of collisions can be dealt with in many ways, for example by reducing the number of small satellites by gathering them on one space platform or by removing spacecraft that have completed their mission from geostationary orbit. The legal problem of responsibility and liability for any damage caused by SPS space segments, however, raises new problems for consideration by the Legal Subcommittee.

Efficient utilisation of the radio spectrum

The International Telecommunications Convention of 1973 stresses, inter alia, that all services must be established and operated in such a way as not to cause

Figure 5 – Organisations presently considering SPS-related questions within the UN framework



any harmful interference to other users of the radio spectrum. This is not easily achievable since the number of channels in the usable portion of the radio spectrum is limited and has to be shared among such competing users as fixed, mobile, broadcast, aeronautical, maritime and space-communications services (Fig. 4). One of the most important factors in selecting a frequency for SPSs is the need, for economic reasons, to minimise losses in the atmosphere.

In addition, the lower the atmospheric losses, the smaller will be any atmospheric disturbance. On the other hand, power transmission should not adversely affect other services in neighbouring frequency bands of the radio spectrum.

While all the technical implications of wireless power transmission from space are not yet precisely known, considerable progress is expected in this field over the next few years.

It was with this in mind that the ESA Executive proposed to its Member State administrations to lay a basis for this new use of space technology by allocating an adequate frequency band for this purpose at the World Administrative Radio Conference in 1979 (WARC 79).

Appropriate studies recommended by the WARC and the CCIR

The role of a World Administrative Radio Conference (WARC) is to update and complete the Radio Regulations of the ITU as and when appropriate. Since the SPS uses microwaves for both power transmission and system operational control, it was widely accepted by the delegations to WARC 79 that the International Radio Consultative Committee (CCIR) should be recommended 'to undertake appropriate studies on all aspects of the effects of such radio transmission of power from space on radio-communication services, and to make appropriate recommendations taking into account the ecological and biological implications'.

The importance of WARC 79 cannot be overemphasised, because the outcome of this conference has established the utilisation of the radio-frequency spectrum worldwide for the next 20 years.

Supported by this recommendation, the CCIR has started to study a number of questions, including:
- the performance characteristics of systems for the transfer of energy by radio techniques
- preferred frequency bands
- factors that affect the practicability of frequency sharing between energy-transmission systems and radio-communication services
- ways in which radio-communication services may be affected by spurious and other out-of-band emissions
- power-flux-density limits (if any) that should be adopted

– potential biological or other hazards that would be posed by energy-transmission systems, both in the design mode and under malfunction conditions.

The CCIR, as an independent body within the ITU, provides a forum for engineers to reach agreement on the answers to technical questions such as those being considered in the context of the SPS. A number of contributions that have been submitted mostly by the United States and the United Kingdom, are already being discussed in the various CCIR study groups.

Biological effects of microwaves

The dangers posed to humans and other biota by potentially harmful effects from the microwave beams are often stressed in SPS assessments. National standards on microwave exposure limits in West and East differ widely and are therefore unsuitable as guidelines for the definition of the SPS's technical parameters. Thus, before an SPS can be built, all the potential biological effects of microwaves must be determined, and nationally and internationally acceptable standards covering all its potential effects must be agreed. Studies on microwave effects promoted by the International Union of Radio Science (URSI) with support from the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) and the World Health Organisation (WHO) are an essential basis for achieving a general consensus and international acceptance (WHO is currently preparing a manual on the health aspects of exposure to nonionising radiation, and provides guidance for protection).

Unispace 1982 – a next step?

At its 1980 meeting, UNCOPUOS completed preliminary planning for the 2nd United Nations Conference on the Exploration and Peaceful Uses of Outer Space. Referred to as Unispace 82*, the Conference will be held in Vienna, from 9 to 21 August 1982. Its theme will be the use of outer space for the solution of Earth-bound problems. It has been suggested that a working group composed of international experts should be established for this conference to review the various SPS-related projects currently under way in different countries, to assess the current technological situation and to submit proposals for establishing international cooperation in the SPS field. It is hoped that this Conference will prove to be a major step in the overall assessment of the concept and perhaps deliver a preliminary answer to the question of whether the SPS could supply an important part of the world's electrical energy demand in the next century.

Conclusion

The satellite power system is one of the limited number of options that could make a large contribution to meeting the world's electrical energy needs in the next century. The SPS seems feasible technically, though there are still many technical, environmental, economic and social uncertainties associated with it. In particular, a number of issues need international agreement for their resolution. A number of United Nations' bodies have already started to assess the potential of the concept as well as the various aspects that could have international implications. ESA continues to provide limited support to this UN assessment process, which is expected to result in preliminary findings being presented at the Unispace Conference in Vienna in 1982.

* See ESA Bulletin No. 24, November 1980, pp 79–80.

Parallel-Processing Computer Systems and Their Possible Applications in the Agency

M. Jones, ESA Computer Department, European Space Operations Centre (ESOC), Darmstadt, Germany

The proposed European Remote-Sensing Programme includes a number of payloads that will deliver extremely high rates of data and could call at the same time for machine processing of image scenes on a time scale of hours and in some cases minutes rather than days. ESA has therefore already begun to investigate the various architectures being proposed for parallel-processing computer systems able to cope with the extreme demands of high-speed image processing for remote sensing and for other applications.

In the past decade, requirements for high-speed computation have increased enormously, this increase being particularly strongly marked in areas such as image processing and pattern recognition, and various kinds of scientific processing. It is apposite perhaps to mention the target computing speeds which form the aims of current research:

- The competitive proposals for the NASA National Aerodynamic Simulation Facility are intended to produce a machine capable of a speed of 1 giga FLOPs (i.e. 10^9 floating-point operations per second).
- The Massively Parallel Processor (MPP) being designed and built for NASA/Goddard Space Flight Center will have processing speeds varying between 6553 million 8-bit operations per second and 373 million 32-bit floating-point operations per second.

By the late 1980s ESA's requirements for high-speed computing could well be comparable with those of NASA. The proposed European Remote-Sensing Programme, for example, will fly a variety of sophisticated instruments producing data at high rates. The proposed Synthetic-Aperture Radar (SAR) will deliver 100 Mbit/s and the Ocean Colour Monitor (OCM), which is a multispectral scanner, will produce image data at about 5 Mbit/s. These rates can be compared with Meteosat, which produces 166 kbit/s. Both types of data will require processing; in the case of the SAR processing it is essential to produce a meaningful image from the raw data, whereas for the OCM various image clean-up and Earth-location operations will be necessary to permit quantitative feature extraction. For certain applications it may be necessary to process a proportion of the scenes relatively quickly. For ocean surveying and ice monitoring, it may be necessary to provide SAR images within an hour or less for a certain proportion of the scenes. Currently available processors for SAR data can take many hours to produce a relatively small image (e.g. corresponding to 50 km × 40 km on the ground) from Seasat SAR data. Although the processing time could be reduced somewhat by development of better algorithms, it is doubtful whether the required response times and throughput (50–100 images/day) can be met by this means alone. It is therefore fruitful to search for high-performance processors. It has to be borne in mind, however, that the remote-sensing data should be available at economic prices, and so these processors should be relatively cheap.

Architectures for parallel-processing systems and their classification

A fast computer can be made either:

(a) by using faster technology within the framework of a traditional serial computer, or

(b) by using parallel architectures which, with a given technology, achieve greater speeds than the traditional serial computer.

Here the 'traditional serial computer' is a computer consisting of a single processor element (PE), memory and a control unit. The processor consists of one arithmetic and logical unit (ALU), capable of

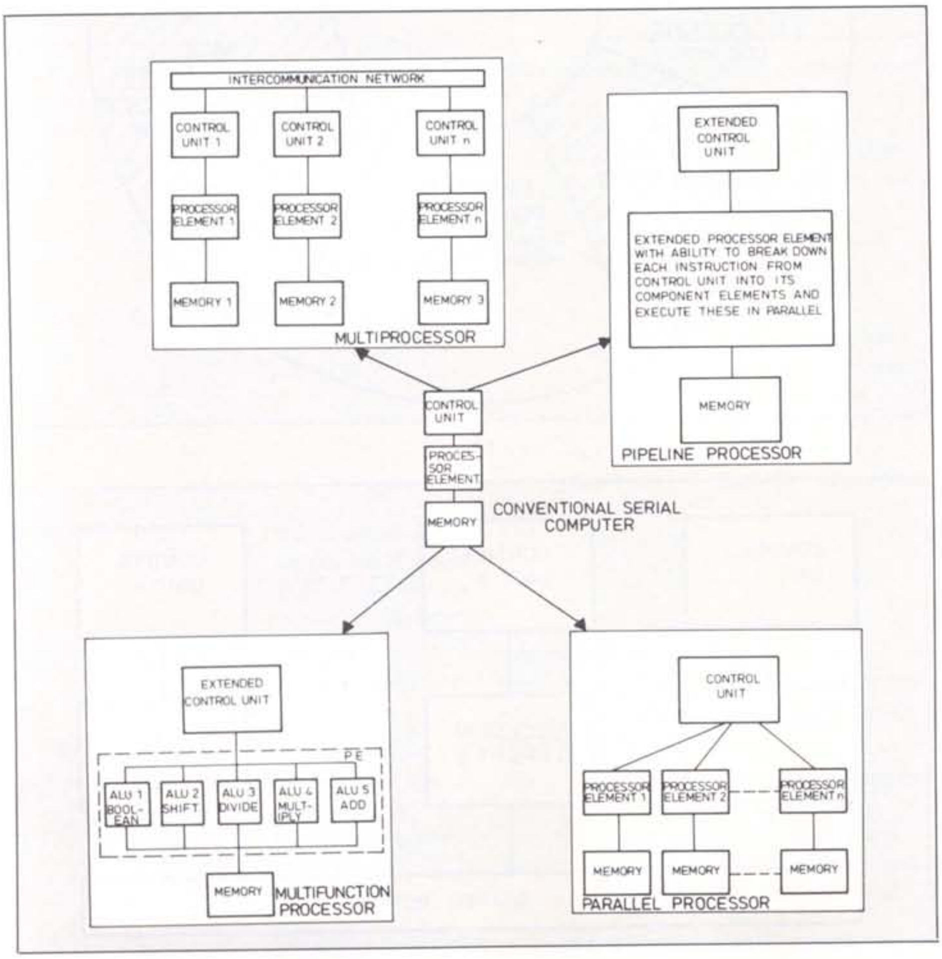


Figure 1 – Parallel computer architectures and their relationships to the von Neumann machine (Representations of the various architectures are schematics and details such as interconnection scheme are purely illustrative)

executing serially instructions sent to it by the control unit. This is the classical von Neumann architecture. As will be seen later, most modern computers have a more complex architecture and do, in fact, already contain elements of parallel processing.

Technique (a) will not be considered here, since all improvements due to technology will have natural physical limits, due to the finite size of circuits, serialism imposed on programs, etc. An example of this type of approach is the use of superconducting technology to achieve speed-up factors of the order of 50 or more compared with existing technology.

Turning to the second approach, parallel architectures can be divided into four classes:

- multiprocessors
- multifunction processors
- parallel processors
- pipeline processors.

These four basic architectures are illustrated in Figure 1, where the structures are grossly simplified. There is no generally agreed taxomony for these architectures, but for simplicity we will follow that of Kuck, which adequately describes all four categories. It is summarised beneath Figure 2. All existing parallel processing systems can be classified according to one of these basic architectures or a combination thereof.

The multiprocessor

Multiprocessors can be defined in two ways:

- Historically, the tandem and other multi-CPU machines made by many major computer manufacturers have been considered as multiprocessors. Such machines normally share the same memory, as shown in Figure 3. They achieve greater throughput for an ensemble of jobs by multi-programming rather than by cutting down the elapsed time for a single program. Examples are the multi-machine CII IRIS 80 systems and the SEL 32/77 with internal processor unit (IPU). It should be noted that because of contention problems for main memory and other resources, the incremental increase in available power as successive CPUs are added falls off sharply. Research has indicated that the power of two such tightly coupled CPUs is 1.8 times the power of one, but three similarly coupled CPUs will only have 2.1 times the power of a single CPU.

- The multiprocessor can also be defined as a traditional machine replicated twice or more, with a suitable interconnection network. This type of machine attempts to achieve faster turnaround for single programs by routing instructions that can be executed in parallel on different processors. This approach is somewhat revolutionary and there are presently no extant, fully operational machines which run in this way. The Burroughs Flow Model Processor (FMP) exists as a design for the NASA/NASF project mentioned earlier, and a design for another data-flow machine has been partially built and successfully demonstrated by Syre and co-workers at Toulouse.

The multifunction processor

In the multifunction processor, several separate ALUs are provided, such as add, multiply, divide, shift, etc., which may work in parallel. The control unit is expanded accordingly to handle the increased number of ALUs. The CDC 6600 is a classical example of this approach.

Figure 2 – Classification of various machine types, with commercial examples. Cross-hatched areas indicate hybrid architectures
SEA – single execution array
MES – multiple execution scalar
MEA – multiple execution array
SES – single execution scalar

Figure 3 – The 'conventional' multiprocessor

The parallel processor

In a parallel processor, the processors are replicated, but they are driven by a single control unit. The same instruction is therefore broadcast to each processor. Since these machines simultaneously execute the same instruction, on many units of data, they are often referred to as SIMD (single instruction multiple data) machines. The classical machine of this type is the ILLIAC IV. Other examples are the ICL Distributed-Array Processor (DAP), the PROPAL II from CIMSA, the Goodyear Aerospace STARAN IV, the Massively Parallel Processor (MPP) also from Goodyear, and the CLIP series of processors, intended for image processing and pattern-recognition applications and built at University College London. The characteristics of these particular examples are summarised in Table 1.

The pipeline processor

Pipelining is based on the fact that execution of most machine instructions stretches over several clock periods, often using some hardware repetitively. If such hardware is replicated, a new pair of operands can be fed into the pipeline allowing a number of operations to flow through the processor at once. However, the speed-up is limited by the number of clock periods required by individual operations, i.e. by the pipeline length. With a single pipeline system, no interconnection or synchronisation problems arise and there is no significant increase in the complexity of a control unit for such a system.

Because pipelining is relatively simple it is relatively cheap, which has led to great commercial success. Many so-called 'array processors' are in fact pipeline processors.

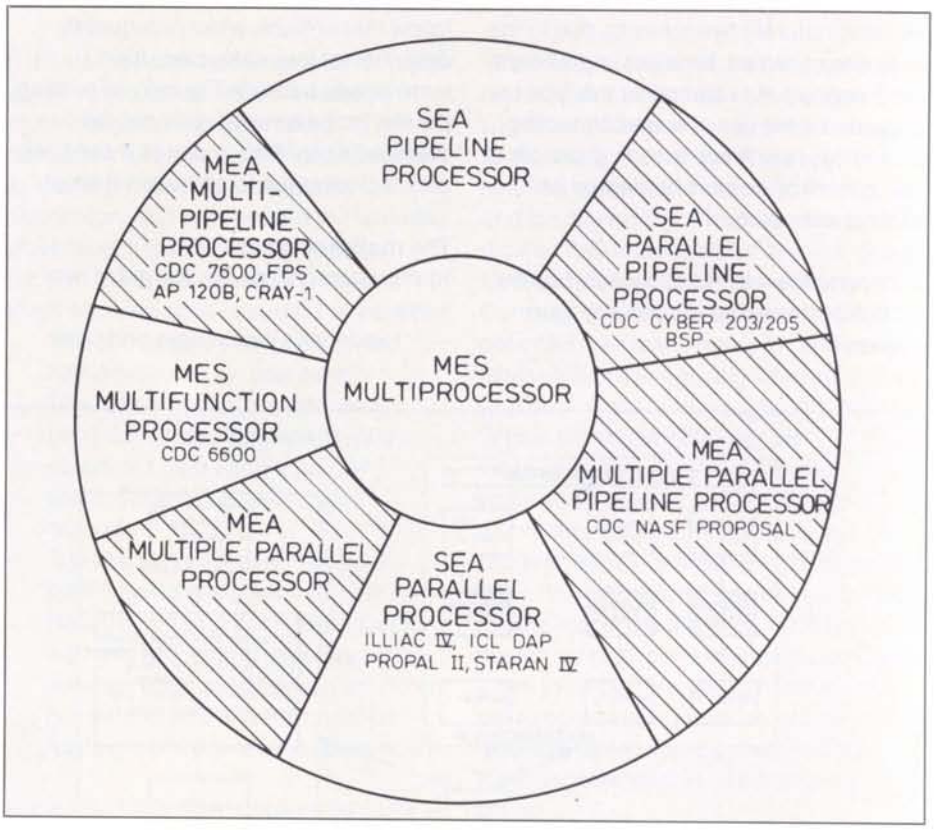
Combinations

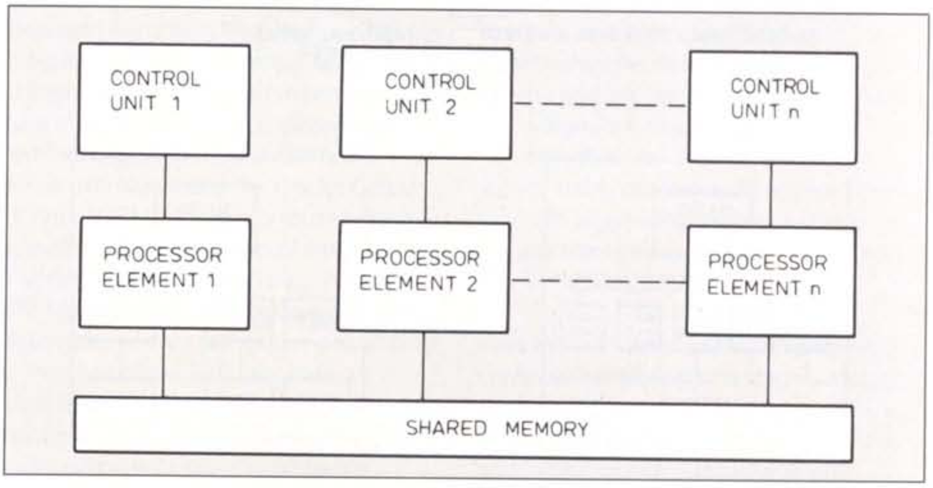
It is clear that combinations of two or more of the four basic architectures can lead to further speed-ups. In Figure 2, hybrid classes are indicated by shaded areas. We have:

– Multi-pipeline machines, e.g. CDC 7600 in which the ALUs of CDC 6600 architecture are pipelined. The CRAY-1 also falls into this category, and has in addition a 12.5 ns clock (cf. 27.5ns for CDC 7600), achieved by keeping all path lengths as short as possible.

Other examples of multi-pipeline machines include so-called 'array processors', such as the AP 120B from Floating Point Systems.

– Parallel pipeline machines, examples of which are the CDC CYBER 203/205 and the Burroughs Scientific Processor (BSP). In these machines a





vector addition is broken down into a number of parallel parts, each carried out on a separate pipeline. Other, more complex combinations are clearly possible; the collection of CDC CYBER 203/205 machines proposed by CDC for the NASA/NASF project, for example, is a multiple parallel pipeline.

Speed-up factors

For pipeline processors, the attainable speed-up is limited by the pipeline length. For parallel, multifunction and multiprocessor architectures, the potential speed-up is unlimited, in that it can always be increased by further replication. In practice, however, two bottlenecks impose limits:

- The irreducible number of serial operations in any real problem, even after steps have been taken to 'parallelise' the program. This point will be discussed below under algorithms and languages.
- Communication at all levels (processor to processor, main memory to CPU, disk input/output from external files, etc.). For a multifunction processor with a common memory shared by a number of ALUs, the speed is ultimately limited by the memory access time. Thus, assuming that each instruction executed requires one piece of data from memory, the maximum speed is of the order of 1/2 t_a operations per second, where t_a is the memory access time in seconds, and will typically be in the range 100–400ns. Suppose, for example, we have a multifunction processor with 20 ALUs, each capable of executing 32-bit floating-point operations at the relatively modest speed of 1 μs, and a memory access time of 100ns; the theoretical maximum speed is then 20 MFLOPs. In practice the maximum speed is 5 MFLOPs, set by memory-access time, not by the power of the individual PEs. Similar limits exist for the other parallel architectures, although there are differences in detail.

Table 1 – Examples of parallel processors and their main characteristics

Processor	Number of processors	Connectivity	Processor-element type	Comments
ILLIAC IV	64	1-dimensional	64-bit floating-point unit	Experimental machine
ICL DAP	4096	64 × 64, 2-dimensional	1-bit serial processor	Memory space of 2 M-bytes (4096 bit/PE) is shared with ICL 2900 series host, which is accessed for input/output
PROPAL II	8 to 2048	1-dimensional, ring connection, but see comment	8-bit	Uses MITRA minicomputer as host. Input/output can take place via a 16-bit highway connecting the PEs or in parallel to each PE, 1 bit at a time
STARAN IV	8192	2-dimensional, arranged as 32 groups of bit processors, each containing 256 elements	1-bit	
MPP	16384	128 × 128, 20 2-dimensional	N-bit shift register (N = 2–30) full adder and combinatorial logic over N bits	DEC PDP/11 host computer. This machine is currently being built
CLIP	The CLIP4 has 9216 processors	2-dimensional, with each processor connected to 8 of its neighbours	1-bit	Specifically designed for pattern-recognition applications in which nearest neighbour data propagations can be used

The conclusion is that, for parallel processors, the processing speed of the components themselves is not so important, since replication can be used to compensate for this. It is more important to concentrate on minimising the effects of the above bottlenecks.

Algorithms and languages

The full power of a parallel architecture can only be realised if suitable parallel algorithms are used to solve the application problems. The algorithm itself will need to be expressed in a computer language, which may itself restrict the parallelism that the algorithm is attempting to achieve.

The theoretical speed-up of an N-processor machine compared with a single-processor machine of the same type is N, if the various problems associated with interprocessor communication and input/output (I/O) are neglected. However, suppose that our real program to be executed on this processor has k% of operations (e.g. decisions) which have to be performed serially. With certain assumptions, it can then be shown that the maximum speed-up through parallelism is 100/k. Thus, if 5% of the computation is serial, the maximum possible speed-up is 20. The *upper limit* to the speed-up factor is thus independent of N and *dependent only on the proportion of serial operations in the problem.*

The principal problem with algorithms and languages is therefore to find the correct combination which minimises k, the proportion of serial operations.

In the limited space available here we can identify two broad lines of approach, namely:

(a) attempting to 'parallelise' existing higher level language code, most of which will be in FORTRAN;
(b) developing a new 'parallel' computer language.

Parallel languages and existing computer languages

The pragmatic or evolutionary approach recognises that large investments have been made in millions of lines of, say, FORTRAN code prior to procurement of parallel computing systems. Of course FORTRAN, and indeed most other higher level languages, such as ALGOL 68 and PASCAL, is purely sequential and so improvements are necessary, such as extensions to describe 'obvious' parallelisms such as vector computations, and development of optimising compilers to match, if possible, the architecture of the machine. In the absence of the latter, hand optimisation is necessary.

Furthermore, users are frequently provided with a library of vector or other parallel-processing subroutines which already use the hardware optimally. One successful example of such adaptation is DAP FORTRAN which to quote a trivial example, allows one to treat a variable as a single name for a set of values thus: $A=B+C$ adds all elements of set *B* to all those in set *C* and stores the result in set *A*.

The work of Kuck at the University of Illinois can be cited as an extreme example of this approach. The object here has been to produce a compiler to analyse FORTRAN code with the aim of detecting the basic building blocks of algorithms (e.g. sequences of single assignment statements, linear loops, etc.) and then the dependencies within these building blocks. This process will, in general, be hardware dependent, and so Kuck's compiler foresees the inputting of information about the target system for which the code is destined.

The data-flow approach

This approach seeks to express problems in a parallel form from the outset, rather than attempting to recast sequential algorithms and language structures in a parallel form. The data-flow approach, based on what is known as data-flow theory, can be divided into two schools based upon data-driven and demand-driven concepts.

To give the flavour of this type of approach we consider data-driven sequencing. In a conventional system the way in which the computer instructions are ordered fixes the order of computation, and therefore the data values at each step. By contrast, in a data-driven system, computations are sequenced by the availability of data. In this scheme an instruction can be executed as soon as its operands are computed, the order in which the instructions are written being irrelevant. For example, consider the program

$B = F+3$	*I1*
$C = D+2$	*I2*
$A = B+C$	*I3*

where *F* and *D* have been preset or have already been computed at a given time. Since *F* and *D* are both available, instructions *I1* and *I2* can be initiated, and can in principle be executed in parallel. As soon as *I1* and *I2* have both executed, operands *B* and *C* will be available and instruction *I3* can be initiated.

It is clear that such a language cannot be properly supported by conventional machines, because they force sequential execution of instructions and are therefore completely incompatible with data-flow concepts.

New approaches to hardware

Two new, but essentially unconnected, approaches to hardware merit mention here, namely data-flow machines and systolic arrays. Both approaches are radically different in that data-flow machines seek to provide control structures for parallel computer languages (see above), while systolic arrays seek to take advantage of VLSI (very large scale integration) technology and provide special-purpose computers tailored to specific CPU-intensive problems.

Data-driven multiprocessor system

A data-driven multiprocessor system has been designed by Syre and co-workers at ONERA-CERT, Toulouse. This system is a multiprocessor system in the sense of our earlier definition, but it has a radically different control structure from the traditional von Neumann machine. Since instructions are not executed sequentially, 'tag' bits are associated with instruction formats to indicate whether or not the operands have been computed. When all the tag bits have been set, the instruction can be initiated. Basic control primitives are provided to manipulate these tag bits (e.g. set, check or mask tag bits), thereby providing the basis of the control system. Instructions that are ready for execution (i.e. having all tag bits set) are sent to a 'file' containing ready instructions waiting for execution, from which they are routed to any available (i.e. idle) processing unit. Instructions ready for execution have no fixed ordering, since as soon as they have been flagged as executable they are independent. This project has involved the design of a single assignment data-driven language, and an associated compiler.

It is likely to be some years before this promising research can be brought to fruition and a data-flow machine is commercially available.

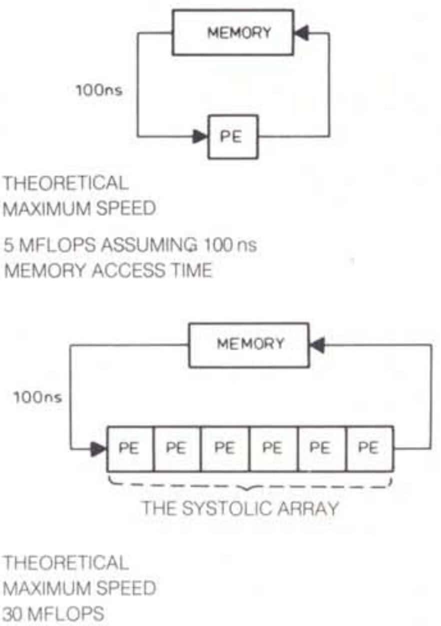


Figure 4 – Principle of the systolic-array approach

Systolic arrays

With current (VLSI) technology it is possible to produce:

- 32-bit floating-point arithmetic chips with an operation time of about 1 μs
- multilayer circuit boards holding up to 200 chips each
- processor elements with around ten circuit boards.

Although in theory such processor elements could achieve a speed of $200 \times 10 \times 10^6 = 2$ giga FLOPs, the two bottlenecks mentioned earlier would prevent this. The systolic array avoids the core-access bottleneck by re-use of each data item many times for a single memory access. This is illustrated in Figure 4, from which it can be seen that a piece of data is brought out from memory and then passes through a sequence of PEs, successive operations being performed on that data item in each one. The speed-ups obtained in this way can be appreciable; if an N-element systolic array is used to perform an N-point discrete Fourier transform, for example, the computation time will be proportional to $\log_2 N$, whereas on a pure serial processor it would be proportional to $N\log_2 N$.

The details of array topology and data flow tend to become quite complex and will not be discussed here. Suffice it to mention that Kung and his co-workers at Carnegie-Mellon University have developed a pattern-matching chip and a tree-processor chip, both of which are useful for data-base applications. They have also designed a prototype image-processing chip.

In view of the suitability of systolic arrays for image-processing operations, it would be interesting to investigate both the practicability and cost aspects of their use in SAR processing.

Conclusion

It is perhaps apt to conclude this paper with a few comments on the relevance of parallel processing to ESA's possible future requirements. It has already been mentioned that the most demanding area of application for high-speed computing is image processing for remote sensing.

The traditional approach within the Agency and elsewhere has been to use an array processor such as an AP 120B attached to a suitable host computer, which could be a low-cost 32-bit mega-mini. This has the potential of offering computing power equivalent to that of a large powerful mainframe computer such as a CDC 7600 or an ICL 2980, but at rather modest costs. One drawback is that it is often difficult to take advantage of the full speed of the array processor, because time is wasted transferring data between it and the host computer. Array processors are now coming onto the market which reduce this overhead by allowing the array processor to share the memory of the host computer. Whether such developments can result in sufficient processing speed for future remote-sensing applications is uncertain.

A better approach, particularly for the demanding but highly repetitive work involved in SAR and other image processing, might be to look at architectures with a higher degree of parallelism, for example the ICL DAP or PROPAL II, although cost and other factors such as proven performance would have to be taken into account in evaluating the suitability of such machines. Earthnet is currently conducting a performance study of these and other machines with, however, the wider aim of producing general benchmarks suitable for evaluating any parallel processor.

Another approach would be to design and build a special processor using, for example, standard chips as processing elements. It could be based on either parallel-processor or systolic-array architectures. An approach along broadly similar lines has already been taken in an ESA breadboard study of a dedicated SAR processor based upon a 'functional pipeline' multiprocessor concept in which a particular processor will handle a given functional step in the processing algorithm and will then hand its results to the next processor for the succeeding step. Another contract is to be let for the definition and design of a multiprocessor machine for image processing.

Finally, it is worth remarking that in the future it may well prove economic to run scientific numerical-analysis jobs and database application jobs on parallel processing systems, particularly where long runs on a general-purpose mainframe can be replaced by short runs on a parallel processing system, which can therefore be shared among many users. This has already been demonstrated in published work on the ICL DAP, which has been applied very effectively to such commercial-type applications as sorting and route finding, as well as to more 'obvious' applications like matrix multiplication.

Training in Satellite Ground-System Operations

F.W. Stainer & H.P. Dworak, Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany

The main ESA ground facilities involved in satellite operations consist of five permanent stations which are supplemented for the launch and early operations phases of geostationary-satellite missions by three VHF network stations (Table 1). Approximately 160 non-ESA technical staff (some on contract, some from other national space agencies) work at these stations. These staff, together with a number of the Agency's own personnel and an increasing number of overseas visitors, make up the pool of trainees. By university standards, this is a small group, but the subjects covered are highly specialised.

The training requirement

It can be argued that all training, provided it is successfully carried out, improves an individual's performance, whether it be training related to that person's ability to do a job, such as the ground-systems operation training described here, or training only indirectly related to that ability; for example, career training, management training, general education, etc. A further category of training has been introduced at ESOC called 'simulation'. Here, the prime aim is still to prepare staff for a specific task, but there is a change in emphasis, from the work of an individual to the work of groups in a realistic environment – in ESOC's case the work of a network of ground stations. These simulations are discussed in more detail later.

There are two main ways in which a requirement for 'job-related' training may arise in satellite ground-system operations. The first is associated with the introduction of new equipment or procedures. In this case a check on the requirements of the staffs' new tasks compared with previous ones can highlight a training requirement. The second is by performance analysis, or in other words an assessment of whether an existing task is being performed optimally.

Two types of performance analysis are employed. The first relies on the routine collection of data on operational and maintenance activities, using the various outputs from the normal ground-network evaluation process. This method has the advantage that problem areas can be accurately defined, but it has the disadvantage that it is not possible to identify the training requirements for individuals. The second and more detailed form of performance analysis, known as the 'skill record', can be used to determine the training requirements of individuals, by using questionnaires to collect information about knowledge and skills in specific areas. Used in combination with the results of network evaluation, the skill record constitutes a powerful tool for overall performance analysis.

Performance analysis identifies areas where training action is necessary; the next step is to define the requirement in detail, in terms of what the ground-system trainee must be able to do after completing the course. It is at this stage that personal requests from trainees or their managers must be taken into account.

Course procurement/preparation

Some ESOC training courses are produced internally, drawing where necessary on the expertise within the Agency for course instructors; other courses are purchased from equipment manufacturers, or from professional training organisations. A permanent training establishment with regular courses and full-time teaching staff would not be an economic way to satisfy the particular requirements of ground-systems operation training.

An example of a package in current use is the self-study microcomputer course illustrated in Figure 2. It consists of a complete microcomputer and workbooks, enabling the user to follow both the hardware and software aspects of the course without supervision. Four kits of this type are in constant use, both in the Operations Control Centre (OCC) and at the other ground stations.

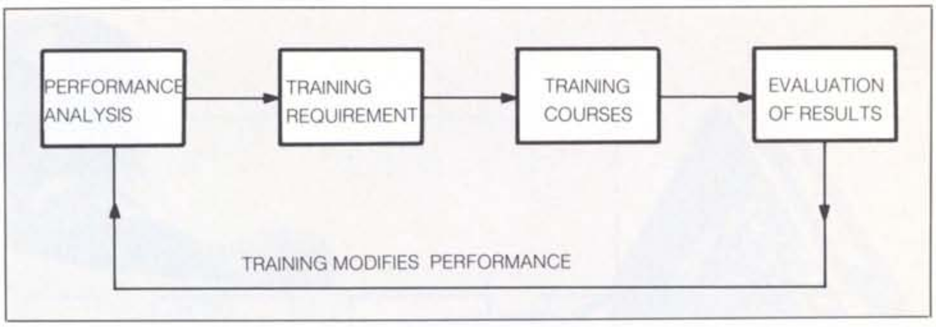
Complete video courses have been produced in house at ESOC, but these are expensive in terms of time and manpower. The video installation has therefore mainly been used for the recording of lectures by acknowledged experts for subsequent playback to trainees unable to attend the original presentations (operators normally work a shift system, and cannot conveniently be brought together for training).

A special 'Personalised System of Instruction' (PSI), was used during the Meteosat-1 programme. This training method was originally developed in the United States for university courses and has proved to be very suitable for ESOC. It allows each trainee to work individually at his own pace, with more emphasis on written, taped, filmed, etc. presentations than on lectures (presented only for 'enrichment' purposes). The PSI method proved highly successful for the particular requirements of the Meteosat mission.

The procedure for preparing a training course for ground-system operations is summarised in Figure 3. The task analysis defines the job for which training has to be given and from it the objectives of a particular course are specified. The course specification includes decisions on how training will be given, and how it will be organised. The course is first constructed in draft form and the draft validated by trying it out, including tests and practical excercises, on a representative sample of trainees. The results of the validation exercise are used in producing the final course.

Most ESOC courses are divided into modules – theory, practice, operations, maintenance, hardware, software, etc. – the course structure dealing, wherever possible, with jobs in the order in which they have to be tackled in practice, applying a whole-to-part approach.

Figure 1 – The training process



Task analysis and job cataloguing

A complete task analysis entails finding out what the trainee has to do, including the standards to be achieved, the working conditions and the frequency of the task(s).

Analyses of this type have been made for all the Agency's satellite ground-system operations and the results compiled in the form of a 'job catalogue', which provides up-to-date information that would otherwise have to be obtained through a one-off task analysis for every training course produced.

The purpose of the job catalogue is to define the individual maintenance and operations tasks associated with ground-system operations. The various posts have been analysed in terms of the equipment involved and the major elements of the job (routine/non-routine operations and routine/non-routine maintenance). The detailed requirements of the job have been specified, and the conditions under which the job is carried out and the frequencies of the various tasks have been defined.

Table 1 – The main ESA ground facilities

Ground facilities	Main current use
Operations Control Centre (OCC), Darmstadt, Germany	Operations control
Redu, Belgium	VHF network Cos-B Geos uplink station OTS and Meteosat back-up
Villafranca, Spain	IUE control centre and observatory
Odenwald, Germany	Meteosat S-band station Geos downlink station
Fucino, Italy	OTS station
Kourou, French Guyana	VHF network
Malindi, Kenya	VHF network
Carnarvon, Australia	VHF network

Figure 2 – A self-study microcomputer course used for training at ESOC and at the remote ground stations

Table 2 – Data sources available at ESOC for training/simulation purposes

Data source	Advantages	Disadvantages
Analogue magnetic tapes	Cheap	Not closed loop Fixed data content
Software simulators:		
– static	Realistic Closed loop	Expensive Used at only one place
– portable	Cheap Closed loop Can be used anywhere	Less realistic
Satellite models	Realistic Closed loop	Limited availability Restricted activity
Suitcase models	Portable Closed loop	Limited facilities Availability
Hardware PCM simulators	Cheap Portable	Not closed loop Not realistic

The catalogue can be used to compare actual jobs and jobs foreseen for the future and thereby to define ground-operations training requirements in detail.

Simulations

The emphasis in simulations is on the training of a complete team as opposed to the training of individuals and on training that uses realistic operational data, configurations and situations. In addition to training personnel, simulations provided a means of pre-proving mission documentation and operational procedures, and providing confidence that equipment and software are performing to the required operational standards.

Simulations involve all activities and personnel directly involved in real-time or near-real-time operations; they can be divided into four categories: Operations Control Centre (OCC) simulations, station simulations, ESTRACK simulations, and network simulations.

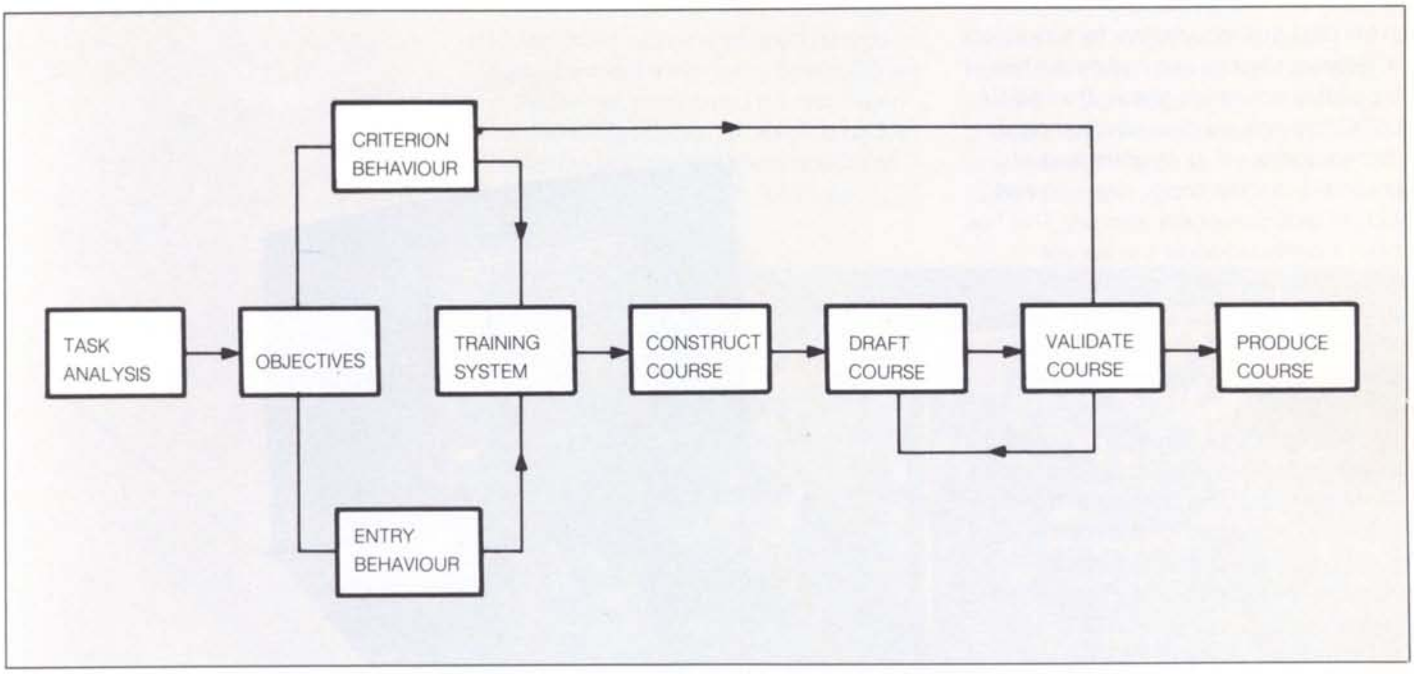
OCC simulations provide OCC operators, flight-control teams, and all operational supervision and support staff at the Centre with practice in:

- interfacing with other members of the team
- use of operational documentation and procedures
- use of equipment and operational software
- reaction to contingencies and unusual situations.

Station simulations provide station operators and operational support staff with experience of the above, without interfacing with the Control Centre.

OCC simulations and station simulations are used as preparation for ESTRACK and network simulations. The ESTRACK simulations provide practice for the OCC and all the participating stations of the ESA tracking network, known as 'ESTRACK'. Finally, the complete ground network, consisting of the OCC, the

Figure 3 – Procedure followed in preparing a ground-system operations course at ESOC



ESTRACK stations and any external agencies involved, is exercised. The launch-site interface staff and all mission-support personnel participate at this stage.

A simulation programme proposal, prepared after study of the requirements of a particular space mission, covers staff participation, activities to be included, data sources, number of times each activity is to be simulated, number of hours of simulation, and the necessary planning. The simulation programme is implemented shortly before a launch, often launch −90 days to launch −4 days.

For practical reasons it usually includes two simulations per week, commencing with OCC and station simulations, and concluding with full network simulations. A final simulation, traditionally referred to as the 'dress rehearsal', takes place around launch −4 days. In the period around launch −30 days the network is in 'mission status', activities are managed by a specially appointed mission team, and all facilities are in a final state of readiness. The simulation programme normally includes at least one simulation that is time-lined to follow the expected real operational times, and at least one simulation of sufficient duration to require a changeover of teams.

A careful note of all errors or deviations from established procedures is made and at the end of the simulation reports are prepared. Any actions resulting from these reports are cleared before the network is declared ready for launch.

Data sources for training and simulations

Apart from analogue tapes and software simulators, the data sources available (Table 2) for training and simulation purposes have been designed initially for other purposes, and this is reflected in their characteristics. In the early days the most useful source was analogue magnetic tape, but the changing role of stations and Control Centre in recent years has meant that, to provide realism, the data source needs to be a closed loop, i.e. with commands sent by the Control Centre being acted upon immediately in the simulator and with appropriate responses appearing in the telemetry data output. This is the main feature of what have come to be known as 'software simulators'. In addition these simulators model realistic satellite subsystems, interface with the operational configuration, and are easy to operate, characteristics that also make them invaluable tools for Control Centre test purposes.

The first ESOC software simulator was developed for the Agency's Cos-B gamma-ray astronomy satellite, launched in 1975, following a feasibility study made using the HEOS-A2 spacecraft. A simulator has been provided for all major missions since Cos-B.

The simulators are installed on computers that form part of the overall on-line data-processing system, such as the CII 10070, which is part of ESOC's Multi-Satellite Support System. There has therefore been no special purchase of hardware for simulation, but this arrangement has led to difficulties in configuring and scheduling for the machines. The large capacity available has, however, permitted very realistic simulation of all satellite systems.

Figure 4 – A microprocessor unit, consisting of keyboard, display, floppy-disk unit and 48 K random-access memory, used in the simulation of Meteosat, Marecs and Exosat operations

In the past any requirement for simulators at network stations was met by the hire of a portable simulation system from NASA. ESOC has now purchased a standard microprocessor (Fig. 4), consisting of keyboard, display, floppy-disk unit and 48 K of random-access memory. This has been modified to allow it to accept commands and generate telemetry to ESA standards. A general program has been written to allow use of a wide variety of formats, bit rates and command types.

The unit is currently capable of simulating Meteosat, Marecs and Exosat operations. It will be used for the first time at the Carnarvon station to simulate Meteosat during the training and simulation exercises for the Ariane L03 launch of that satellite.

It is not feasible to include the simulation of all subsystems and their interactions in such a simulator. The possibility for simulating dynamic characteristics is very restricted and in this respect it does not replace the larger simulators. It does, however, provide a cheap and powerful tool not only for training and for simulations, but also for many aspects of ground-system hardware and software testing.

Table 3 – Simulation record for a sample of past and future ESA satellites

Satellite	Number of simulations	Overall duration (weeks)	Total corrective actions
Completed			
Geos-1	24	11	230
OTS-1	28	26	209
Meteosat-1	26	13	263
OTS-2	14	8	102
Geos-2	8	6	47
Firewheel	5	4	25
Planned			
Meteosat-2/Apple	11	5	–
Marecs-A	17	9	–
Marecs-B/Sirio-2	19	10	–
Exosat	18	8	–

Conclusions

This summary of the approach to training staff at ESA satellite ground facilities has hopefully served to illustrate the variety of the requirements inherent in the task. As an example of the volume of training undertaken, 22 courses were arranged during 1980, amounting to approximately 570 student-days. The simulations are summarised in Table 3, which includes some recent and some future missions. The number of action items identified during past simulations gives an indication of their importance in launch preparations.

In Brief

Spacelab Engineering Model delivered to NASA

A milestone in European/US space cooperation was reached on 28 November 1980 at the premises of VFW-ERNO (Bremen), the Agency's prime contractor for Spacelab, with the official handover of the Engineering Model to NASA. The delivery of the Engineering Model, which was transported by wide-bodied aircraft to Kennedy Space Center in December, constituted the first major transfer of Spacelab hardware to NASA under the ESA/NASA Memorandum of Understanding signed in 1973 (two Spacelab pallets have already been delivered in 1978/9). The first Spacelab flight unit will be delivered later this year and NASA has a second Spacelab flight unit on order from ESA for delivery in 1982/3.

The first two Spacelab flights are currently scheduled by NASA for June and November 1983. The first flight will be a joint ESA/NASA mission and it will carry scientific experiments presently under development in both Europe and the United States.

The Spacelab roll-out ceremony at VFW/ERNO on 28 November 1980

photo nasa

Spacelab Orientation Course given in Japan and China

Members of the Spacelab presentation team at the first presentation of the course in the Tokyo Grand Hotel. They are from left to right, Messrs Ermisch and Zimberlin (ERNO), Dr Shapland (ESA Space Transportation Systems Directorate) and Dr Kappler (ERNO). In the background is Mr Norio Soichi of NASDA's Space Shuttle Utilisation Office

An ESA/ERNO team gave a two-day course on Spacelab for potential users in Tokyo on 2 and 3 October and in Peking on 7 and 8 October 1980. The purpose of the course was to present Spacelab and its capabilities, to demonstrate European knowhow, and to promote European industry.

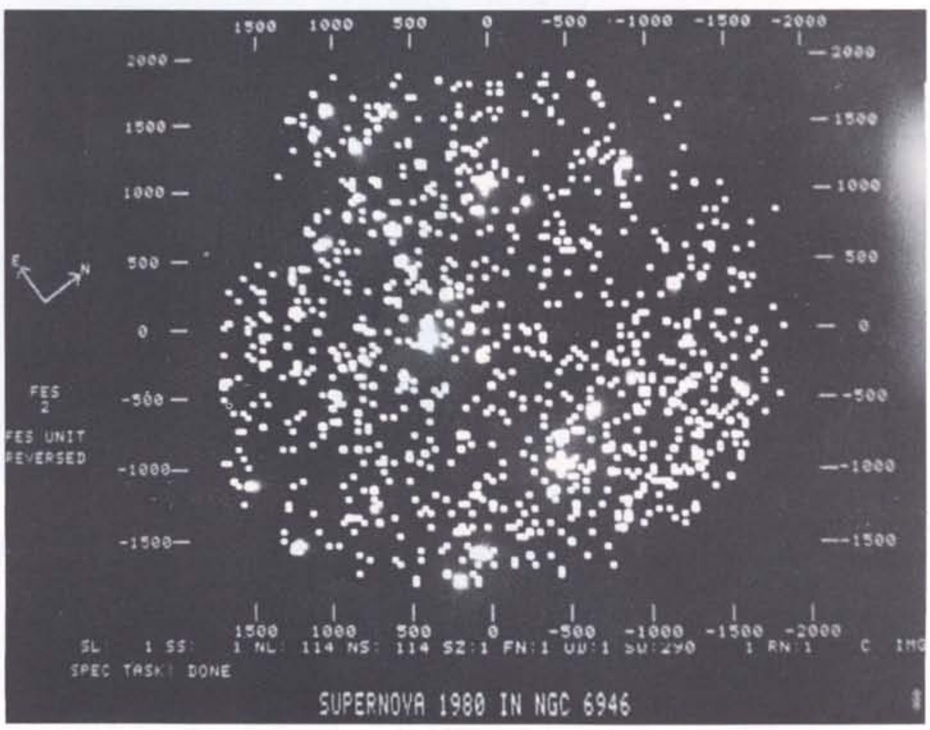
Entitled 'Spacelab Users Orientation Course', the course was presented to 152 people in Tokyo at a meeting arranged by NASDA, the Japanese Space Agency. The audience consisted of representatives from NASDA, other national institutes, universities and private industry. In Peking, 310 people attended the course, which was arranged by the Chinese Academy of Sciences for potential users representing 28 institutes.

The great interest in ESA's Spacelab in both countries was evidenced both by the large number of attendees and by the many and varied questions that were asked. In fact, Spacelab is now a strong contender for future co-operative activities between ESA and these countries.

European Astronomers study Bright New Supernova with IUE

On 28 October Professor P Wild of the University of Berne's Astronomical Institute discovered a new bright supernova in the spiral galaxy NGC 6946, and immediately alerted the astronomical community. The first spectrum of this object was acquired in the ultraviolet by European astronomers working with the International Ultraviolet Explorer (IUE) satellite, from the Agency's Villafranca Satellite Tracking Station, on 30 October, within three hours of being notified of the event, and before optical astronomers had taken spectra from the ground.

The flaring up of a bright supernova is an exciting astronomical event in which a single star ends its life in an explosion as bright as a whole galaxy of one billion stars. Supernovae of comparable apparent magnitude to that in NGC 6946 are very rare events indeed, with an average of only two such happenings per decade. The early spectra captured at Villafranca reveal a supernova near its maximum brightness and fading slowly, with a strong continuum representing a temperature of perhaps 20 000 degrees.



IUE finder telescope image. The new supernova can be seen in the bottom right quadrant of the image directly above the cross.

NGC 6946 is a comparatively close galaxy which has proved to be a steady source of supernovae (five in the past 63 years). In the next few months, before the supernova fades too far, it will be the target of concerted observational efforts throughout the electromagnetic spectrum.

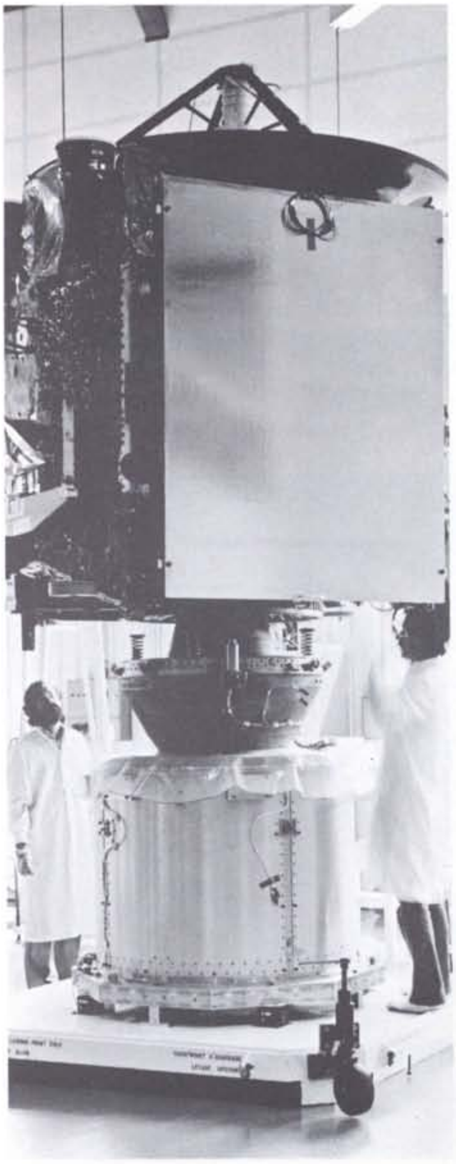
Entry into Force of the ESA Convention

On 30 October 1980 France deposited its instrument of ratification of the Convention for the Establishment of a European Space Agency, thus completing the legal formalities required for the Convention's entry into force. Although the countries that had signed the Convention on 30 May 1975 had agreed to apply its provisions immediately – enabling ESA to operate 'de facto' for more than five years – its formal entry into force means that the eleven Member States now have the means of taking advantage of all of the possibilities offered by the Convention, the purpose of which is to give Europe's space effort a truly European dimension (see article on page 6).

New Director of Applications Programmes

Mr. E.S. Mallett (UK), who is 57 years of age and a physics graduate, spent six years in industry before joining the Scientific Civil Service in the UK, holding a number of scientific posts in the Royal Aircraft Establishment (Farnborough) and becoming Director Space in the Department of Industry in 1976. As such, he was a Delegate to the ESA Council and Chairman of the Joint Communications Board. In 1978 he became Under Secretary, responsible for the Research and Technology Requirements and Space Division. In 1979 he was appointed Director of the National Maritime Institute.

He takes up duty at ESA on 19 January 1981.



Inmarsat to lease Marecs Satellites from ESA

At its meeting on 12–19 November, in London, the Council of the International Maritime Satellite Organisation, Inmarsat, awarded the Agency a contract for the lease of two Marecs satellites (Marecs A and B, operating in the 4/6 GHz and 1.5/1.6 GHz bands).

This contract, which is planned to start early in 1982, will run initially for a five-year period and involves approximately US $13 million per year (firm fixed price).

The two satellites, which will form part of the Inmarsat global maritime satellite communications system, will be located over the Atlantic and Indian or Pacific Oceans.

Both Marecs satellites are currently in their assembly, integration and test phases, leading up to launches in the second half of 1981.

The complete Inmarsat system will cover the Atlantic, Pacific and Indian Oceans with a combination of the Marecs satellites, Intelsat-IV satellites equipped with maritime communications payloads, and one of the already orbiting Marisat satellites. The European-built Marecs satellites will be contributing to a maritime communications system that will provide dial-up telephone and telex links between shore-based subscribers and ships at sea. The system will allow ship-to-shore search and rescue messages to be relayed quickly, as well as being invaluable for the transmission of messages of a more routine character.

Marecs structural model during vibration tests at SOPEMEA, Toulouse

Ireland Eleventh ESA Member State

Ireland became the eleventh Member State of the European Space Agency on Wednesday 10 December. Ireland had signed the ESA Convention on 31 December 1975 but this Convention only entered into force on 30 October 1980 when France deposited her instrument of ratification. Ireland's contribution to the Agency's mandatory budget amounts to 0.54% of the total. Ireland also participates in the remote-sensing programme and in the Ariane production programme for the promotional series of six launchers (see article on page 6).

Mr Erik Quistgaard, ESA's Director General opening the YES exhibition.

'Man and Space' Art Competition: Exhibition of Winning Entries

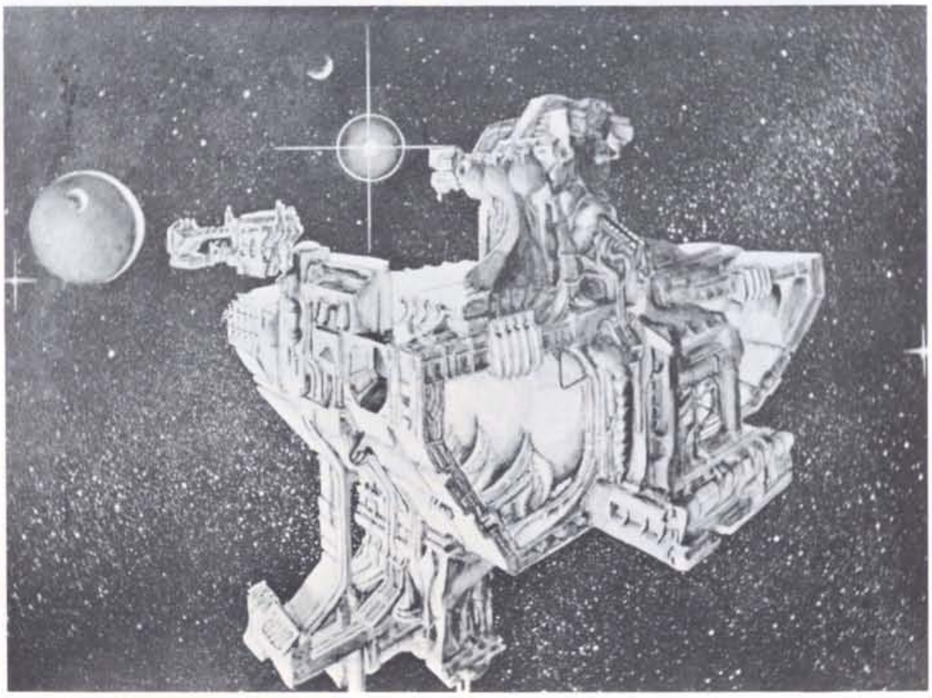
In January 1980 ESA organised an art competition for young Europeans on the subject of 'Man and Space', as part of the 'Young Europeans and Spacelab' (YES) programme developed by the Agency to promote the Spacelab programme and its evolution, to promote interest in scientific/technical space-oriented hobbies among young people, and to promote future European cooperation in space ventures.

More than 1300 works by young people aged between 7 and 20 were received by the national sponsoring bodies in Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom.

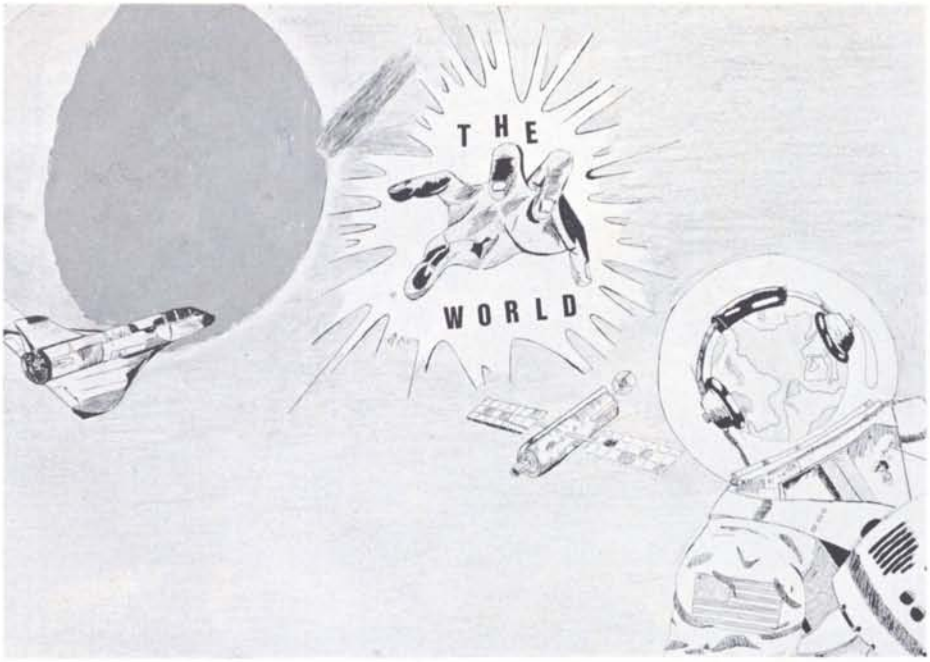
An exhibition of 85 works selected at national level, comprising paintings, drawings, poems and musical compositions, was held in Paris from 29 November to 7 December 1980 at the Conservatoire National des Arts et Métiers (CNAM). The originators of these selected works were invited to Paris for the four days of the exhibition as ESA's guests.

Visitors to the exhibition were asked to make a further selection of twelve works (one per country) for awards at a European level. The originators of these twelve winning entries (see below and subsequent pages) are to be ESA's guests on a visit to Kennedy Space Center in Florida, where they will tour the Shuttle/Spacelab facilities.

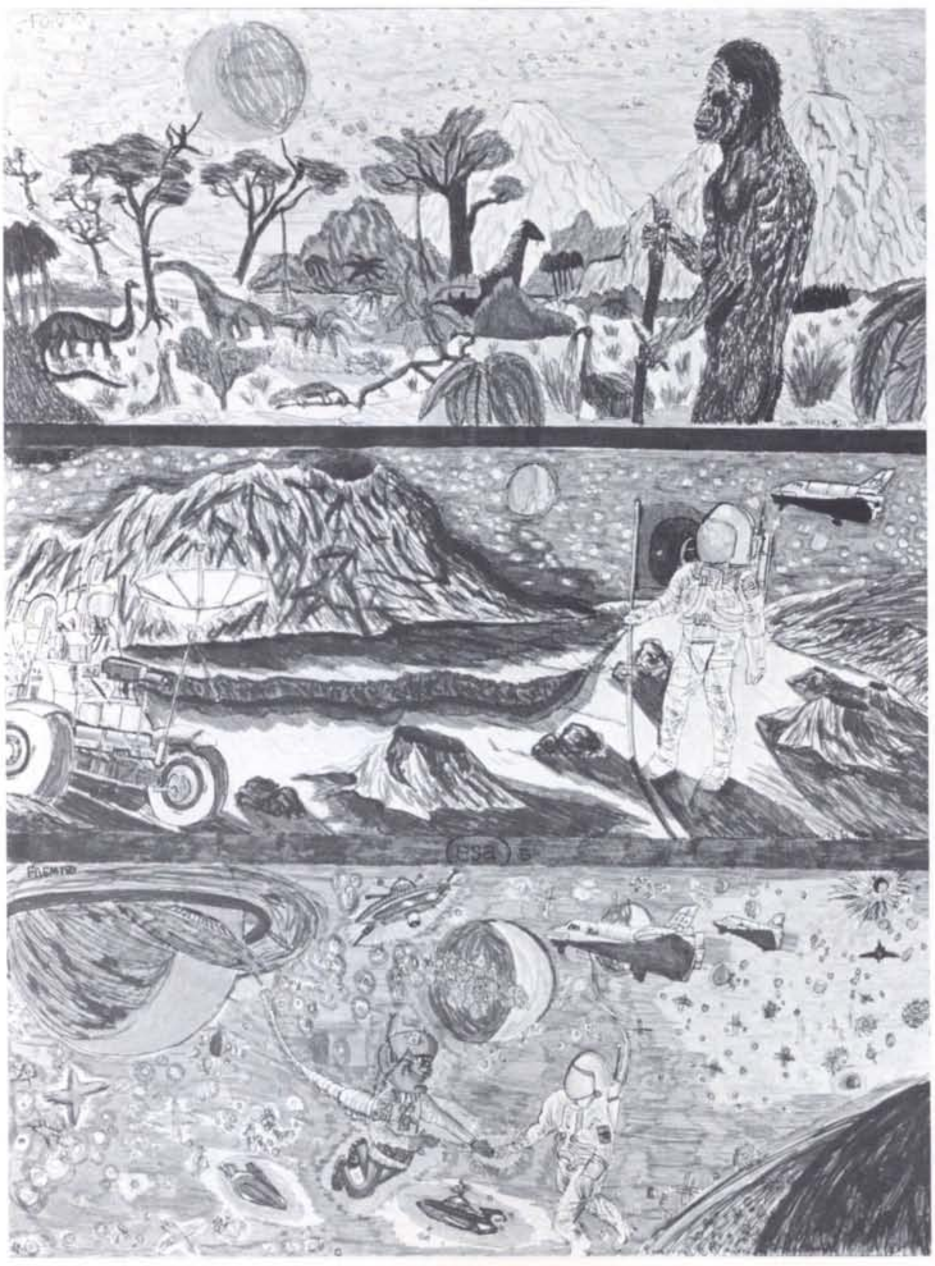
A souvenir booklet containing the works selected for the Paris exhibition is available at a nominal charge from ESA's Scientific and Technical Publications Branch (ESA Special Publication SP-1024).



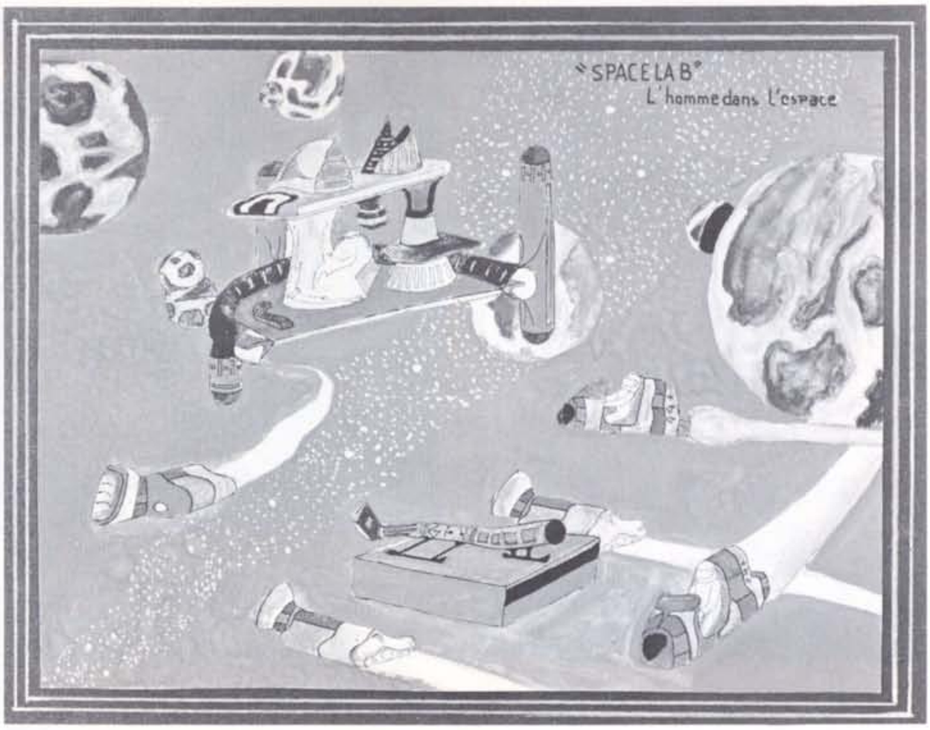
SPACECRAFT AND PLANETS
Stefan Riedl (aged 18)
Austria



SPACELAB
Carlos Oliveira (aged 13)
Belgium

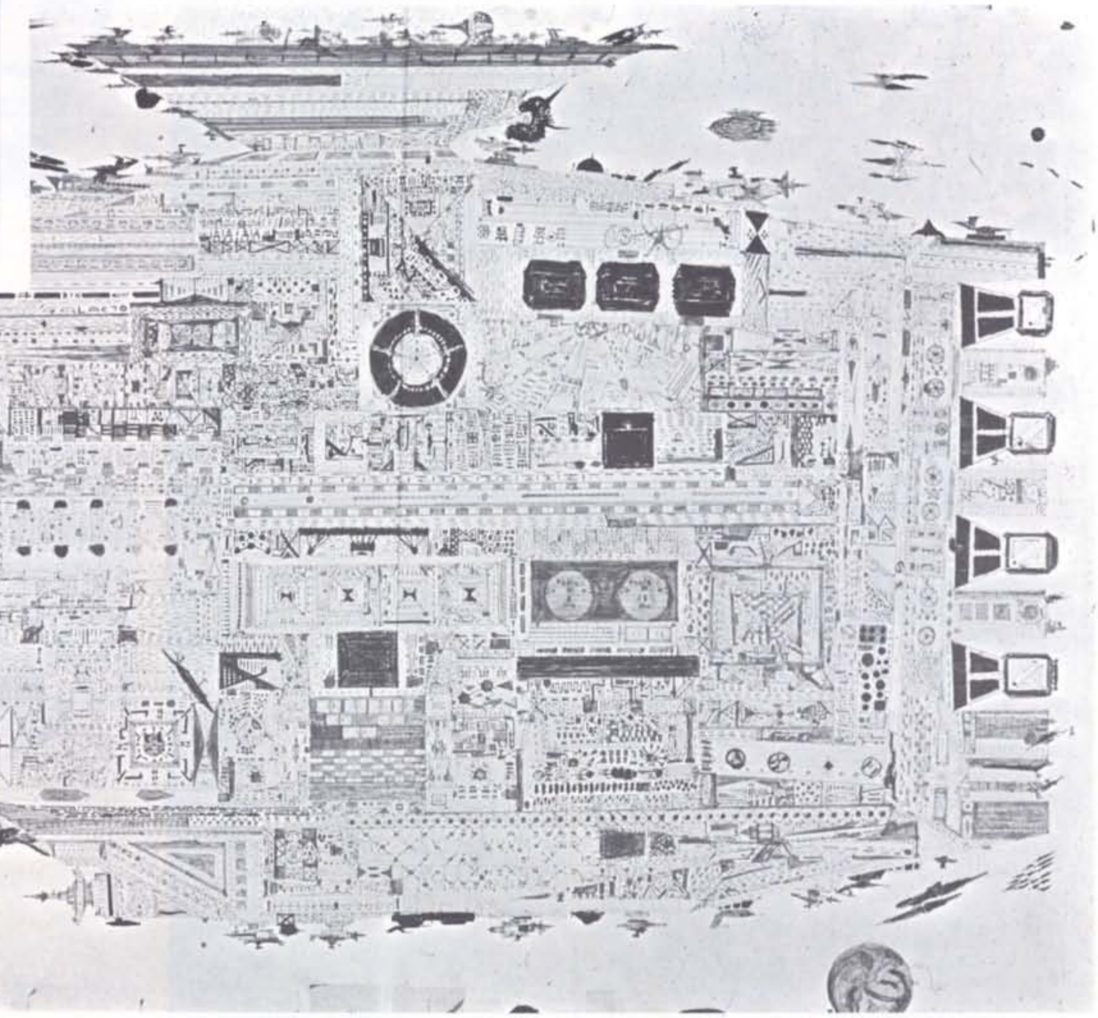


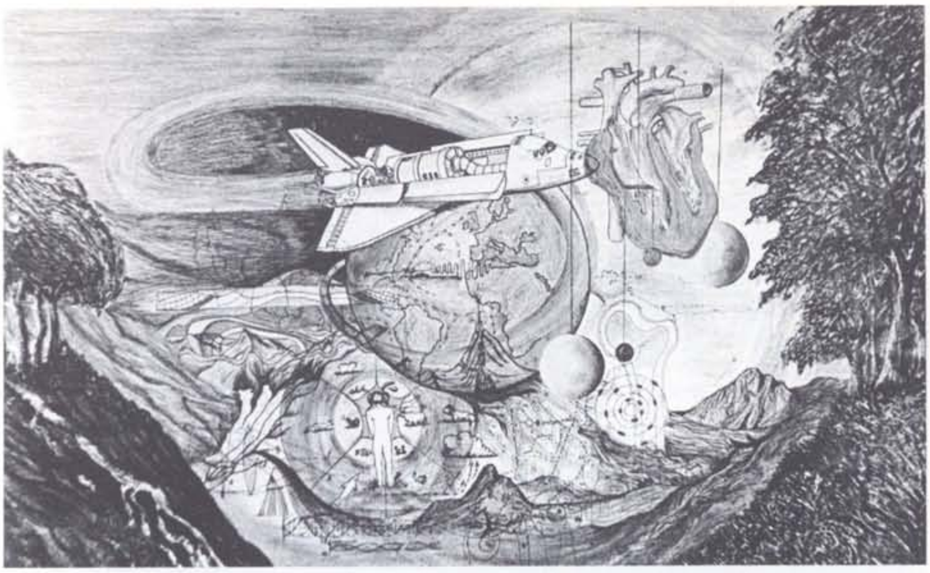
PAST, PRESENT, FUTURE
Lars Vester (aged 12)
Denmark



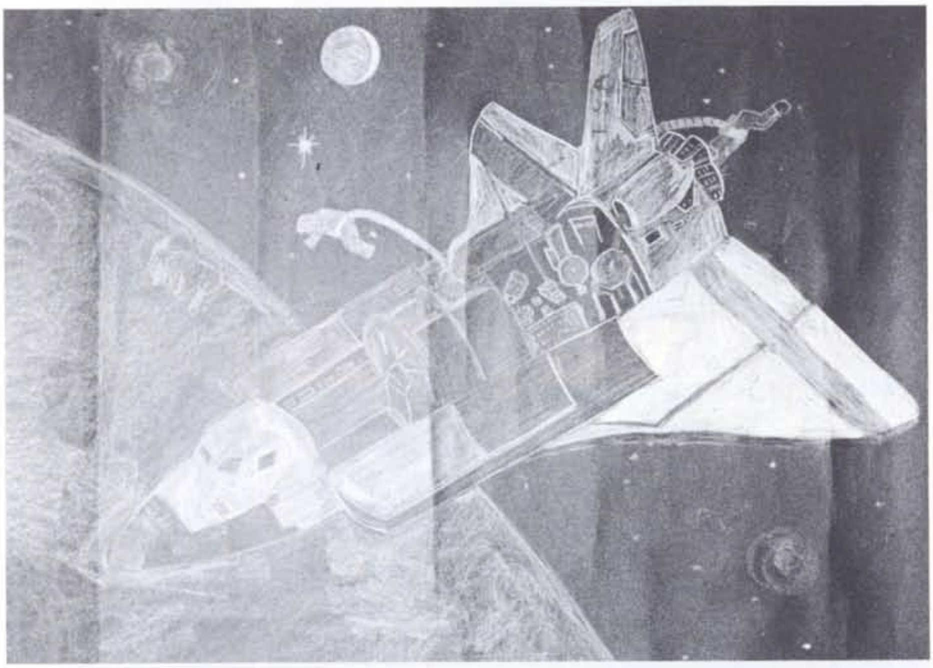
SPACELAB – MAN IN SPACE
Delphine Lamarque (aged 13)
France

SPACE SHIP
Oliver Dieckhoff (aged 14)
Germany

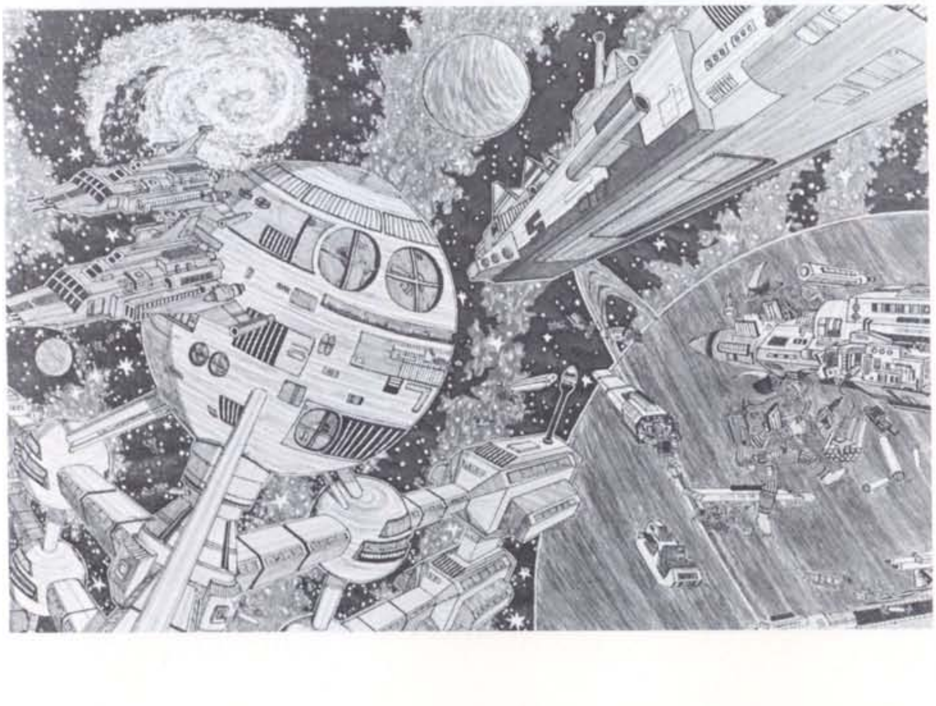




EVERYONE IS BEGINNING TO UNDERSTAND
Liam O'Sullivan (aged 19)
Ireland

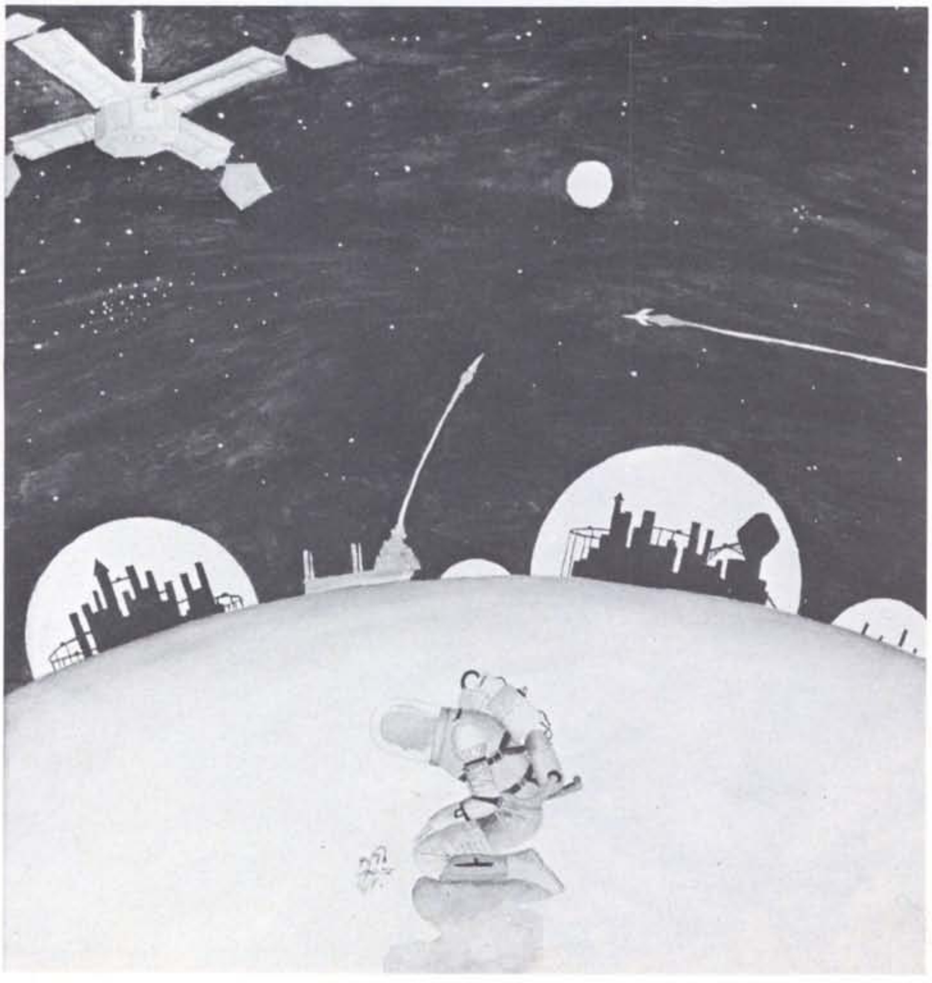


SPACELAB
Marco Campanella (aged 9)
Italy



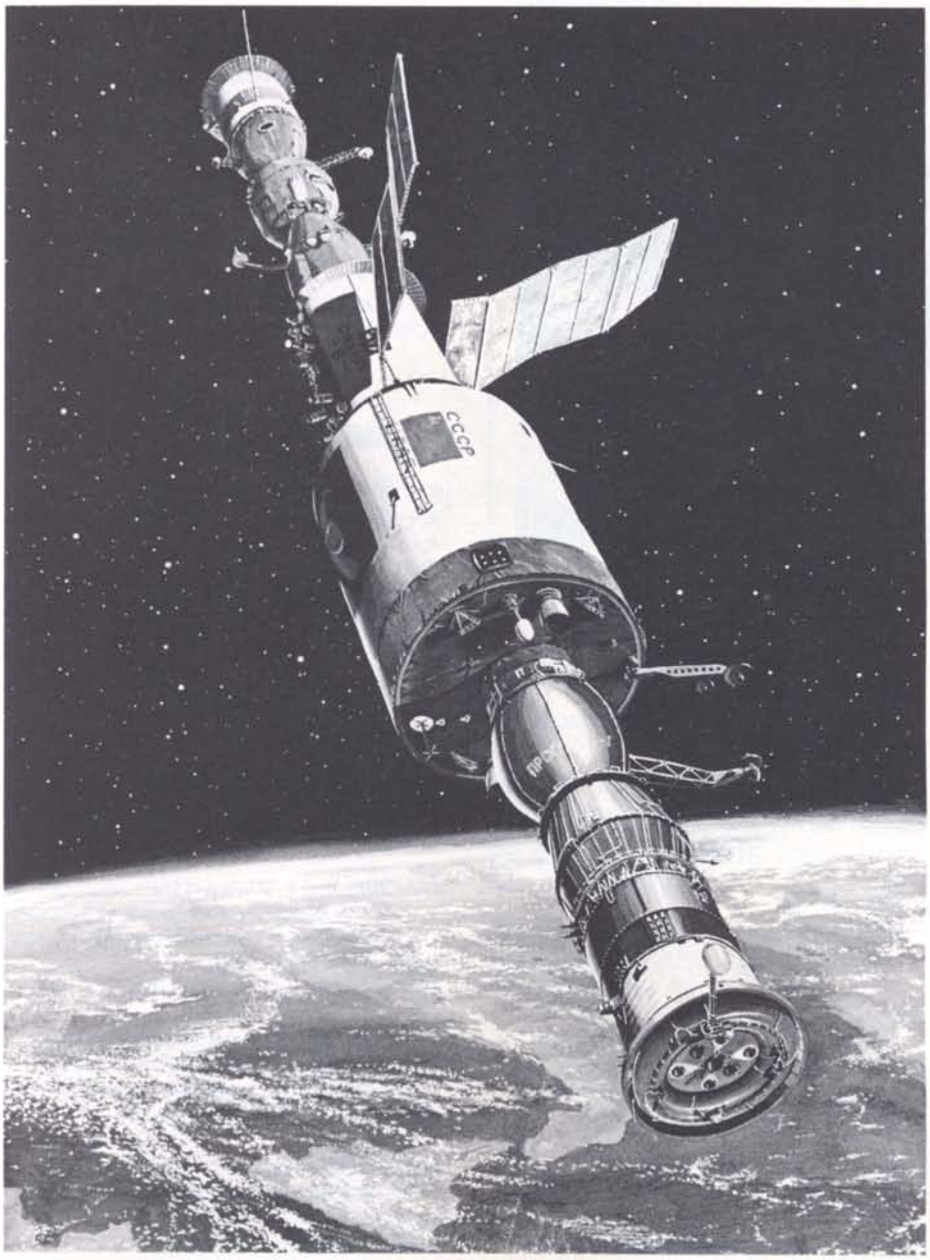
RESEARCH ON URANUS
Hendrik van Walraven (aged 15)
Netherlands

SPACE: MAN'S TERRITORY
Irene Vilana Parramón (aged 18)
Spain



WHEN THE LAST FLOWER DIES
Bjorn Bergenholtz (aged 18)
Sweden

MAESTRO
Linda Soto (aged 14)
Switzerland



SOYUZ 26/SALYUT 6/PROGRESS 1
Glenn Johnson (aged 18)
United Kingdom

Publications

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The following papers were published in ESA Journal Vol 4 No 4:

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BOETTCHER R-D, KOPPENWALLNER G & LEGGE H

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JONES M, HAMMAR R O & LAUQUE J-P

OUTGOING-LONGWAVE-FLUX COMPUTATION FROM METEOSAT DATA
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CAPEL A, CLIQUE M & FOSSARD A J

Procedures, Standards and Specifications

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PRODUCT ASSURANCE DIVISION, ESTEC
PRICE CODE E1

Special Publications

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PRICE CODE C2

ESA SP-1031 *INSTRUMENTATION FOR PREPROCESSING OF SAR DATA TO IMAGE FORM*
LONGDON N (ED)
PRICE CODE C1

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HOFFMANN H-E, DFVLR, GERMANY

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ONERA, FRANCE

TT-654 *INFLUENCE OF THE FLIGHT ALTITUDE AND LIMITATION OF THE FIELD OF VIEW OF THE VISIBILITY OF TARGETS ON THE GROUND AND THE MAXIMUM VISIBILITY FLIGHT ALTITUDE*
HOFFMANN H-E, DFVLR, GERMANY

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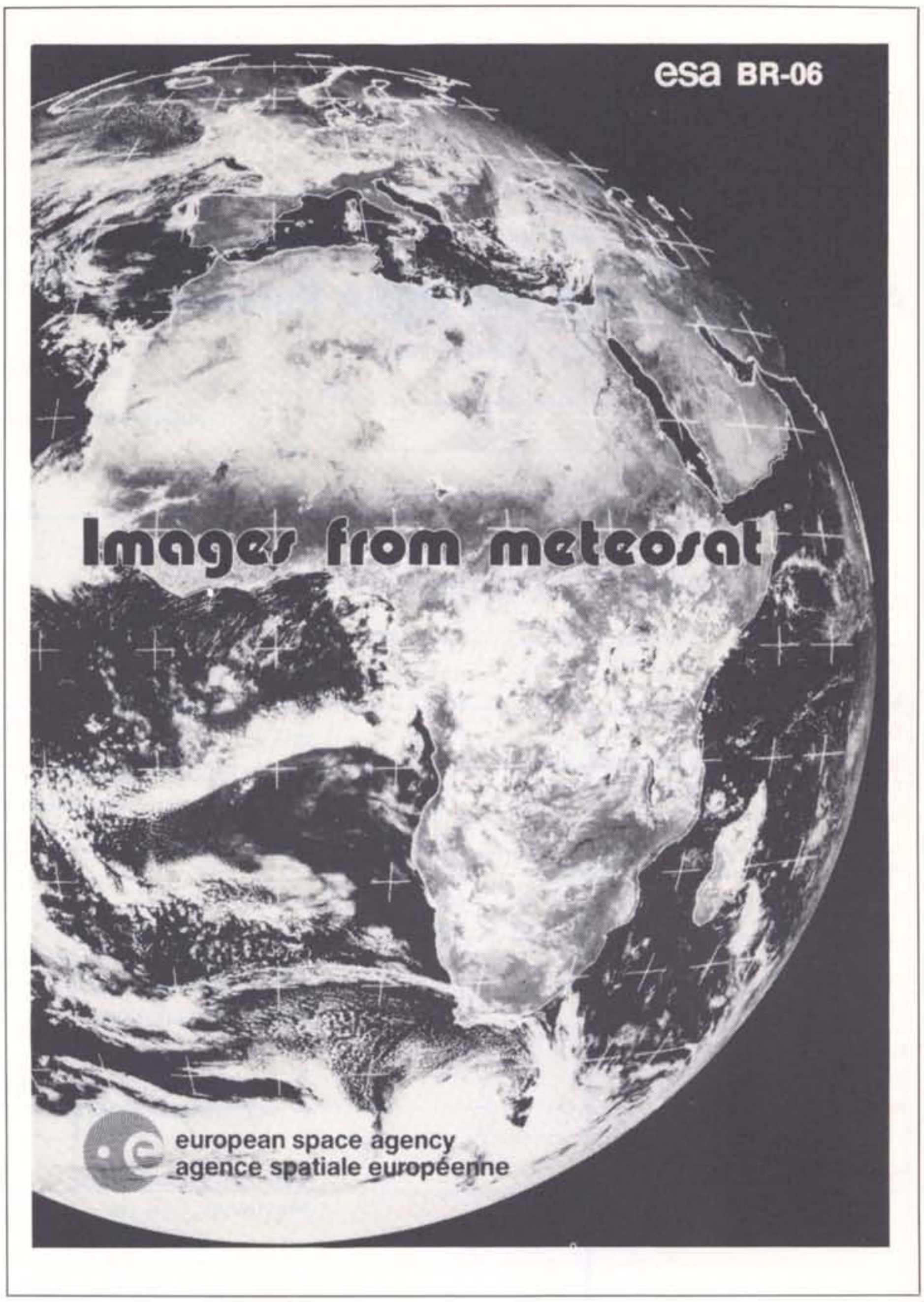

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