esa bulletin

number 30

may 1982

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

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

Director General: Mr. E. Quistgaard.

agence spatiale européenne

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

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

Directeur général: M. E. Quistgaard.

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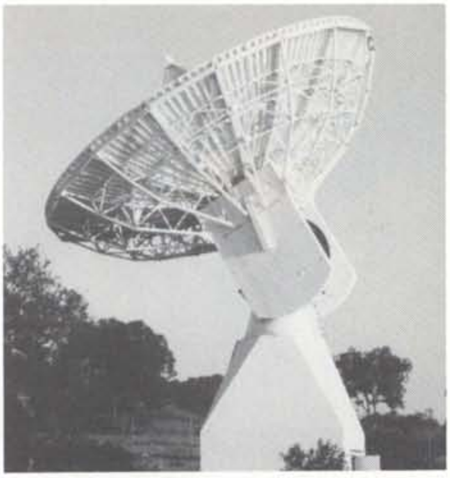

Front cover: The new 15 m S/X-band antenna at Villafranca (see page 21).

Back cover: An Ariane Viking motor injector under test (photo. courtesy of SEP).

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Le cadre institutionnel des nouveaux programmes de l'Agence spatiale européenne

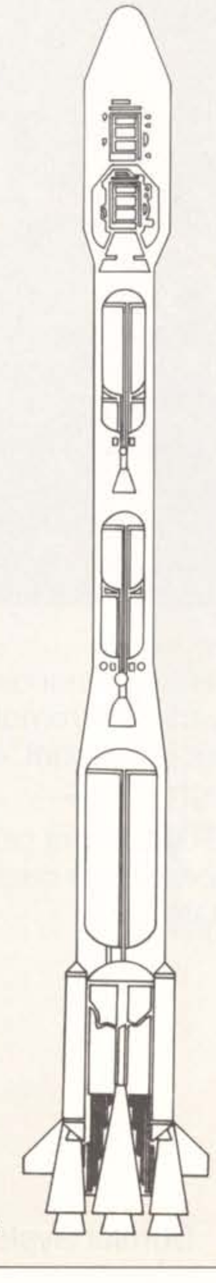
M. Bourély, Conseiller juridique, Agence spatiale européenne, Paris

Les récentes décisions prises par les Etats membres de l'Agence spatiale européenne à la fin de l'année 1981 et au début de 1982 ont eu pour effet de doter l'Agence d'un ensemble de programmes nouveaux et importants appelés à prendre la suite des programmes décidés il y a une dizaine d'années et qui sont actuellement en cours d'achèvement. Le développement du lanceur Ariane-4, le programme d'améliorations de Spacelab, la construction du satellite européen de télévision directe (L-Sat) et le programme d'observation de la Terre, autant de programmes dont l'importance technologique assurera la continuité de la présence de l'Europe dans les activités spatiales des années 1980 et dont le volume financier total prolongera l'effort entrepris dans la décennie qui vient de s'achever. Pour le juriste, le démarrage de ces programmes a été rendu possible grâce aux dispositions prévues par la Convention portant création de l'Agence spatiale européenne, dont il marque, pour la première fois et de façon spectaculaire, la mise en oeuvre complète.

Il est vrai que la Convention de l'ESA, signée le 30 mai 1975 et entrée en vigueur le 30 octobre 1980 seulement, avait déjà été appliquée 'de facto' pendant une longue période transitoire. Un certain nombre de programmes avaient été ainsi entrepris, mais il s'agissait, soit de compléter ceux qui avaient été décidés il y a dix ans, soit d'entreprendre de nouveaux programmes d'une taille relativement restreinte. L'intérêt des décisions récentes réside dans le fait que les nouveaux grands programmes qui viennent de commencer sont les premiers à être intégralement fondés sur les dispositions de la Convention de l'Agence.

On sait que la Convention du CERS/ESRO ne connaissait pas la distinction entre le *programme obligatoire* (programme scientifique) et les *programmes facultatifs* (programmes d'application) qui constitue la grande nouveauté institutionnelle de la Convention de l'Agence spatiale européenne. Au lieu d'avoir recours, comme autrefois, à des accords directs entre Etats (les Arrangements), ainsi que cela fut le cas pour les programmes de Télécommunications et de Météorologie, Ariane et le Spacelab, il suffit désormais aux Etats membres de l'Agence de suivre la procédure prévue par la Convention elle-même pour donner une valeur juridique à leur décision d'entreprendre un programme facultatif et fixer leurs droits et leurs obligations à cet égard.

Le système prévu par la Convention repose sur l'idée fondamentale que les programmes facultatifs sont des programmes de l'Agence elle-même. Celle-ci fournit donc le cadre dans lequel ils sont exécutés, en utilisant le personnel et les moyens matériels (établissements et installations d'usage commun) nécessaires. En revanche, ces programmes sont financés uniquement par ceux des Etats membres qui le désirent et qui sont appelés les 'Participants'. Il s'ensuit que seuls ces derniers auront leur mot à dire dans le processus de décision relatif à ces programmes. Pour mettre en oeuvre ce double principe, la Convention prévoit



Ariane-4

The Institutional Framework for ESA's New Programmes

The result of the decisions recently taken by the Member States of the European Space Agency, in late 1981 and early 1982, has been to give the Agency a set of new, major programmes that will take over from programmes that were decided upon some ten years ago and are now approaching completion. Development of the Ariane-4 launcher, the programme of Spacelab improvements, the building of the European direct-TV satellite (L-Sat) and the Earth-observation programme are all projects whose technological importance will ensure that Europe continues to occupy a place in space activities in the 1980s; the total investment they represent will carry on the financial effort made over the past ten years. Legally, the starting up of these programmes has been made possible by the provisions of the Convention for the establishment of the European Space Agency, and marks the first full – and spectacular – implementation of these clauses.

The ESA Convention, which was signed on 30 May 1975 but came into force only on 30 October 1980, had admittedly already been applied 'de facto' over a long transitional period. A number of programmes were undertaken in this way, but these involved either supplementing programmes that had been decided upon ten years previously or the starting of new programmes of relatively limited scope. The recent decisions are interesting because the new, large programmes just begun are the first to be based wholly on the provisions of the ESA Convention.

It will be remembered that the ESRO Convention did not distinguish between the *mandatory programme* (scientific programme) and the *optional programmes* (applications programmes), and this distinction is the new institutional feature of the ESA Convention. Instead of having to resort, as in the past, to direct Arrangements between States – these were used for the telecommunications, meteorological, Ariane and Spacelab programmes – all that the ESA Member States now have to do in order to give full legal force to their decision to undertake an optional programme and to set out their rights and obligations in this regard, is to follow the procedure laid down in the Convention itself.

The system provided for in the Convention rests on the basic idea that the optional programmes are programmes of the Agency itself. The latter thus provides the framework within which they are carried out, using the staff and physical resources (establishments and shared-use facilities) needed to do so. On the other hand, these programmes are funded solely by the States that want to do so, who are known as 'the Participants'; it follows that only these States will have a voice in reaching the decisions connected with the programmes. To put this two-fold principle into effect, the Convention provides for the use of three legal instruments:
First, a **Resolution** of the Council (sometimes called an 'Enabling Resolution'), by which Council agrees that the optional programme in question shall be carried out within the Agency framework;
Secondly, a **Declaration** subscribed to by the ESA Member States who want to undertake an optional programme together and within the ESA framework. Those who drafted the Convention sought to encourage the carrying out of such programmes by laying down that each Member State will be assumed to want to take part in each of the optional programmes unless it formally gives notice that it is not interested in doing so. Every Declaration contains a number of articles setting out the commitments of the Participants; it is accompanied by two annexes, one technical and giving a description in greater or lesser detail of the programme, its objectives, timetable, phases and so on, the other financial and defining the financial envelope for carrying out the whole of the programme and the scale of contributions to be paid. Two important comments need to be made about the financial annex:

- the *financial envelope* is an estimate, but is binding on the Participants. They agree, however, from the outset that it may be increased by up to 20% without the programme being jeopardised. If there is going to be an overrun greater than this, each Participant is entitled to withdraw from the programme.
- the *contributions* are, as a general rule, calculated on the basis of the net national income of the Participants, though the latter have the right to decide on some other scale for sharing expenditure. Such is in fact the case for the new programmes, apart from the Earth-observation programme.

l'intervention de trois instruments juridiques:

Une **Résolution du Conseil** (dite parfois 'Résolution habilitante') par laquelle celui-ci accepte que le programme facultatif envisagé soit réalisé 'dans le cadre de l'Agence'.

Une **Déclaration,** souscrite par les Etats membres de l'Agence qui désirent entreprendre en commun et dans le cadre de l'Agence, un programme facultatif. Les rédacteurs de la Convention ont voulu encourager l'exécution de tels programmes, en prévoyant que chacun des Etats membres est présumé participer à chacun des programmes facultatifs, à moins qu'il n'ait fait savoir formellement qu'il n'est pas intéressé à y participer. Chaque Déclaration contient un certain nombre d'articles définissant les engagements des Participants; elle est complétée par deux annexes, l'une technique donnant une description plus ou moins détaillée du programme, de ses objectifs, de son calendrier, de ses phases, etc., l'autre financière, définissant une enveloppe pour l'exécution de l'ensemble du programme et déterminant le barème des contributions. Deux remarques importantes doivent être faites à ce propos:

- *l'enveloppe financière* est estimative, mais elle s'impose aux Participants. Toutefois, ceux-ci admettent, dès le départ, qu'elle peut subir une augmentation de 20% sans que le programme soit remis en cause. Si le dépassement éventuel doit atteindre un pourcentage supérieur, chaque Participant sera libre de se retirer du programme;
- les *contributions* sont calculées en principe sur la base du revenu national des Participants, mais ceux-ci ont le droit de convenir tout autre barème pour la répartition des dépenses. Tel est d'ailleurs le cas pour les nouveaux programmes – à l'exception de celui d'observation de la Terre.

Un **Règlement d'exécution,** adopté par les Participants et qui contient les modalités détaillées dont ceux-ci sont convenus pour exécuter le programme, en particulier en ce qui concerne la prise des décisions nécessaires (désignation de l'organe délibérant compétent, règles de vote), ainsi que l'application – sous réserve d'exceptions expresses – des règles de l'Agence aux matières contractuelles, financières, etc. Ce Règlement prévoit aussi les conditions auxquelles certains Etats non membres pourront être admis à se joindre aux Participants pour la réalisation du programme en cause.

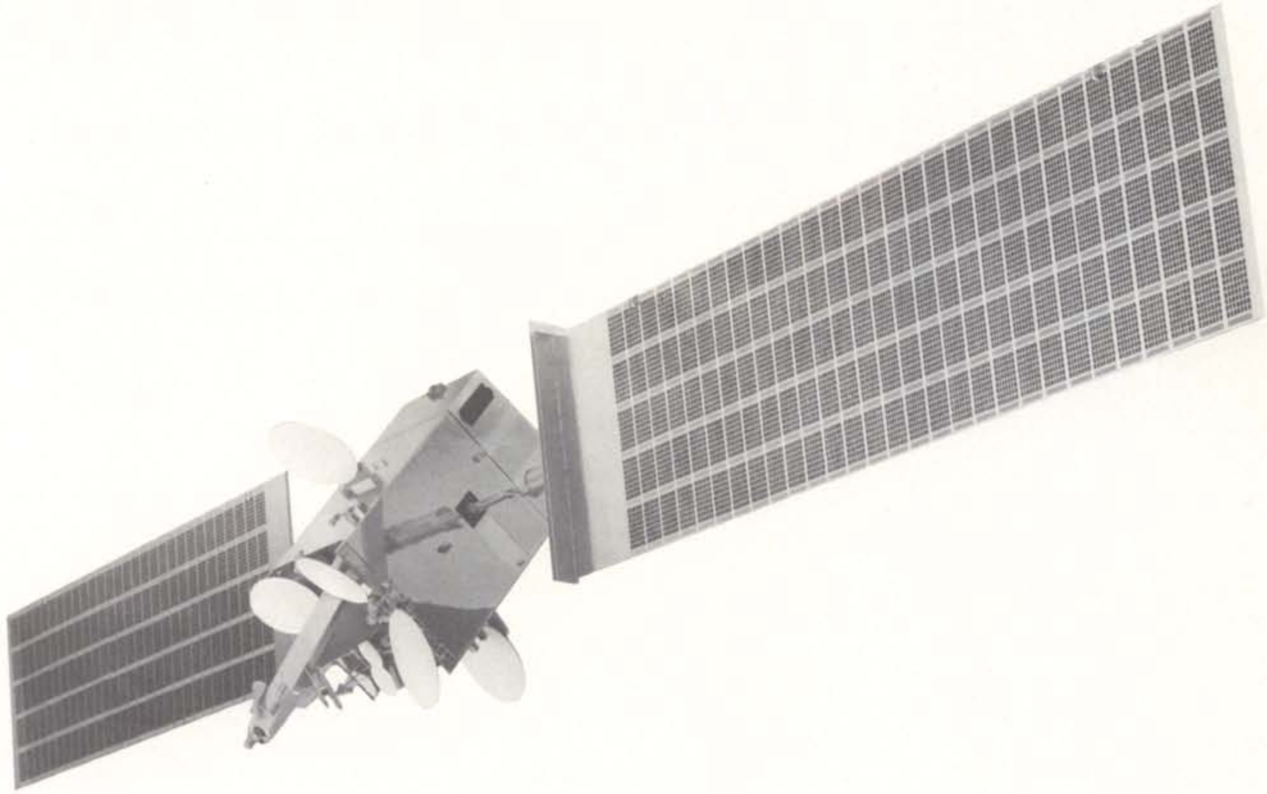
On indiquera enfin que la Résolution habilitante est votée par le Conseil (à la majorité simple) c'est-à-dire par tous les Etats membres, alors que la Déclaration – qui est elaborée et souscrite unanimement par tous les Participants – n'est soumise au Conseil que pour information. Quant au Règlement d'exécution, élaboré lui aussi par les Participants seulement, il doit être soumis à l'approbation du Conseil (à la majorité simple).

L'expérience acquise pendant la période de fonctionnement 'de facto' de la Convention a été mise à profit pour essayer de résoudre quelques problèmes qui découlent de cette procédure. Le principal d'entre eux est celui que pose le jeu de la présomption de participation mentionnée ci-dessus. Le délai de trois mois accordé par la Convention aux Etats membres pour se déclarer formellement 'non intéressés' est apparu parfois trop bref, étant donné que le Conseil est la plupart du temps sollicité de voter une 'Résolution habilitante', sans que les intentions de participation des Etats membres, ni les droits et obligations des futurs Participants, aient pu être fixés préalablement avec précision. D'où les efforts faits pour renverser la chronologie et pour tenter d'avancer la préparation des projets de Déclaration et de Règlement d'exécution en vue de disposer de textes à peu près définitifs au moment où le Conseil examine la Résolution habilitante. Un autre problème est celui de la liberté laissée aux Participants dans la rédaction des Règlements d'exécution, alors que la Convention les invite à prendre pour modèle les dispositions applicables à l'ensemble des programmes et activités, lesquelles ne devraient faire l'objet de dérogations que dans des cas exceptionnels. Il en découle, et souvent sans raison valable, un manque regrettable de cohérence dans l'exécution des divers programme. Enfin, dans le cas des programmes en cause, certains auraient souhaité, pour des raisons politiques, que l'adoption des instruments juridiques puisse avoir lieu au même moment pour les quatre programmes – ce qui n'a d'ailleurs pas pu être le cas.

Ces questions ont été longuement débattues ces derniers temps tant au Conseil et au Comité administratif et financier, qu'au sein des Conseils directeurs de programme existants. On ne peut dire que toutes les difficultés aient été surmontées, mais il a été reconnu par tous que les inconvénients signalés plus haut pourraient être réduits par l'adoption d'une procédure-type tendant à les atténuer grâce à des mesures d'ordre pratique, telles que la tenue de réunions préparatoires, réunissant les participants potentiels aux nouveaux programmes de façon à ce que le Conseil puisse être effectivement saisi de l'ensemble des instruments juridiques prévus par la Convention.

Ces discussions ont en tout cas permis de souligner la grande souplesse du nouveau système institutionnel qui a incontestablement facilité l'adoption des nouveaux grands programmes facultatifs qui seront exécutés dans le cadre de l'Agence.

The L-Sat spacecraft.



Thirdly, **Implementing Rules** are adopted by the Participants; these set out in detail the way the Participants have agreed the programme shall be carried out, in particular as regards the taking of the necessary decisions (designating the body empowered to take decisions, laying down voting rules and so on) and the application – unless expressly excluded – of the Agency's rules on contractual, financial and other matters. These Implementing Rules also stipulate the conditions under which certain non-Member States may be allowed to join the Participants in carrying out the programme in question.

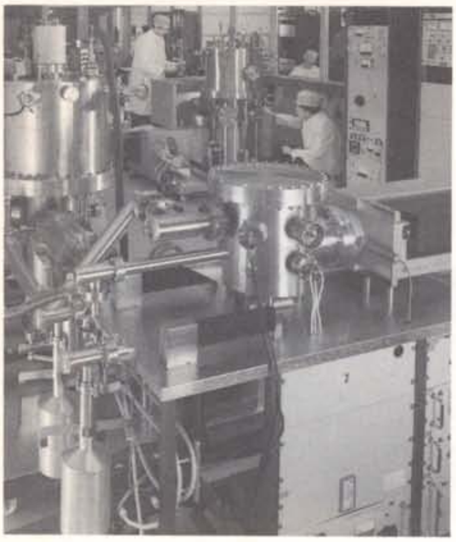
It may be noted that the Enabling Resolution is voted (by a simple majority) by Council, that is to say by all the Member States, while the Declaration – drawn up and subscribed to by all the Participants acting unanimously – is submitted to Council only for information. The Implementing Rules, which are likewise drawn up by the Participants alone, have to be submitted to Council for approval (by a simple majority).

The experience gained over the period when the ESA Convention was in force 'de facto' has been drawn on in trying to solve a number of problems that arise from this procedure. Principal among these is that posed by the effects of the presumption of participation, mentioned earlier; the period of three months within which, under the Convention, Member States have to state formally that they are 'not interested' has sometimes been found to be too short, bearing in mind that Council is often asked to vote an 'Enabling Resolution' before it has been possible to discover with any accuracy either the intentions of the Member States as to participation or the rights and obligations of the future Participants. It is this that has led to efforts to reverse the sequence, and to try to bring forward the preparation of draft Declarations and Implementing Rules so as to have texts available in their virtually final form at the time the Enabling Resolution is being discussed by Council. Another problem is that of the latitude left to Participants in drafting the Implementing Rules, bearing in mind that the Convention calls on them to take as their model the provisions applying to all the programmes and activities, from which there should be departures only in exceptional cases. The result, often for no good reason, is a regrettable lack of coherence in the carrying-out of the various programmes.

And finally, in the case of the programmes in question, certain people would for political reasons have liked it to have been possible for the legal instruments to be adopted at the same time for all four programmes; this was not in fact the case.

These questions have been discussed at length in recent times, both in Council and the Administrative and Finance Committee and in the existing Programme Boards. It cannot be said that all the problems have been overcome, but it has been recognised that all the drawbacks just described could be lessened by adopting a standard procedure; this would improve matters by practical measures such as the holding of preparatory meetings, bringing together the potential Participants in the new programmes so that Council could be presented, at the same time, with all the legal instruments called for under the Convention.

These discussions have in any case highlighted the great flexibility of the new institutional system, which has, unarguably, made it easier to adopt the major new programmes to be carried out within the ESA framework.



The European Space Tribology Laboratory – The First Ten Years

H.M. Briscoe, Power & Control Systems Division, ESTEC, Noordwijk, The Netherlands

The European Space Tribology Laboratory (ESTL) was created by ESA, in its former identity as ESRO, early in 1972 and, after a tender action, was set up at the United Kingdom Atomic Energy Authority (UKAEA) establishment at Risley, England. The Laboratory is operated by the National Centre of Tribology, itself part of UKAEA, under contract from the Agency. In February 1982 it will have completed ten years of operation and it is useful, and one hopes informative, to review its development, and perhaps look into its future activity as one of the Agency's established facilities.

An article describing ESTL appeared in ESA Bulletin No. 6, in August 1976, and it is not the intention of the author to repeat all that was written there. The purpose of this article is more to review the progress of the laboratory over the ten years of its operation with particular emphasis on some recent developments.

Since the word tribology, although now an established branch of technology, is not likely to be familiar to many readers of this publication, we should perhaps define it. It was coined in the UK in 1966 as a portmanteau word to bring together two surfaces moving in contact, and therefore embraces bearings, lubricants, surface physics, electrical contacts, special coatings, oil technology and self-lubricating materials. It is thus a truly interdisciplinary subject of great complexity.

Its importance in space engineering becomes readily apparent when some of the special problems are understood. The high vacuum of space, involving the absence of oxygen, and thus the protective oxide surfaces, leads also to rapid evaporation of many liquid lubricants. Unprotected surfaces in high vacuum can easily weld together with catastrophic results, even if the load intensity is quite low, and so any two surfaces in a space environment in relative motion constitute a tribological problem.

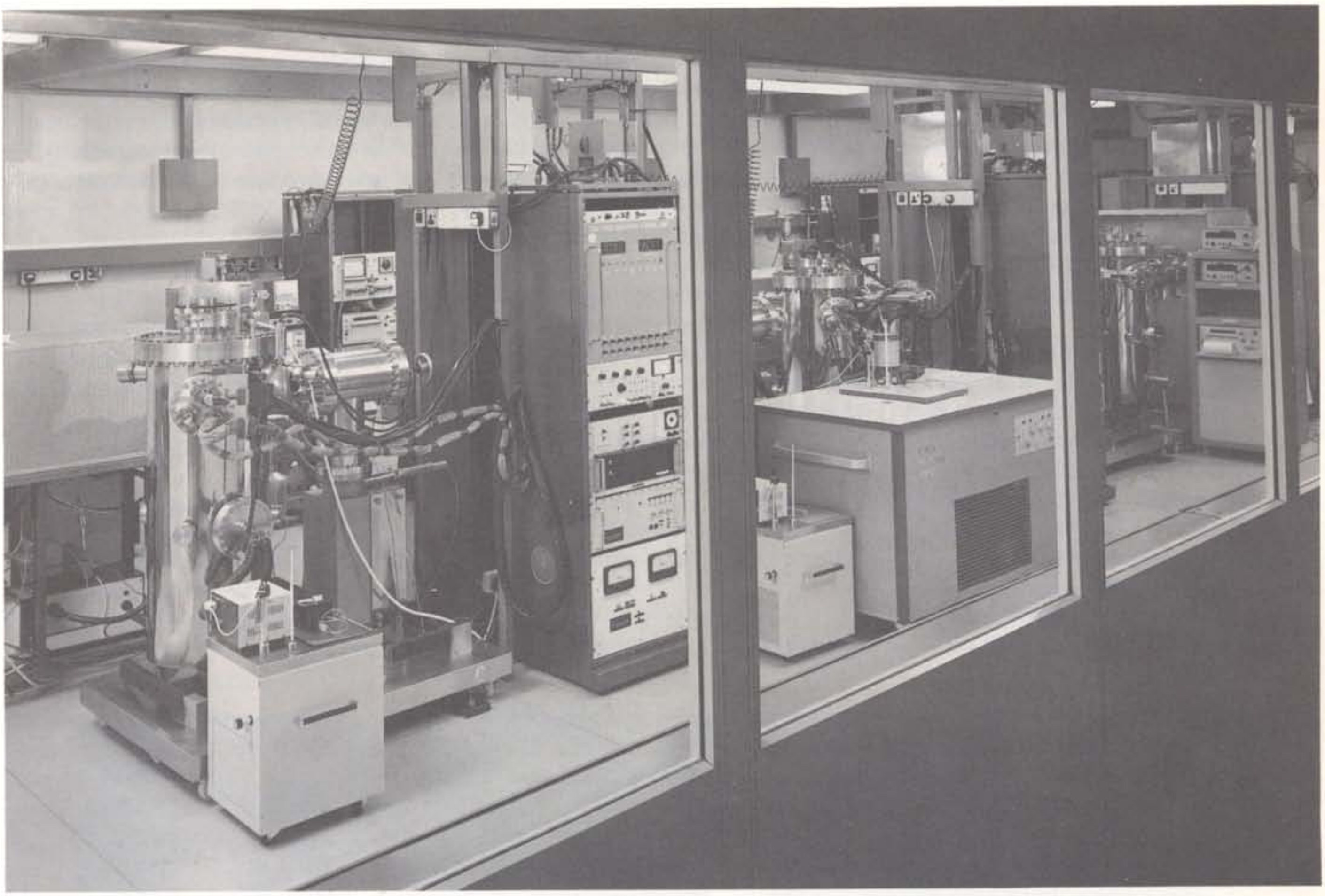
Of course many of these problems are very simply solved if the action occurs only once, such as in solar-panel or boom hinges which operate only during deployment, but for critical mechanisms which must operate throughout the life of a communication satellite, for example, the tribological problems are critical. Such satellites are now aiming for lives of ten to twelve years operation throughout which solar-panel drives, antenna pointing mechanisms, momentum wheels and sensors must operate faultlessly. Satellites for Earth resources surveying with equally long life requirements bring the additional problem of the scanning system in the optical instrument. All of these machines are totally dependent upon the efficacy of the tribological systems applied to them, which can only be assured, firstly by developing and testing the lubrication systems required and, secondly by testing the complete mechanism under conditions which rigorously simulate the conditions in space. ESTL has been created, equipped and developed to fulfil both of these requirements.

The laboratory is run on a series of four-year contracts, the first of which ended in 1976 and the second in 1979. The present contract runs until the end of 1983 when it is expected to be renewed for a further period of four years. In 1972 contracts of four years duration were a novelty in the Agency but it was considered that a laboratory of this type must enjoy a stable existence which would enable it to undertake long-term testing without interruption. In the event, the decision has been fully substantiated and it is not too much to say that it has contributed significantly to the enterprise's success.

The growth of the laboratory and its equipment

From the very beginning the laboratory

Figure 1 – General view of the Laboratory from the observation corridor, as it was in 1973.



was conceived as a self-contained clean room and this decision has not only never been regretted, but has shown itself to have been fundamental to its success (Fig. 1). Without strict control of cleanliness at least half the work done in the laboratory would be impossible. The initial equipment consisted of six 40 cm diameter vacuum chambers pumped by ion pumps to guarantee cleanliness. Since an essential element in space-mechanism testing is to be able to drive a rapidly varying and reversible thermal gradient through the machine, all chambers are fitted with thermal shrouds and radiating pancakes which may be independently controlled. Additionally eight small chambers without thermal shrouds were installed to allow testing of small items, such as slip rings or bearings, under high vacuum.

Before the laboratory had been in operation for two years it became clear that larger chambers were necessary, and two 60 cm diameter units were installed, which rapidly established themselves as the main workhorse facilities of the laboratory.

By 1975 it was realised that the initial size of the laboratory had been much too modestly planned for the equipment necessary to carry out the programme. The cramped conditions made Product Assurance activities very difficult and hazard to personnel became a reality. As a result a decision was taken to double the size of the laboratory and with the cooperation of the National Centre of Tribology (UK Atomic Energy Authority) an area alongside was cleared. By very careful planning the original air conditioning system was made to serve the enlarged laboratory without reducing the standard of cleanliness.

At the same time the NCT (UKAEA) extended the building at the rear to provide office accommodation, storage and a small instrumentation workshop. The net result, which was completed in early 1977, was to make a unified laboratory system dedicated to space tribology unique in the world.

The Agency's involvement in larger satellites, particularly the solar-array system for Space Telescope, showed that the testing of larger mechanisms was to become an urgent requirement. The nature of the tests themselves was also changing to make greater demands on the equipment and techniques required.

Figure 2 — The new ESTL extension, with the 1 metre diameter chamber.

The need for a larger chamber was accepted and a study made, in 1978, to determine how best to meet the need. A proposal for a chamber 4 m long by 2 m in diameter was abandoned after lengthy study on the grounds of initial cost and expense in operation, and a compromise solution was reached for a 1 m diameter, top-hat-type chamber pumped by cryo pumps.

Very quickly it became clear that to install a chamber of this size into the laboratory would re-create the overcrowding of 1975 and render it unmanageable and hazardous, so once again it was necessary to consider a further extension. Again the National Centre of Tribology cleared a space alongside and the extension was planned, but this time the existing air conditioning system could not be further stretched and the need for a new system became manifest. The final decision was for an independent extension with a dedicated air-conditioning unit, separate from the existing laboratory but connected to it by a large double door. This was completed mid 1980, and the new chamber installed and commissioned early in 1981 (Fig. 2).

The needs for improvement and updating in such a laboratory never, however, became completely static and certain other developments are now in progress. The confirmation of the L-Sat programme raised an immediate need for two more 60 cm diameter chambers, but to satisfy the requirement a scheme to increase the size of two of the 40 cm chambers is being implemented to make maximum use of existing equipment.

Another activity is the creation of a special test facility for antenna pointing mechanisms in one of the existing 60 cm chambers. The requirements for testing this type of mechanism are very stringent since it is necessary to measure to 0.001 degree in two axes under thermal vacuum conditions, possibly throughout the whole period of the test.

As part of this test facility and, ultimately, as a service to the whole laboratory the opportunity is being taken to update the somewhat primitive and inadequate data handling system to a modern computerised system.

If any of my readers have gained the impression from this history that the laboratory is in a permanent state of expansion and the next ten years will see it treble its present size, I can say that by the end of 1982 the size and equipment

should be adequate to meet the demands on its services for a period of four to six years. Beyond that it is difficult to predict what the space programme in Europe is going to be and what its needs may be, but the laboratory will be ready to meet them.

Mechanism test programme
A review of all the mechanisms that have been tested in the laboratory to date numbers more than fifty. This may not seem to be an impressive number, but it must be remembered that even the simplest test may occupy a chamber for three or six weeks and two real-time life tests which will complete seven years continuous operation in 1982, occupy two of the 40 cm chambers.

The tests may be divided into four categories:
- qualification tests
- acceptance tests
- life tests, which in some cases may be accelerated
- development tests.

In each case the fundamental requirement is to simulate realistically the thermal vacuum conditions experienced by the mechanism when operating on a satellite in space, which will certainly include thermal gradients as well as varying temperature levels. To render the test effective from a tribological point of view it is important to exclude oxygen and other active gases to prevent the formation of protective oxides on surfaces. To this end it is necessary to reduce the partial pressure of oxygen in the system to 10^{-10} torr.

The rationale for carrying out meticulously controlled tests on mechanisms was explained at some length in Bulletin No. 6, but such an essential element in the achievement of reliability in a hostile environment is worthy of brief reiteration. An essential prerequisite to reliable mechanism design is the recognition of every failure mode which it may experience and, if possible, their elimination. Many of these modes of failure are easily recognised and avoided, but many others depend upon subtle interactions of physical phenomena at molecular level and are very difficult to predict. Clearly the only method of ensuring that they have been avoided is representative testing over the required life of the machine. In the case of dry-lubricated machines we have now adopted and validated a system of accelerated life tests by increasing the operating speed by a factor which, in some cases, may be as high as twenty-four. But in the case of liquid-lubricated systems no such easy way out of the difficulty exists since any change of speed at once changes the operating regime of the lubricant and invalidates the test.

There are two real-time life tests in progress at ESTL, both of which will have completed seven years of operation in the course of 1982. One of them is a solar-array drive unit rotating at one revolution per day and thermally cycled to simulate operation during eclipse of the satellite. It is supported on a pair of lead-lubricated ball bearings and has a unique slip-ring system made on a ceramic glass disc. It is intended to stop the test during the year and strip and examine all the elements of the machine.

The other is a despin mechanism for the antenna of a spin-stabilised satellite rotating at 60 rpm. It is supported on two grease-and-oil-lubricated bearings and has both a slip-ring system and two rotating transformers for power and signal transmission. Both of these mechanisms have performed almost faultlessly over the seven years.

Of course such real-time life tests are also tests of the monitoring equipment itself and although there have been incidents of failure none of them has been serious enough to make it necessary to abandon a test programme. All the 60 and 40 cm chambers have the facility to change a vacuum pump without breaking the vacuum, but the reliability of the ion pumps is so good that it has never been necessary to do it.

All of the Bearing and Power Transfer Assemblies (BAPTAs) for the OTS and Marecs satellites have been qualified and acceptance tested at the laboratory, as well as those for Exosat and the Indian Apple satellite (Fig. 3). Two 40 cm chambers are indefinitely alloted to this programme.

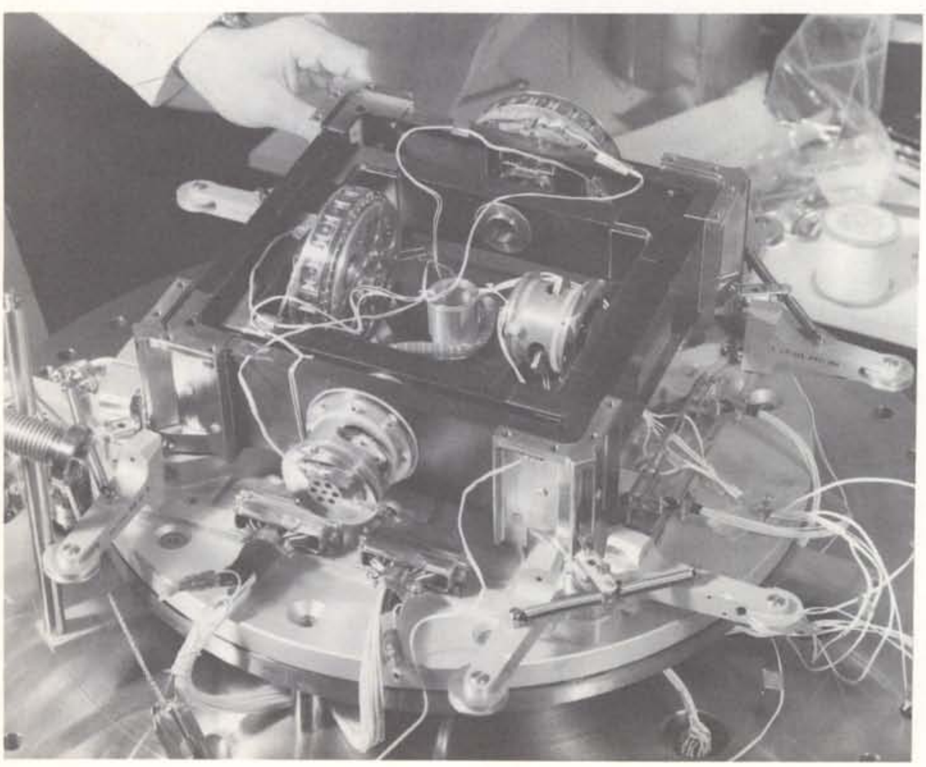
The value of thermal vacuum testing of mechanisms has been clearly demonstrated and substantiated by the number of potential failure modes revealed, a few of which may be quoted as examples:
- motor rotor touching the stator
- incorrect flexure of the diaphragms preloading the bearings when exposed to low temperature
- inadequate torque or mis-stepping of motors at low temperature
- excessive slip-ring noise
- failure of an optical encoder due to thermal cycling.

These incidents should not be interpreted as reflections on the competence of the manufacturers of the mechanisms but rather as demonstrations of the efficacy of thermal vacuum testing in revealing build variations from mechanism to mechanism.

Some examples of other mechanisms that have been qualification or acceptance tested at the laboratory include an antenna pointing mechanism developed in Germany by Dornier System (Fig. 4). The performance of this machine was measured to some 30 arc seconds throughout a thermal vacuum life test, during which it performed faultlessly. Other mechanisms include actuating devices for the Space Telescope, both double and single gimballed momentum wheels, the focussing and filter mechanisms for the Faint Object Camera and a fast-acting shutter mechanism for Culham Laboratories, which illustrates the variety of devices which are presented for test.

Figure 3 — Modified BAPTA with 1200 steps per revolution, ready for test.

Figure 4 — The Dornier System antenna pointing mechanism being prepared for test.



An entirely different job done for Fokker was the development of a method of cleaning and lubricating, with a controlled thickness of vacuum oil, the cables for the mechanism used to extend and retract experiments from the airlock on Spacelab. The technique has been thoroughly tested in the laboratory and is now used more widely to ensure controlled, clean lubrication for cables in spacecraft.

Finally it should be said that all of these tests are carried out under the surveillance of the product-assurance (PA) support which has been established at ESTL, under the guidance of the specialists at ESTEC. The PA system in the laboratory complies fully with the Agency's PA requirements and is subject to audit on this subject by both ESTEC and contractor's PA inspectors. It is claimed to be the only test house in Europe which complies to the letter with the Agency's PA system and every effort is made to ensure that the standard is maintained.

The development programme at ESTL

It was pointed out in Bulletin No. 6 that a very important part of the activities at ESTL was the maintenance of a programme of development in space tribology in support of ESA programmes. In 1972 the need for such development was very obvious and incontravertible and it is useful to review the results ten years later and also to examine the role of such a development programme in the eighties.

One of the most important and significant developments has been in the application of lead films to bearings for space operation. When the laboratory was started the use of lead for the lubrication of bearings in vacuum had been well established and much significant test data were available, but the method used to deposit the film of lead was not sufficiently controllable to ensure consistent film thickness. In consequence a method of depositing the film, called 'ion plating' was developed at the laboratory and tests with the resulting films showed them to be thinner, more consistent and more adherent than the vacuum-deposited films. The process has been further developed and tested and has been fully codified and documented as a standard procedure. The importance of formalising the process in this way cannot be over-emphasised since it is the only way of ensuring repeatability and of meeting the product-assurance requirements. All of the bearings in the BAPTAs for OTS, ECS, Marecs, Exosat and L-Sat are lead plated, as will be those being used in the French Spot satellite solar-array drive. Other applications are bearings in the Space Telescope's Faint Object Camera and Solar Array, the tilting mechanism on Exosat and ball-screw actuators flying on Nimbus. The most recent application is to the bearings of the despin mechanism for Giotto, the satellite which will intercept Halley's comet. The process is also being applied to gears which will be used in the L-Sat solar-array drive. It is now so well established that at least one American space firm has adopted it for their mechanisms, but they have set up their own ion-plating facility.

A second development activity has been slip-ring systems, where much work has been done on testing the wear rate of competing brush materials, one of which was a hot-pressed material developed by the Agency. Work is now in progress to determine the role of silver-sulphide contamination on slip rings and to measure and evaluate the noise. This problem is perhaps the last in achieving slip rings of totally predictable performance for slow-moving systems. However, for faster turning mechanisms in the 5 to 100 rpm range wear rate and noise are still problems requiring solution and there is much work in progress and much remains to be done.

A problem which is almost unique to space flight is that of the torque and torque noise in bearings rotating at very, very slow speeds, since this is not a duty which ball bearings are normally required to perform. For solar-array drives, gimbal systems and pointing mechanisms a thorough understanding of the bearing behaviour is imperative. A method of predicting the torque of a slowly rotating bearing has been developed and validated at the laboratory, supported by extensive experiment.

A problem which arose on the Primary Deployment Mechanism of Space Telescope showed that a slowly oscillating pair of bearings exhibited an increase in torque which eventually blocked the rotation. The study of this phenomenon led to an extended test programme both in Switzerland and at ESTL, until ESTL finally traced the problem to a very small axial misalignment, which was also shown to be systematic.

Some years ago the Agency had designed and built by NLR, Netherlands, a rig to measure the heat transfer through a rolling bearing both whilst stationary and moving. The results obtained have been published and appear to be unique in the world. The same rig is now being used to measure heat transfer across a large-diameter, thin-section bearing required for the L-Sat antenna pointing mechanism.

Several years ago, Montedison in Italy introduced a new polyfluoralkylether oil with a very high viscosity index and an extremely low vapour pressure, both properties which are very attractive for use in space. The oil, designated Z25, is now the subject of a careful programme of evaluation in bearings running in vacuum. At present its use is limited to very slow speed bearings until its behaviour under conditions of elasto-hydrodynamic lubrication are more firmly established. The vapour pressure is so low that it is possible to foresee its use in critical optical systems as a lubricant for focussing mechanisms.

The above is just a sample of some of the more important developments made or under study in the laboratory and is not an exhaustive list. Work is also in progress on gear lubrication, cage instability in ball bearings, dry-film lubrication and the evaluation of two space oils available from BP Ltd.

Looking towards the future it is clear, at least to a tribologist, that a continuing development programme is essential. But whereas in the past the aim has been to provide and to validate space lubrication systems to enable the mechanisms to operate with an acceptable reliability, the aim in the future must be to reduce the cost of space lubrication systems without in any way decreasing their validity. Some commercially available systems may be used in space in short-life systems, but it is essential to evaluate and validate them under representative conditions before they may be recommended. This validation must be repeated at intervals since manufacturers change the formulation of their products without notice. The objective must therefore be to reduce the cost of the lead lubrication process, to validate completely a small number of liquid lubricants, to document and codify the sputtering process for molybdenum disulphide and to continue the evaluation of cheap commercially available systems where relevant.

Regarding the need for new developments in space lubrication we can at once recognise the growing interest in the operation of mechanisms at cyrogenic temperatures down to 4° Kelvin. Work is already in progress but at present it is not known how long a life any of the common dry-lubricant systems can sustain at that temperature; and today extended life is the most important single requirement for a space system.

ESTL as consultant

One of the original objectives in creating ESTL was to provide an expert consultancy service to be available to the space industry of Europe. The ability to provide such a consultancy does not arise spontaneously on the inauguration of the laboratory, but must grow and mature as experience grows. The policy has been to maintain, as far as practicable, the same individual staff over the life of the laboratory, to allow the experience to accumulate and to mature. The result has been to create a body of expertise unequalled in Europe, and possibly in the world, in the testing of space mechanisms and in the tribology which is essential for their successful operation in space.

Considerable theoretical work has been done to establish programmes to calculate bearing torque at low speed under varying conditions of preload, and also to predict preload changes resulting from thermal gradients. These programmes can be run at short notice in response to enquiries from customers, even over the telephone. To improve the speed of response and to remove the formalities of purchase orders or contracts, the first ten hours of consultancy is free of all charges.

Because ESTL is operated by the National Centre of Tribology the extent of the consultancy service available is broader than space tribology alone. The total of experience to support it is substantial and embraces such special areas of competence as metallurgy, the chemistry of lubricants, hydrodynamic bearing theory and the tribological behaviour of self-lubricating plastics.

For the future the Agency would like to see greater use made of this fund of knowledge and ability and also perhaps to extend it into the more general field of mechanism design. The tribology characteristics of any mechanism are an integral part of its design and cannot be considered separately. An advisory consultancy on design, where a customer can bring a mechanism design for an unbiased assessment by specialists of wide experience, could help to prevent some of the more prevalent misconceptions which regularly occur; again the first ten hours of service would be free of charge.

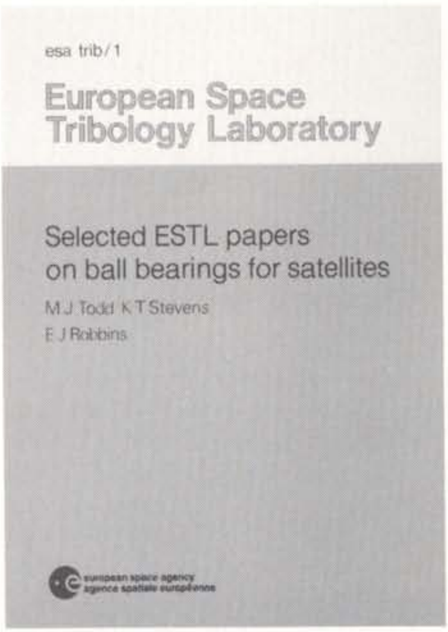
Figure 5 — Examples of reports emanating from ESTL.

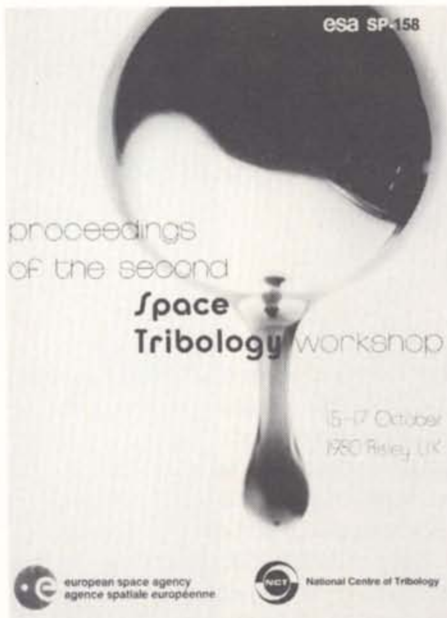
Publications

Publish or disappear into obscurity: such is the fate of university researchers and a similar judgement can overtake any specialist laboratory. At ESTL, however, very little real research is done and development and evaluation are more suitable words to describe the activities of the laboratory, which nevertheless must be reported and recorded. At the time of writing 52 reports have been issued, excluding those referring to mechanism tests carried out for contractors on ESA projects. All of these reports have been distributed in the Agency's Contractor Report series and have found their way into international bibliographies. In addition 33 Technical Notes have been issued reporting minor experiments or work not yet complete, and in a few cases work which should not be widely published due to commercial confidentiality. Under normal conditions the Technical Notes are distributed only within the Agency.

About eighteen months ago it was proposed to inaugurate a new series of Agency publications called the Trib series. These include collations of selected work from the laboratory which is judged to be of permanent value, although the series is not limited to the reporting of ESTL work. So far the first four of the series have been published and two others are in preparation for publication during the first half of 1982. Collectively, the series will constitute a permanent record of significant contributions to space tribology.

Information about any of the above





reports may be obtained from the Agency's Scientific and Technical Publications Branch at ESTEC.

Two workshops have been held at ESTL, the first in 1978 and the second in October 1980. The Proceedings of the latter, 'The Second Space Tribology Workshop', are available as an ESA Special Publication, SP-158, also from ESA Publications Branch (Fig. 5).

Conclusions

The act of setting up and operating a laboratory specialised in space tribology was an imaginative and courageous initiative of the Agency which might have become a liability. The fact that it has already been necessary to extend it on two occasions and that its present reputation for competence and integrity is unquestionable must stand as confirmation of its success. The foreseeable programme will certainly keep ESTL fully occupied during the coming two years and, if the space programme matures as anticipated, it will continue to be the centre of space tribology in Europe and can develop into a centre of space-mechanism design.

Clearly, however, major efforts must be made to reduce the cost of mechanism development and testing, which essentially means doing the same work with fewer people. This is easy to say but not easy to achieve when it is realised that space engineering will never enjoy the benefits of mass production and demands a reliability of performance higher than in any other machine. This is the challenge of the eighties and the future development of ESTL will be guided by the precept that more out of less is better.

The Meteorological Product: 'Cloud-Top Height'

R.A. Bowen, Meteosat Data Management Department, European Space Operations Centre (ESOC), Darmstadt, Germany

Integrated meteorological processing of Meteosat data is routinely performed at the European Space Operations Centre in Darmstadt. Unlike the other products of the system, Cloud-Top Height (CTH) maps are disseminated via the satellite for capture by users for visual analysis. The method of presentation is therefore of considerable importance; both this and the method of extraction had reached an acceptable standard when the imagery mission of Meteosat-1 came to an end in November 1979, and it is hoped to be able to provide a similar product based on Meteosat-2 data in the near future.

The Meteosat series of satellites normally produce three images simultaneously every half an hour at different wavelengths and at two different resolutions*. The infrared (11 μm) and water-vapour (6 μm) channels produce images of 2500 × 2500 pixels, whereas the visible (0.4 – 11 μm) channel produces 5000 × 2500 (or 5000) pixels. The water-vapour imaging is not always switched on and not all of these images and channels are used for the product discussed here.

The absolute minimum requirement for the product is one IR image; the quality improves significantly if the corresponding WV image is available and used. The corresponding VIS image is employed for manual qualitative analysis of the product before despatch to the customers. The adjacent images in time can be used for the same purpose, but shortage of manpower and time limits this. However, they can – if available – be used retrospectively for post-mortem analysis.

What the customer sees

An early decision was to output the product in the same standard format as Automatic Picture Transmissions (APT) and WEFAX meteorological transmissions, which utilise 800 × 800 points of digital data. By compressing the original Meteosat data of roughly 2500 × 2500 pixels by four in each direction, the resulting presentation of the product can be inserted in such an APT/WEFAX format with space around the edges for comments and grey scales. The resulting amalgam of 4 × 4 original pixels at IR resolution is referred to as a 'super pixel'. This means that the resolution of the product at the subsatellite point is just under 20 km, and at southern European latitudes just under 30 km.

For visual understanding it was felt that eight grey levels would be best and these have been chosen to show clouds above 12 000 m elevation, decreasing in steps of 1500 m to above 3000 m, with the last step reserved both for clouds below 3000 m in elevation and for locations with no cloud at all. Thus the CTH product only shows, and distinguishes between levels of, cloud above 3000 m. This is compatible with the concept of utilising this product primarily for aviation purposes, for which it was felt that location of the highest clouds would be of greatest interest.

Figure 1 is a reproduction of an actual APT chart of the CTH product. It was derived from the Meteosat data which is displayed in Figure 2 in a way that is probably more familiar to readers.

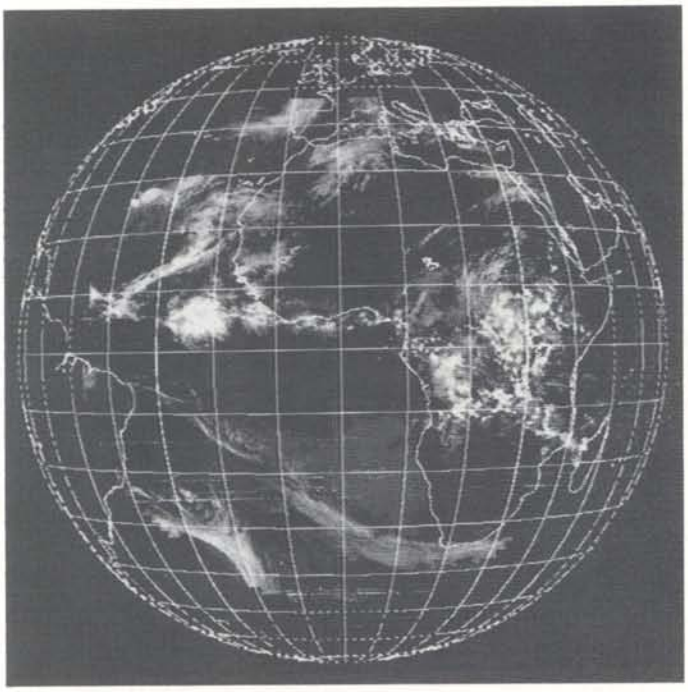
Meteorological computations

Because Meteosat observes radiances and not distances, the overall concept of the Integrated Meteorological Processing (IMP) is to consider many segments of the field of view, and then to group observed radiances in each of these into so-called 'clusters' of like data. The IMP yields background (ground or sea) cluster data for the infrared channel and the equivalent value for the water-vapour channel. The latter is used to apply a correction to the radiances to allow for cloud semi-transparency. These background values are used by the

* At the time of going to press, a reduced mode of operation is in effect (image-taking once every 3 h) whilst a radiometer anomaly is investigated. Image quality is not affected.

Figure 1 — Cloud-Top Height (CTH) picture received by a user equipped to receive an APT chart. The image was replayed from tape, giving rise to noise in the south west Atlantic. Note the sharp cut-off of results at 50° great circle from the subsatellite point (SSP) just south of the English Channel.

Figure 2 — The Meteosat images from which Figure 1 was derived. (a) and (b) are the 6 µm and 11 µm channel images; (c) is the corresponding visible image. Interestingly the height of the cloud band near Cape Town is in the 7.5–9 km range, whereas over the mid-Atlantic it is 12 km or more. The patchy cloud off the coast of Africa rarely extends above 4.5 km.



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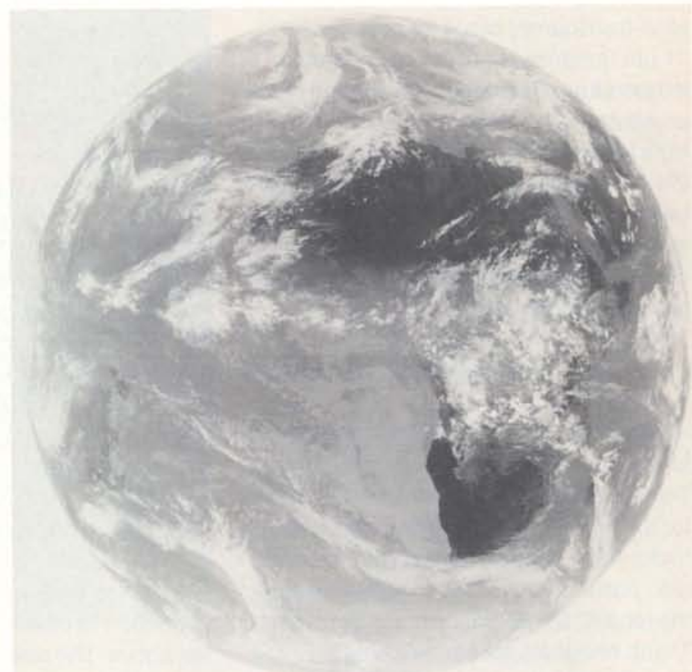

2a

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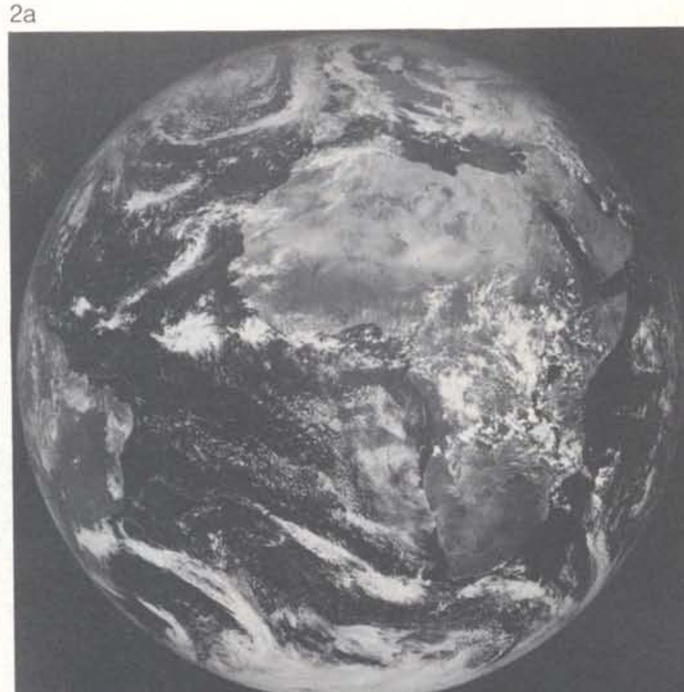


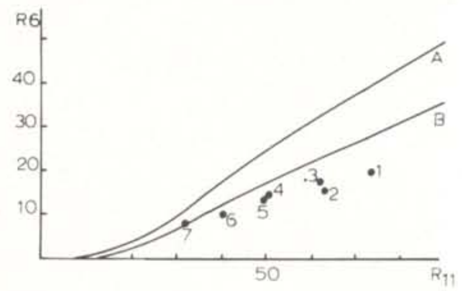
2c

cloud-top-height product for the same purpose, as explained below.

What values are actually given to the user? The principle is to determine the lowest radiance in the super pixel described above and to associate a height with this value. It is not sufficient to merely take the lowest radiance found; during nominal processing the average radiance of the super pixel is corrected for semi-transparency and if found to be lower than any of the individual values it is used in preference to any of the original 16.

The semi-transparency correction
The problem is that high clouds are often

*Figure 3 — Typical relationship between 6 μm and 11 μm responses with a few observations shown (for more details see Cayla & Tomassini**).*



semi-transparent cirrus for which the 11 μm radiance is not directly related to temperature. One needs knowledge of the emissivity of the cloud and the radiation from lower levels. It is postulated* that at the frequencies measured reflectivity is relatively unimportant and that a measured radiance (R_m) is related to cloud radiance (R_c) and the background radiance (R_b) by

$$R_m = T * R_b + (1-T) * R_c \qquad (1)$$

where T is a normalised transparency factor related to the wavelengths. Cayla & Tomassini** argue, following Hunt, that for the wavelength used the transparency factor is the same for both channels. It is also postulated that the contribution to the measured radiances of the 6 μm and 11 μm channels above the cirrus is relatively stable and can be expressed as an empirical function

$$R_{6c} = G(R_{11c}) \qquad (2)$$

Given two measurements A and B, the relation between the 6 μm and 11 μm cloud radiances where the transmissivity at both frequencies is the same, can be expressed as

$$\frac{R^A_{11m} - R^B_{11m}}{R^A_{6m} - R^B_{6c}} = \frac{R_{11c} - R^B_{11m}}{R_{6c} - R^B_{6m}} \qquad (3)$$

This means that if the background value is available, we can relate observed measurements to cloud and background radiances in a very simple, linear manner:

$$(R_{11} - B_{11}) * (C_6 - B_6) = (C_{11} - B_{11}) * (R_6 - B_6) \qquad (4)$$

where B is a background radiance, C a cloud radiance and R the observed radiance.

To resolve this, the function given in Equation 2 is used, the function G being found by experiment to have the form shown in Figure 3. This curve is rather more dependent on the absolute calibration constants of the radiometer than is convenient, and so provision is made for regular updating with the calibration constant used elsewhere within the IMP. It is also dependent on the zenith angle. The Meteosat-1 product did not take this latter factor into account.

All of this is only applicable to semi-transparent cirrus clouds and so care has to be taken not to apply the correction to other clouds when no cirrus lies above. The response of the 6 μm channel when observing space is known. When considering the water-vapour radiance observed from the Earth's disc, it is possible to say with some certainty that the observed radiation comes from a solid 'body' such as a thick cloud or a semi-transparent cloud. This test is applied conservatively in that the correction will only be applied when thin cirrus is definitely present. More tuning of the method is needed in this area, so as to come nearer to the limits of its applicability without any danger of 'correcting' a thick cloud.

The correlation between the resulting lowest radiance and height is established using look-up tables constructed by the IMP in a routine manner, taking into account surface features, climatology and incoming forecasts.

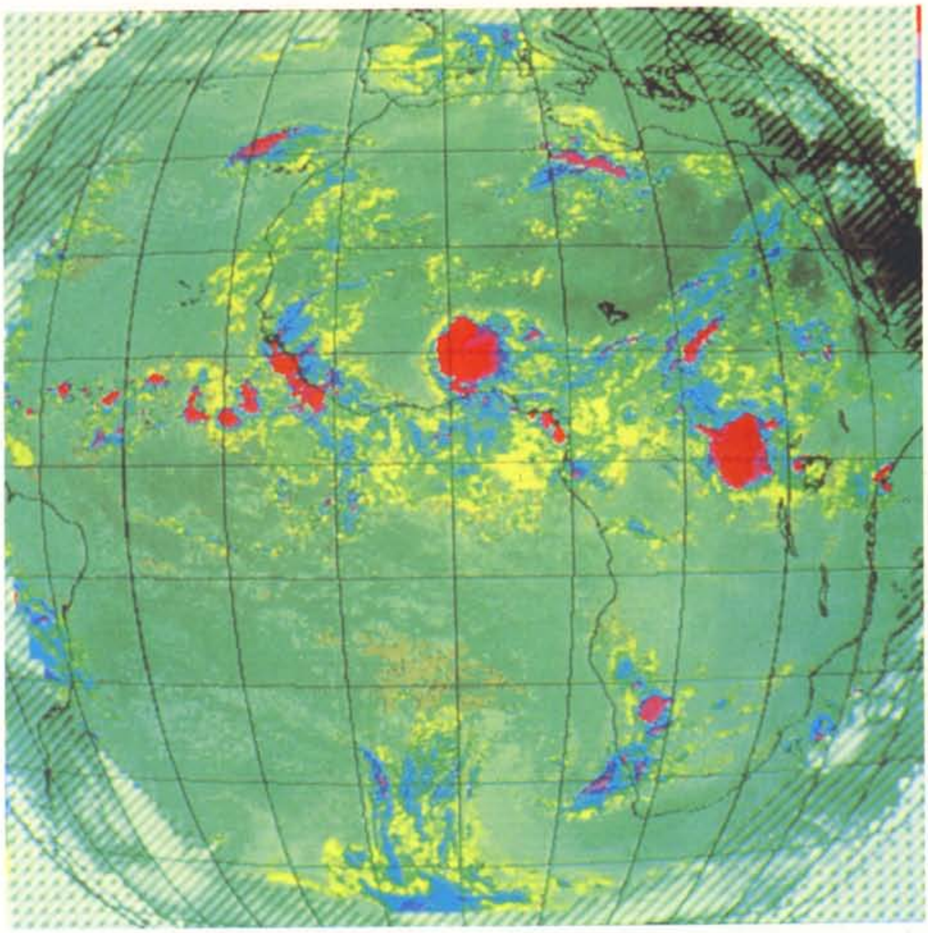
Quality control

Those familiar with the other ESOC Meteorological Information Extraction Centre (MIEC) products will be wondering if there is any on-line product control quality. The answer is yes; it is performed simply, by a meteorologist using the MIEC interactive display system. Here the results of the processing tasks can be displayed as a coloured image, showing the tops of eight separate cloud layers in contrasting colours. This coloured image can be superimposed on the relevant grey-scaled infrared, water-vapour or visible image (Fig. 4) and an animation loop displaying any combination of these three overlaid images in quick succession can be obtained. This animation technique, together with a zoom facility (Fig. 5), enables the meteorologist to readily compare the CTH results with the original images, and to delete results for any areas that are considered anomalous. To delete an erroneous value, a similar technique to that used for the other MIEC products is applied. A cursor is moved on the screen to the position of an incorrect value, and a keyboard-activated command superimposes a small black square (very similar to those in Fig. 6).

Computer-produced printout can also be used as an additional aid in this process. It is essential when developing the programs. Two families of printout exist: one in which the grey level is given specifically and one in which a representation of the grey level is given by overprinting various characters to give a tone on the paper. It is possible to show the whole disc results or those for a limited area with more resolution. Figure 7 shows the computer printout for the whole disc corresponding to the results in Figure 1. By repeating each value across the page, the Earth appears more round than would otherwise be the case and it allows both the original value and superimposed grid value to be displayed if desired. Such a printout is given in Figure 8.

* Hunt, G.E., Radiative properties of terrestrial clouds and infrared thermal window wavelengths, Quart. J. Roy. Meteorol. Soc., Vol 99, No. 420, April 1973.

** Cayla, F.R. & Tomassini, C., Determination of the temperature of semi-transparent cirrus, ESA Special Publication SP-143, October 1979.



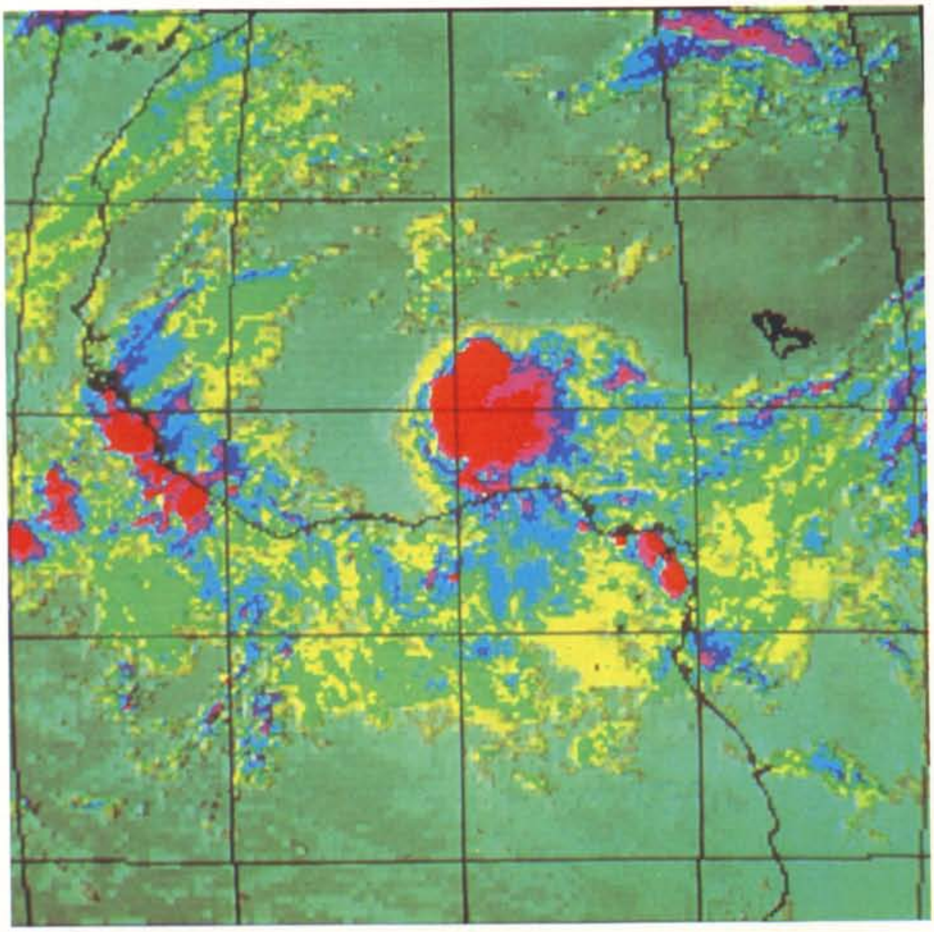


Figure 4 — Cloud-top-height results superimposed on the relevant infrared image. The hatched regions are outside the normal processing area.

Figure 5 — A zoom of Figure 4 showing the results over the Gulf of Guinea and surrounding areas of West Africa in more detail. The tops of cumulonimbus clouds are indicated in red.

Production schedule

Clearly, for optimum use of the data, the time lapse between acquisition of the image by the satellite and availability of the CTH product to users should be a minimum. With present planning it should be possible to have available for dissemination around 12.40 pm the CTH chart derived from the Meteosat images taken between 10.00 am and 10.25 am and to repeat this cycle four times a day at six-hourly intervals.

State of the art

What, then, are the limitations? The height association depends, of course, on how well the conversion table has been set up, which in turn depends on how well the automatic system has behaved and how good the forecasts are, and locally on the correctness of the baseline climatology. Work is proceeding in all of these fields and improvements here will, from time to time, reduce inaccuracies.

The main purpose of the product is to provide aircraft pilots with an interpreted image in which the height of the cloud tops is clearly shown. It would also be useful to know if the clouds whose tops are given are cumulonimbus or merely cirrus. This distinction is not made at present.

The CTH product does not have the resolution of the visible image, but when used in conjunction with such images the user should be able to obtain even more useful information. With Meteosat-1, the CTH product was only available for a short period, so that no continuous use was made of it. It is hoped that, after a trial period with Meteosat-2, users' suggestions for improvement can be incorporated.

The algorithm for finding the representative radiance of a super pixel

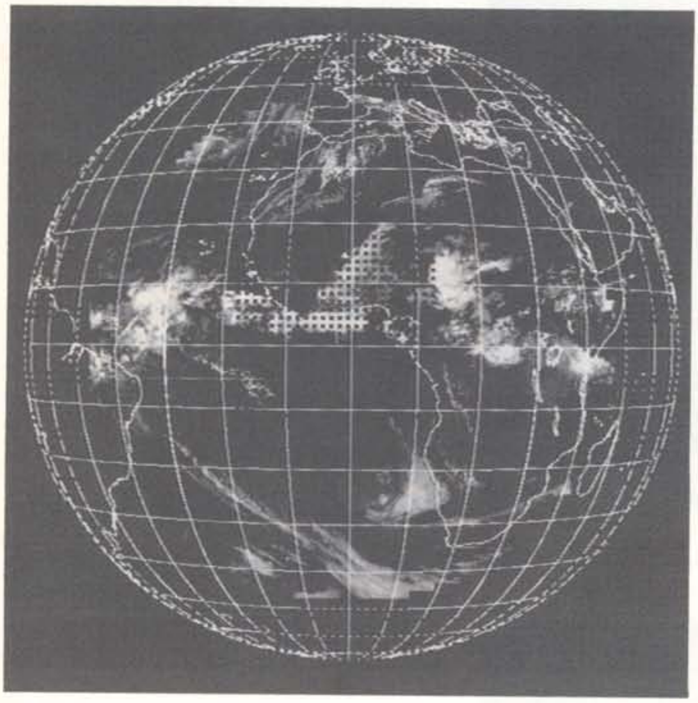


Figure 6 — Cloud-top-height product after quality control. For demonstration purposes a large area of cloud over the Gulf of Guinea and surrounding areas has been deleted. The small squares are half the size of a segment, cover a quarter of its area, and are centred on the segment centre. When interpreting the results it is important to realise that the area just outside the black squares has also been rejected by manual quality control.

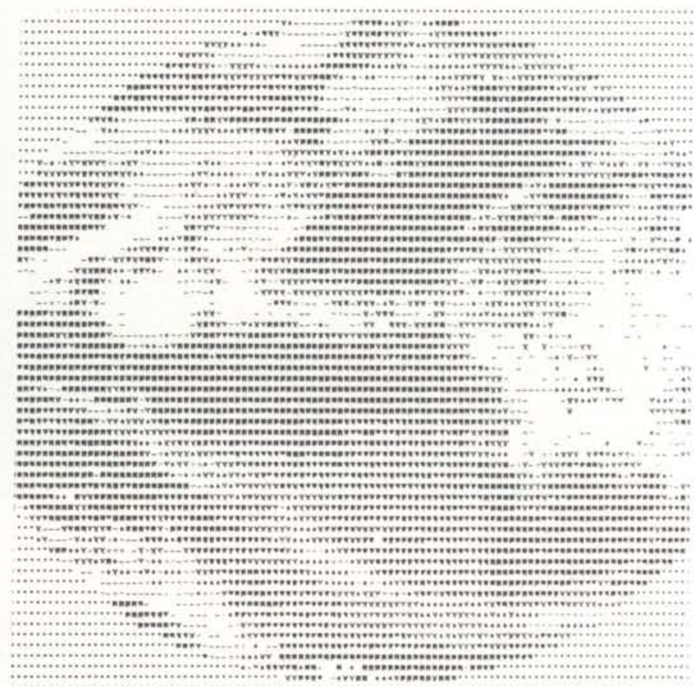


Figure 7 — Computer representation of the CTH picture in Figure 1, obtained by selecting the highest level in a set of 8 × 8 APT pixels (super pixels). The noise on the original image played back from the tape is responsible for the spurious results over the south west Atlantic. The absence of tone corresponds to cloud tops above 12 000 m while the darkest tone corresponds to no clouds or cloud tops below 3000 m.

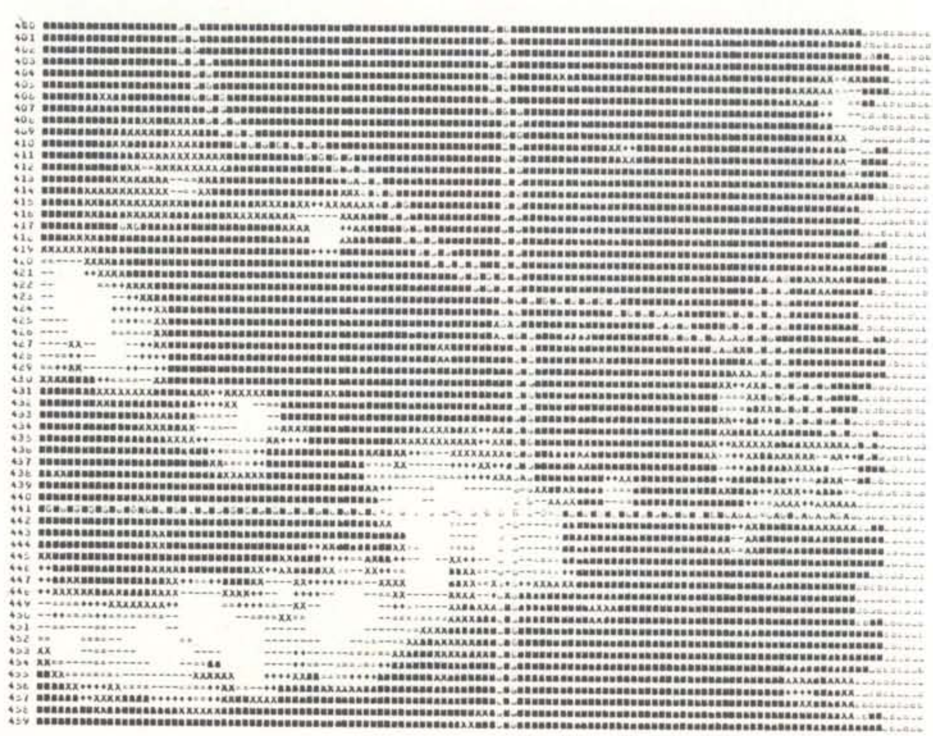


Figure 8 — Section of computer printout showing CTH. The resolution is that of super pixels which are repeated across the page. The superimposed coastlines and grids 'G' are only shown on one of the two print positions. The area shown is that around Sao Luis in South America, in the usual ESOC projection with the North Pole at the foot of the page and east to the left. (Meteosat-2, 11 March 1982, 14.00 h).

was originally chosen in order to minimise computer time. This restriction is no longer an overriding factor, and it is hoped to investigate other possibilities for obtaining the representative radiance and to check if the results obtained thereby are significantly better.

Acknowledgement

The Meteosat CTH product is by no means the work of the author alone. Help has come from many sources within the MET team and from other colleagues at ESOC, and only by regular discussion with the operators responsible for quality control has the present stage of product development been reached.

ESA's New Standard 15 m S/X-Band Antenna – First Installation at Villafranca

P. Maldari, Ground-System Engineering Department, European Space Operations Centre (ESOC), Darmstadt, Germany

Acceptance testing of the first of a new series of 15 m antennas designed for transmission and reception at S-band, and possible extension to simultaneous X-band reception, has recently been completed. Designed to meet a wide spectrum of operational requirements, the antenna is capable of very high slew rates and accelerations, together with accurate tracking and pointing. Its design combines high gain with good sidelobe suppression. The antenna is fitted with a defocussing mechanism which allows tracking of low-orbiting satellites in near-zenith passes. The first unit of this type has been installed at the Agency's Villafranca del Castillo ground station, near Madrid, and a second one is presently being procured for the Carnarvon ground station in Australia.

The need for a new antenna standard
The World Administrative Radio Conference held in Geneva in 1979 redefined the frequency bands to be used for future space applications. The results of the Conference reflected the tendency to gradually reduce the use of VHF bands and reinforced the preference for the use of higher frequency bands. In particular, the S-band (sub band c) and the X-band (sub band c) were selected for future Earth-orbiter and deep-space missions.

On this basis ESA took the decision to expand its ground-support network so as to permit operations in the newly selected bands while maintaining its existing VHF operational capabilities for a transitional phase (until 1990). This implied the development of new station-equipment

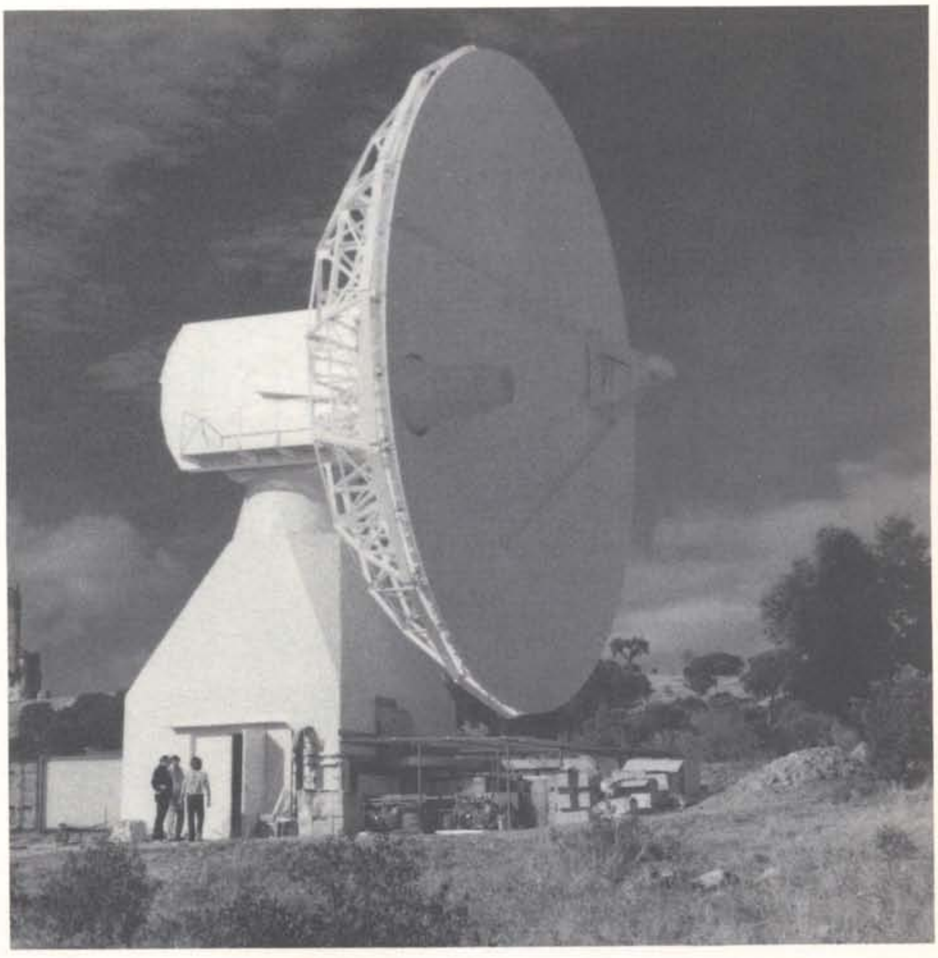


Figure 1 – The Villafranca 15 m antenna installation

concepts, centred upon an antenna whose characteristics were to be determined by the types of missions to be supported in the bands allocated.

In particular, the dynamic performance specifications for the antenna mount (e.g. angular accelerations and slew rates in azimuth and elevation) have been derived from the need to track satellites in low Earth orbit, whereas the radio-frequency performance characteristics of the antenna have been imposed by the need to operate satellites in highly eccentric Earth orbits.

Given the required antenna radio-frequency performance characteristics (in particular the system figure of merit G/T and the required station EIRP) an analysis of available and potential low-noise and high-power amplifier technology and the related costs, have led to the selection of a 15 m diameter main reflector on the basis of lowest costs for the requisite performance.

The first antenna of this design is installed at ESA's Villafranca ground station (Fig. 1). This antenna, presently equipped with S-band support capabilities only, has been designed for later extension to X-band. The frequency bands supported by the final configuration will include S-band transmissions (2025–2120 MHz), S-band reception (2200–2300 MHz) and simultaneous X-band reception (8025–8500 MHz).

Antenna architecture

The main elements of the antenna structure (Fig. 2) are the reinforced-concrete tower and the moveable mechanical structure, anchored to the tower by the antenna pedestal.

The prime goal of the mechanical design has been to achieve a stiff yet light mechanical structure able to meet the imposed pointing-accuracy requirements under adverse environmental conditions (temperature variations and wind loadings), and to maximise acceleration and slew rates by minimising the moment of inertia of the rotating elements. This has led to a compact design in which the rotating masses are concentrated around the two antenna axes (azimuth and elevation), and to the choice of aluminium for the dish structure (Fig. 3).

Adequate housing has been provided for electronic equipment in the antenna

Figure 2 – Antenna architecture

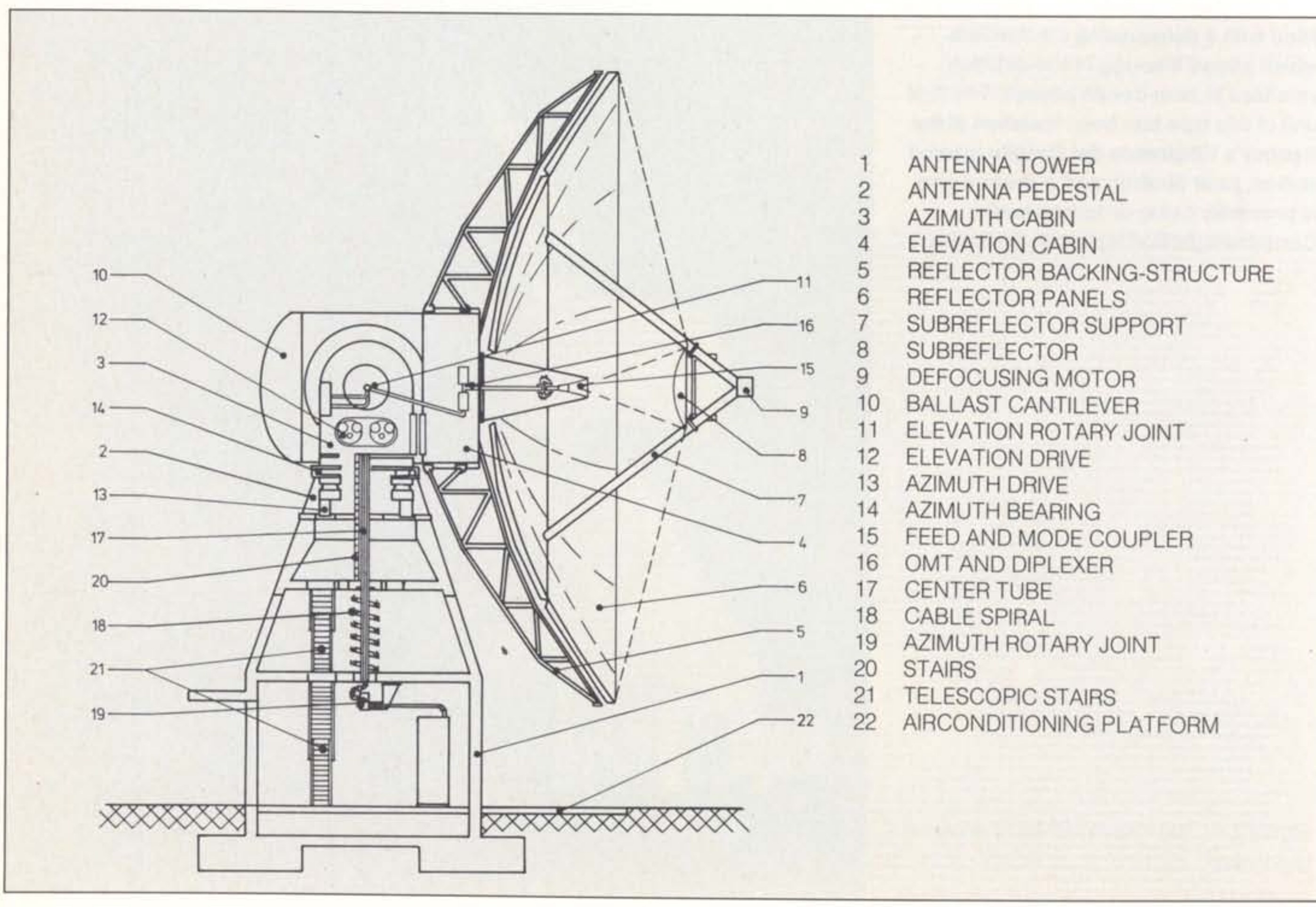
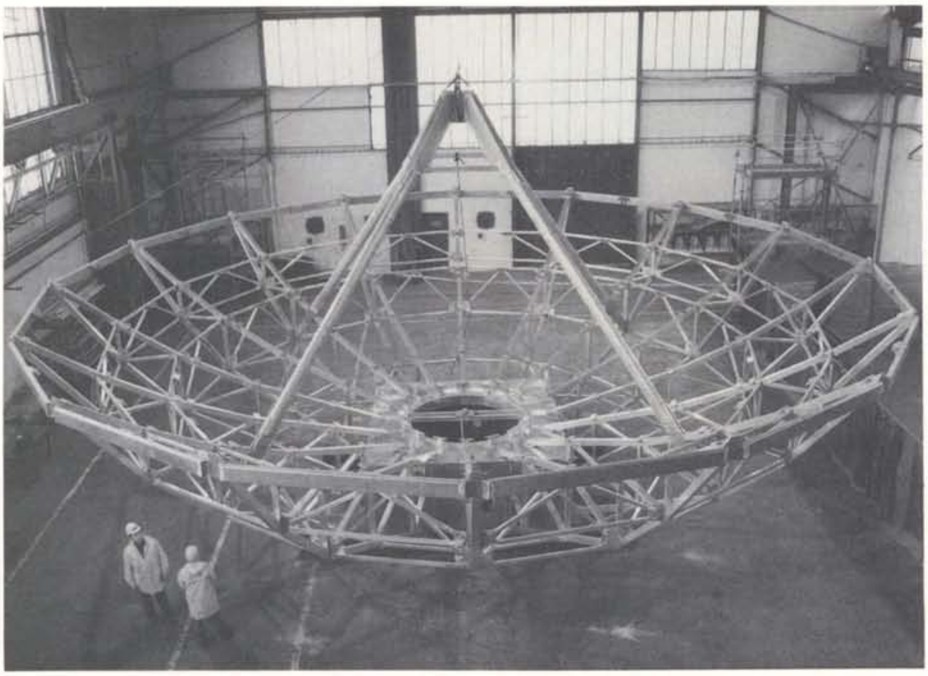


Figure 3 — The antenna backing structure, preassembled at the factory (Krupp) for final adjustment before disassembly and shipment

Figure 4 — Antenna-basement layout



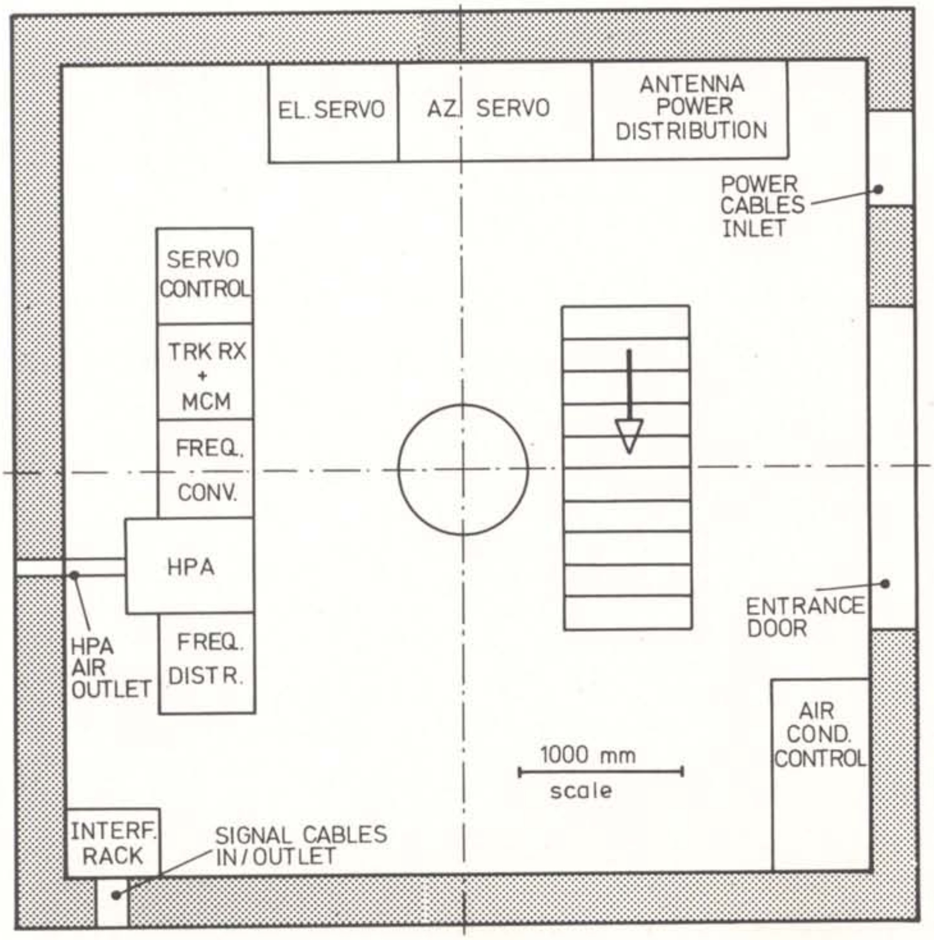


Table 1 — S-band performance specifications for the Villafranca antenna

RF/IF performance

Receive frequency band	2200 – 2300 MHz
Transmit frequency band	2025 – 2120 MHz
Receive polarisations	All
Cross polarisation	Better than 25 dB within the 3 σ tracking error
Transmit polarisation	Left or right-hand circularly polarised, switch selectable
Receive gain to the LNA input	47.6 dB
Transmit gain from HPA output	46.5 dB
Receive G/T at zenith position	27.5 dbB/K, assuming LNA noise temperature of 55 K and LNA gain of 45 dB
Sidelobe envelope	Below recommended CCIR mask
Isolation between transmit and receive band	Better than 100 dB
Receive output signals	Left-hand and right-hand circularly polarised
Receive IF frequency	67.6 MHz
Receive IF bandwidth	40 MHz
Transmit IF frequency	230 MHz
Transmit IF bandwidth	5 MHz

Servo and tracking performance

Azimuth slew range	720°
Azimuth slew rate (maximum)	15°/sec
Azimuth acceleration (maximum)	7.5°/sec^2
Elevation slew range	184°
Elevation slew rate (maximum)	5°/sec
Elevation acceleration (maximum)	2.5°/sec^2
Overall pointing accuracy	0.03°
Antenna pointing modes	– Monopulse autotrack – Programme track – Manual pointing – Manual slewing – Hand crank
Autotrack system sensitivity	As required to operate within the specified pointing accuracy down to a satellite-signal flux density of – 169 dBW/m^2

basement (Fig. 4) and in the elevation cabin. All antenna rooms and cabins are air-conditioned, to ensure stable operation of the electronics.

Radio-frequency system

The main elements of this system, including its interfaces to the antenna servo-control system, are shown in Figure 5.

A far-field Cassegrain dual-reflector design has been selected, the 15 m diameter paraboloidal main reflector having a focal depth/diameter ratio of 0.32. The hyperboloidal subreflector has a diameter of 1.95 m.

Both reflector surfaces are shaped to maximise the gain of the antenna in the two frequency bands of interest. This shaping (taking into account the feed design) allows the sidelobe radiations to be reduced to a level below that recommended by the CCIR (Comité consultatif international des Radiocommunications).

The feed system (the feed horn and its mode couplers) provides good reflector illumination characteristics and allows tracking error signals to be derived if the antenna is not accurately aligned with the signal source (the satellite). The choice of an integrated feed and mode-coupler design allows a high feed efficiency (maximum antenna gain) to be combined with low cross-polarisation losses.

During the various phases of their missions satellites present the antenna with a wide variety of signal characteristics, depending upon the spacecraft's attitude and aspect angle with respect to the ground station. This makes it necessary to be able to receive reliably signals with all possible polarisations. Reliable commanding is achieved under the worst conditions by being able to select the polarisation of the transmitted signal independently from that of the received signal.

These requirements have been met by using an orthogonal-mode hybrid which decomposes the received signal into two components. The power in these two components then depends only on the polarisation of the incoming signal. This allows the antenna tracking system to be

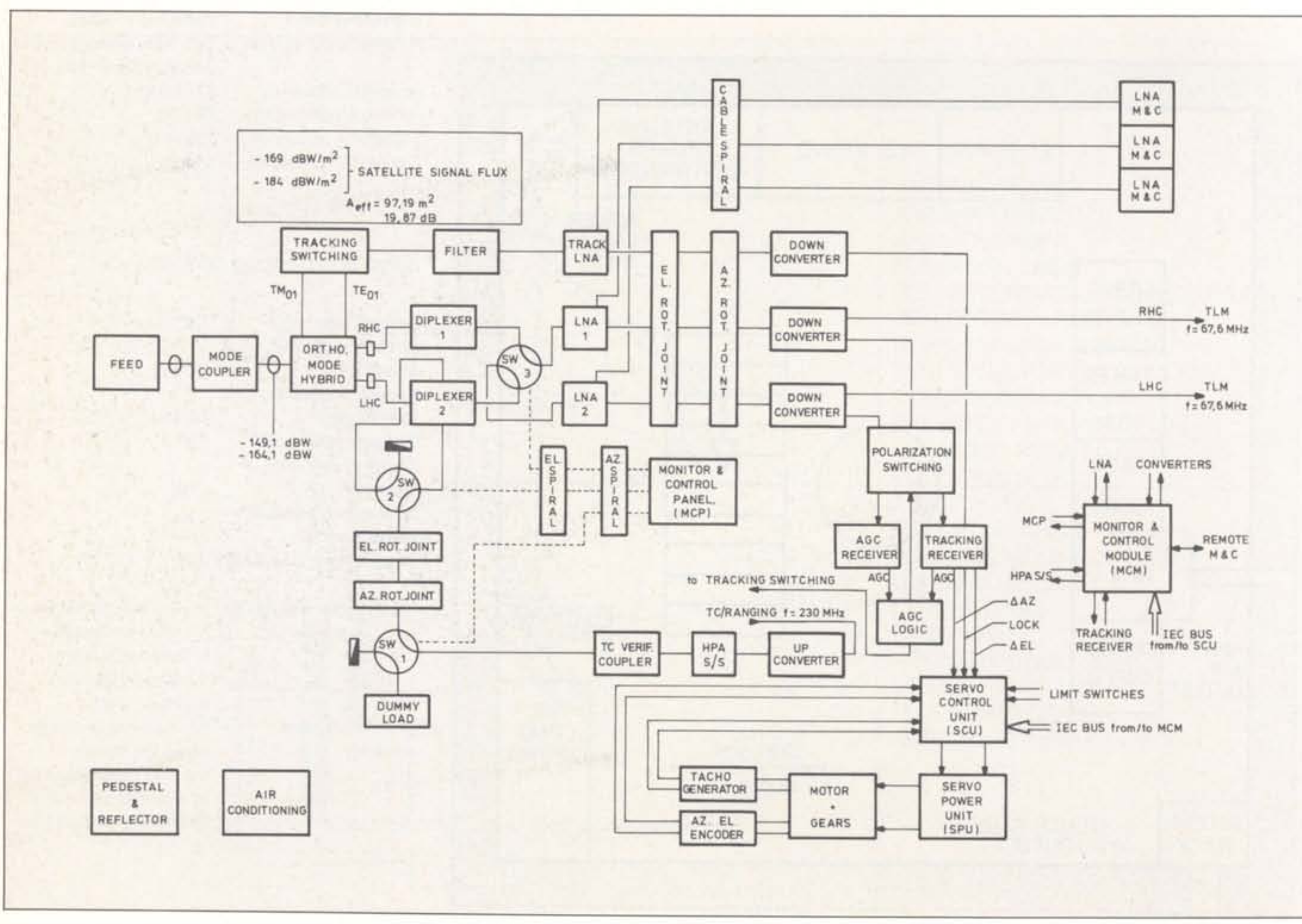
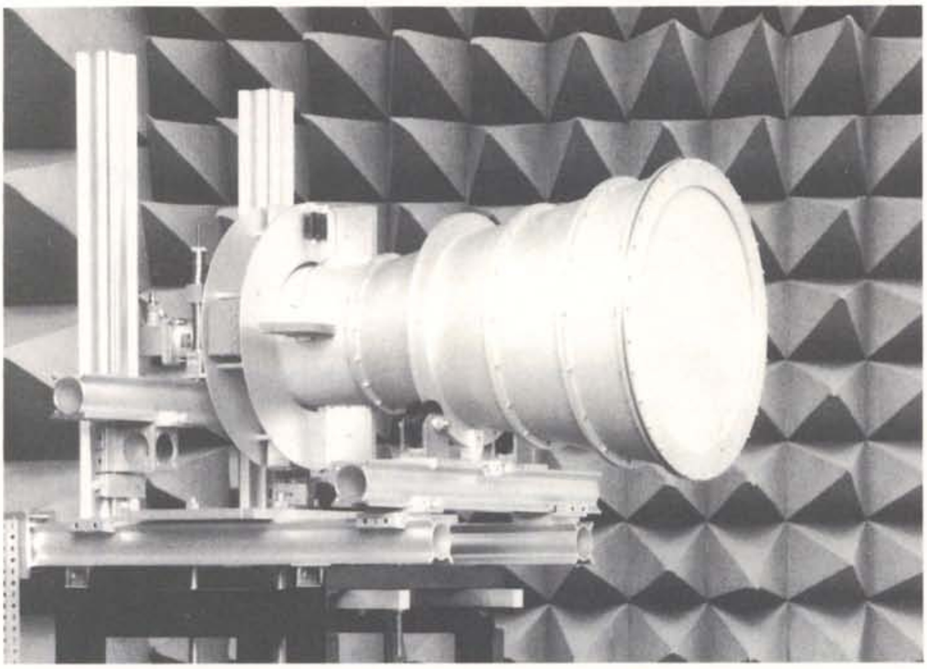


Figure 5 — Overall block diagram of the 15 m antenna

Figure 6 — S-band feed system of the Villafranca antenna during testing in the manufacturer's (MBB) anechoic chamber



switched automatically to the strongest signal and at the same time implies recombination of the two signals after down-conversion to reconstitute the telemetry signal power.

The polarisation of transmitted signals can be chosen independently by selecting the appropriate input port in the orthogonal-mode hybrid.

Coverage of the full receive and transmit bands is obtained by driving the local oscillators of the frequency converters from programmable frequency synthesizers.

Servo system

Movement of the antenna in both azimuth and elevation is controlled by the servo system. Two permanent-magnet, direct-current servo motors driven by high-power servo amplifiers are installed in each drive axis. They are arranged to operate in counter torque to minimise mechanical backlash. A microcomputer is used to close the servo loop. This computer also allows the antenna's movement and positioning to be externally controlled.

Defocussing

A 15 m diameter main reflector provides a beamwidth of 0.7° opening angle at S-band frequencies and 0.2° opening angle at X-band frequencies.

Clearly the antenna has to be pointed so that the satellite lies inside these beamwidths and has to be moved to keep the satellite within the beam during its entire passage over the station from horizon to horizon.

When the satellite flies overhead near the local zenith, the antenna must rotate at a very high speed around its azimuthal axis to follow the spacecraft. This rotational speed around the azimuthal axis is limited for practical reasons; in the present case it has been limited to 15° per second.

Should it be necessary to exceed this rotational speed, the antenna will be unable to track the satellite for a small portion of the pass near zenith. To minimise the period during which tracking cannot be maintained within the focussed beam of the antenna, a method of 'defocussing' has been applied for temporarily enlarging the antenna beamwidth. The method consists of moving the subreflector a fixed distance along the main axis of the antenna in the direction of the main reflector. In this way a temporary increase in beamwidth to 1.8° in S-band and 0.7° in X-band is achieved. The associated loss in antenna gain is 10 dB.

Defocussing can also be used to advantage to locate the satellite when it first comes over the station horizon.

Refocussing is achieved by moving the subreflector back to its original, calibrated position.

Continuing development

The system design has been finalised and proved by extensive testing. It remains, however, to develop a feed system that will allow the reception of X-band signals without degrading S-band transmit and receive performance, and the necessary design and development programme has already been initiated by the antenna supplier, with some ESA support. This development programme will be completed in 1983, after which ESA will procure two S/X-band coaxial feeds for retrofitting to the Villafranca and Carnarvon antennas. The final feed configuration is expected to allow antenna gains of 47.5 dB and 55.5 dB to be achieved in the S-band and X-band, respectively.

Further antennas of the S/X-band type, with either 15 m or 10 m-diameter main reflectors, will probably be procured in the context of network expansion programmes approved for the coming years, particularly the launch network's extension to permit simultaneous operation of two satellites in geostationary transfer orbit and the construction of a station at high northern latitude for the Earth-resources satellites of the Earth-observation programme. These further installations will lead to effective amortisation of the development costs incurred by the Agency.

Ariane Double Launches – An Operational Challenge

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The next Ariane launch will carry two spacecraft simultaneously into orbit. The European Space Operations Centre (ESOC) and its associated ground stations will be called upon for the first time to give full support to two spacecraft in the launch and early orbit phase simultaneously. The challenges of supporting this double launch are reflected in the flight-dynamics operations, which are outlined in this article.

Ariane's ability to launch two spacecraft simultaneously and to inject them both into geostationary transfer orbit has already been proven by the combined launch in June 1981 of ESA's Meteosat-2 spacecraft and Apple, the Indian communications test satellite. On this occasion ESOC was called upon to give only limited support to the Indian spacecraft. For the next launch, ESOC will be responsible for fully supporting both satellites : the Agency's second maritime satellite Marecs-B, to be positioned over the Pacific and the Agency's Sirio-2, a laser-time-synchronisation and meteorological-data distribution satellite to be positioned over the Atlantic. The two spacecraft missions will share the same ground-station network and both will be controlled from ESOC.

Present planning requires that Sirio-2 be injected into near-synchronous orbit at its second or fourth apogee pass in transfer orbit while for Marecs-B this injection into synchronous orbit is planned for the third apogee. Subsequently, both spacecraft will drift to their operational longitudes – 25° West and 177° East, respectively – where actual payload operations will begin.

In highlighting the particular challenges in flight dynamics encountered in the preparations for and operations during a double launch, this article concentrates on the orbital and attitude characteristics of such a double launch, including the critical spacecraft manoeuvres needed to ensure correct injection of both spacecraft into geostationary orbit.

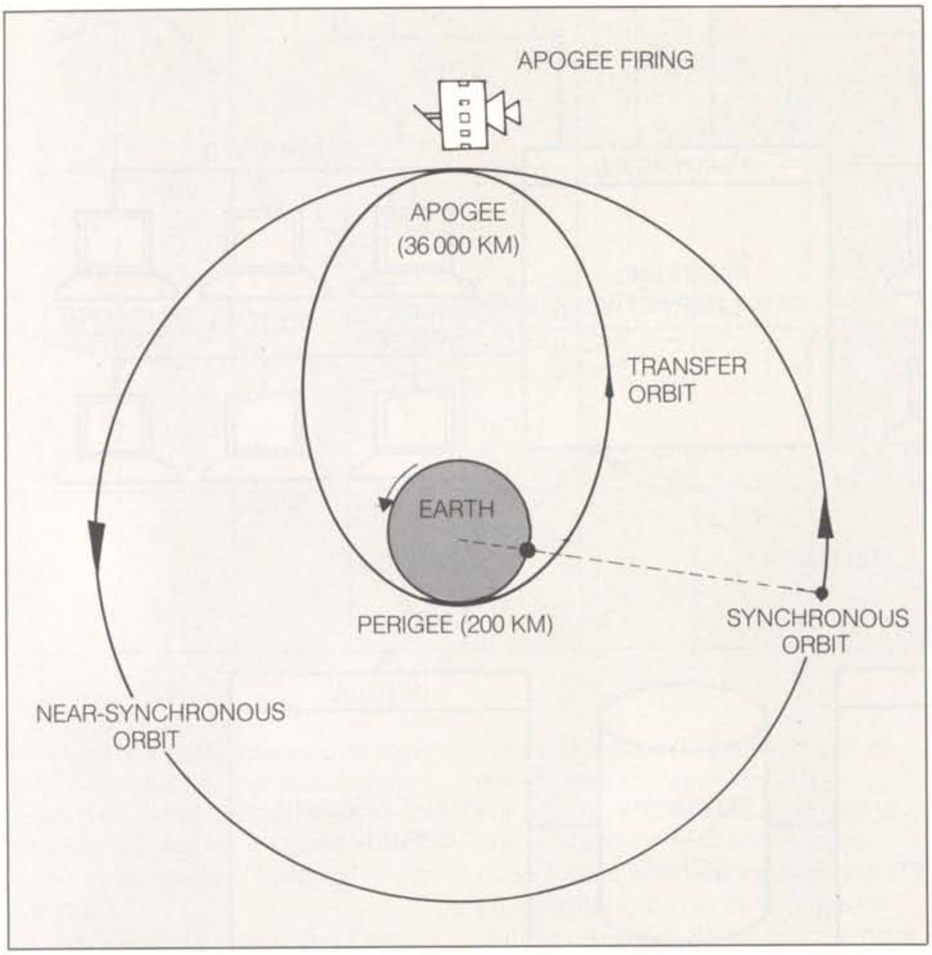
The launch and early-orbit phase

Figure 1 illustrates the geometrical principles underlying a geostationary-orbit injection procedure. After Ariane's lift-off from the ESA launch site in Kourou, French Guyana, and after a powered flight of approximately 15 minutes, the launch vehicle's third stage and the two spacecraft enter a transfer orbit with a period of 10.5 h, a perigee of 200 km and an apogee of 36 000 km. This apogee corresponds approximately to the radius of the circular orbit that a spacecraft must have in order to appear stationary from the ground.

Once in transfer orbit, the launcher's third stage performs a pre-programmed attitude re-orientation. It is then spun-up to about 10 rpm, before the two spacecraft are released. Spring forces cause the three bodies to enter slightly different orbit trajectories, reducing the risk of subsequent collision. A 0.5 m/s separation velocity causes the orbits of the two spacecraft to differ by 30 km in apogee and 35 s in orbital period.

When looking at Figure 1, one must bear in mind that the plane of the circular, geosynchronous orbit coincides approximately with the Earth's equatorial plane, while the elliptical transfer orbit is inclined some 10° to the Earth's equator. Approximately at the intersection of the two orbits, near apogee, the spacecraft apogee motor is fired to roughly double the orbital velocity so that a near-circular orbit results. The exact timing and direction of this firing depend on the characteristics of the transfer orbit. They are determined by a sophisticated

Figure 1 – Orbit-injection geometry



mathematical optimisation which takes into account the total propellant on board and the characteristics of the intended geosynchronous orbit. Although the spin-axis direction, which is aligned with the apogee motor, has already been set by the third-stage attitude re-orientation before separation, the final optimal attitudes can differ by the order of 10° and further reorientations using the spacecraft's own propulsion system are therefore needed during transfer orbit.

In view of the load on the ground facilities and the various activities necessary to prepare for apogee-motor firing, it is highly desirable to perform the burns for Marecs and Sirio-2 at different apogees.

Once the two spacecraft have been put into near-circular orbits, changes in their orbital characteristics will be introduced so that they will drift, over a period of about 20 days, to their operational locations, where they will be stopped and will remain on station for their operational lifetimes.

The ground-support system

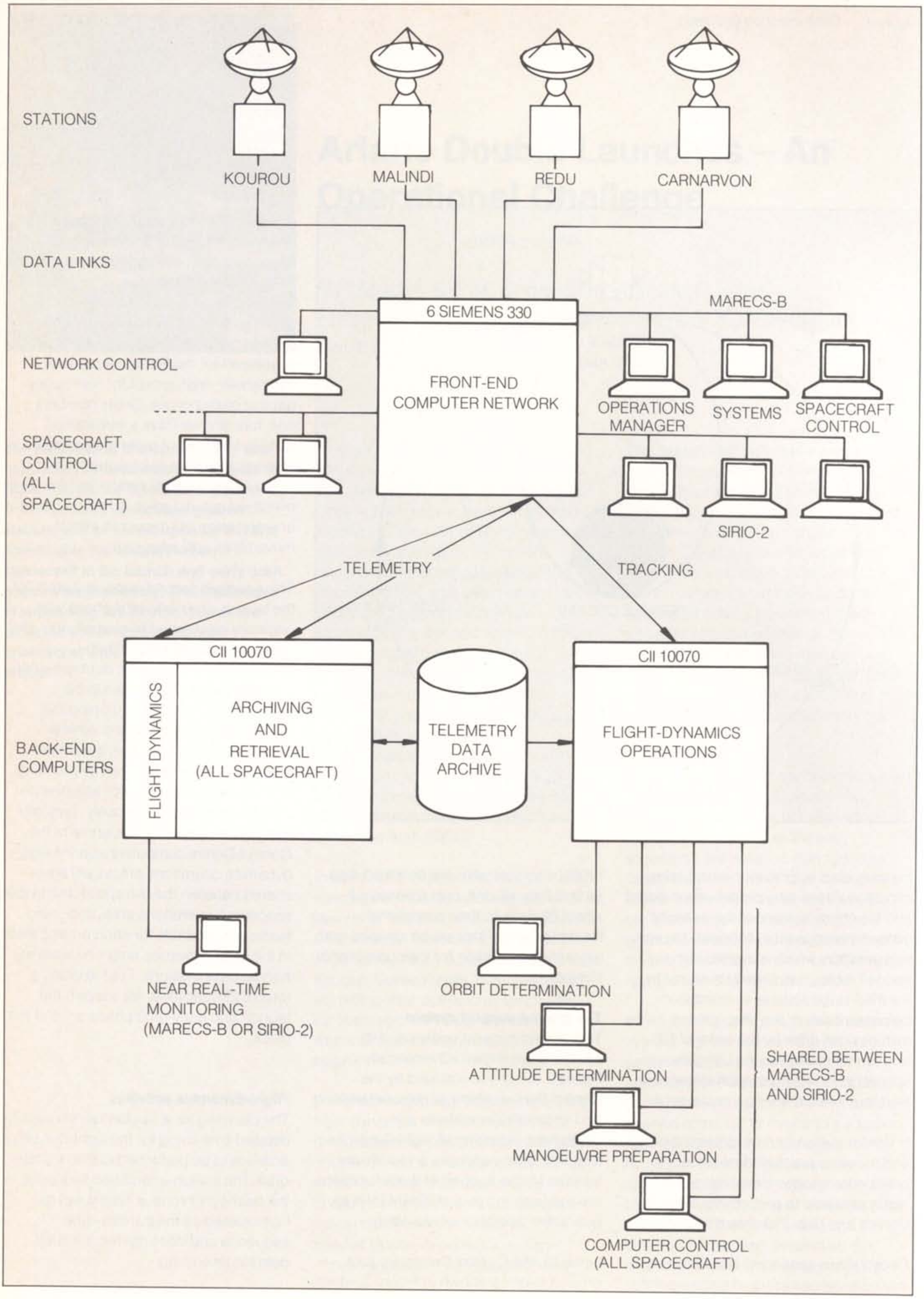
The ground-support system and its functions are shown schematically in Figure 2. A key role is played by the Control Centre, where all data-networking and spacecraft operations are centralised, including all flight-dynamics activities. Most hardware and software facilities for the support of these functions are available in fully redundant form to guarantee operational availability.

Linked to the Control Centre are four ground stations, shown in Figure 3, which provide direct contact with the spacecraft and make it possible to receive both spacecraft telemetry streams in real time. Telecommands to the two spacecraft and the necessary tracking information are also handled by these stations. They provide continuous contact with both spacecraft for the first six revolutions in the transfer orbit, except for half-hourly gaps at each perigee. Orbits numbers one, four and six have simultaneous visibility from two or more ground stations, whereas the other revolutions have only single, or partial dual station visibility. The overlayed ground track in Figure 3 gives an impression of spacecraft orbital movements until apogee 4.

The Agency's ground-support system for the launch and early-orbit phase was originally established to support only one spacecraft per launch. With the introduction of the Ariane double-launch concept, modifications had to be implemented, such as equipping the ground stations with dual downlink capabilities. Other facilities are shared between the two spacecraft by planning operations such that major activities do not take place simultaneously. Typically, the ground-station uplink, some of the Control-Centre computers and the flight-dynamics operations are largely time-shared between the two spacecraft.In the spacecraft-operations area, dedicated teams are available for each project, while in the flight-dynamics area one team will handle both missions. For the latter, a total of 22 specialists will support the launch and early-orbit phase around the clock.

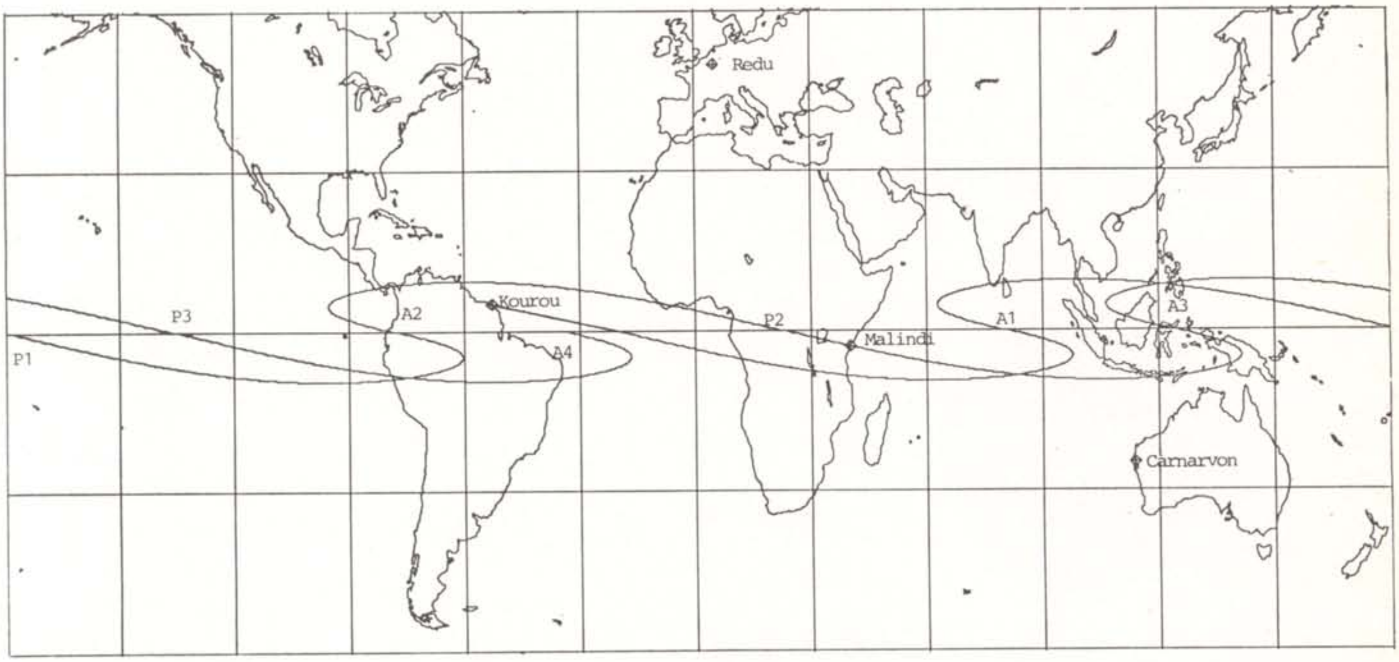
Flight-dynamics activities

The planning for a double launch calls for detailed time-lining for the flight-dynamics activities to be performed during transfer orbit. The station-acquisition sequence in the near-synchronous orbit is not as compressed as the transfer-orbit sequence and does not require such detailed time-lining.


STATIONS
KOUROU
MALINDI
REDU
CARNARVON
DATA LINKS
6 SIEMENS 330
MARECS-B
NETWORK CONTROL
FRONT-END
COMPUTER NETWORK
OPERATIONS
MANAGER
SYSTEMS
SPACECRAFT
CONTROL
SPACECRAFT
CONTROL
(ALL
SPACECRAFT)
SIRIO-2
TELEMETRY
TRACKING
CII 10070
CII 10070
FLIGHT DYNAMICS
ARCHIVING
AND
RETRIEVAL
(ALL SPACECRAFT)
TELEMETRY
DATA
ARCHIVE
FLIGHT-DYNAMICS
OPERATIONS
BACK-END
COMPUTERS
NEAR REAL-TIME
MONITORING
(MARECS-B OR SIRIO-2)
ORBIT DETERMINATION
ATTITUDE DETERMINATION
SHARED BETWEEN
MARECS-B
AND SIRIO-2
MANOEUVRE PREPARATION
COMPUTER CONTROL
(ALL SPACECRAFT)

◀ *Figure 2 – Ground-support system for a double launch*

Figure 3 – ESA ground stations and transfer-orbit ground track until fourth apogee



Once the appropriate sequence has been set up, the overall ground system has to be validated. In the case of the flight-dynamics activities this will be done via Double Launch System Tests for validation of:

- the operational computer software
- the spacecraft and mission parameters
- the events sequence (nominal and non-nominal) vis-à-vis the computer resources and manning schedule.

The tests have to be conducted in the real operational environment. Only in this way can readiness for launch be demonstrated and a guarantee given that the demands of nominal, and more importantly non-nominal, situations can be coped with.

The major flight-dynamics operations to be conducted during the transfer-orbit and near-synchronous-orbit phases are:

- orbit determination
- attitude determination
- near-real-time monitoring
- manoeuvre preparation
- system identification
- quality control
- computer and data interfacing.

Orbit determination is performed by iterated least-squares fitting of a numerically integrated arc of an orbit to one or several hours of accumulated tracking data. After determination, the orbit is extrapolated forward in time for planning purposes. Before apogee-motor firing, the transfer orbit that has been achieved must be determined to within a few hundred metres in apogee and a few seconds along track.

Attitude determination is performed in a similar way, processing accumulated data at the end of a coverage period with additional computer runs early in the transfer orbit and just before apogee-motor firing.

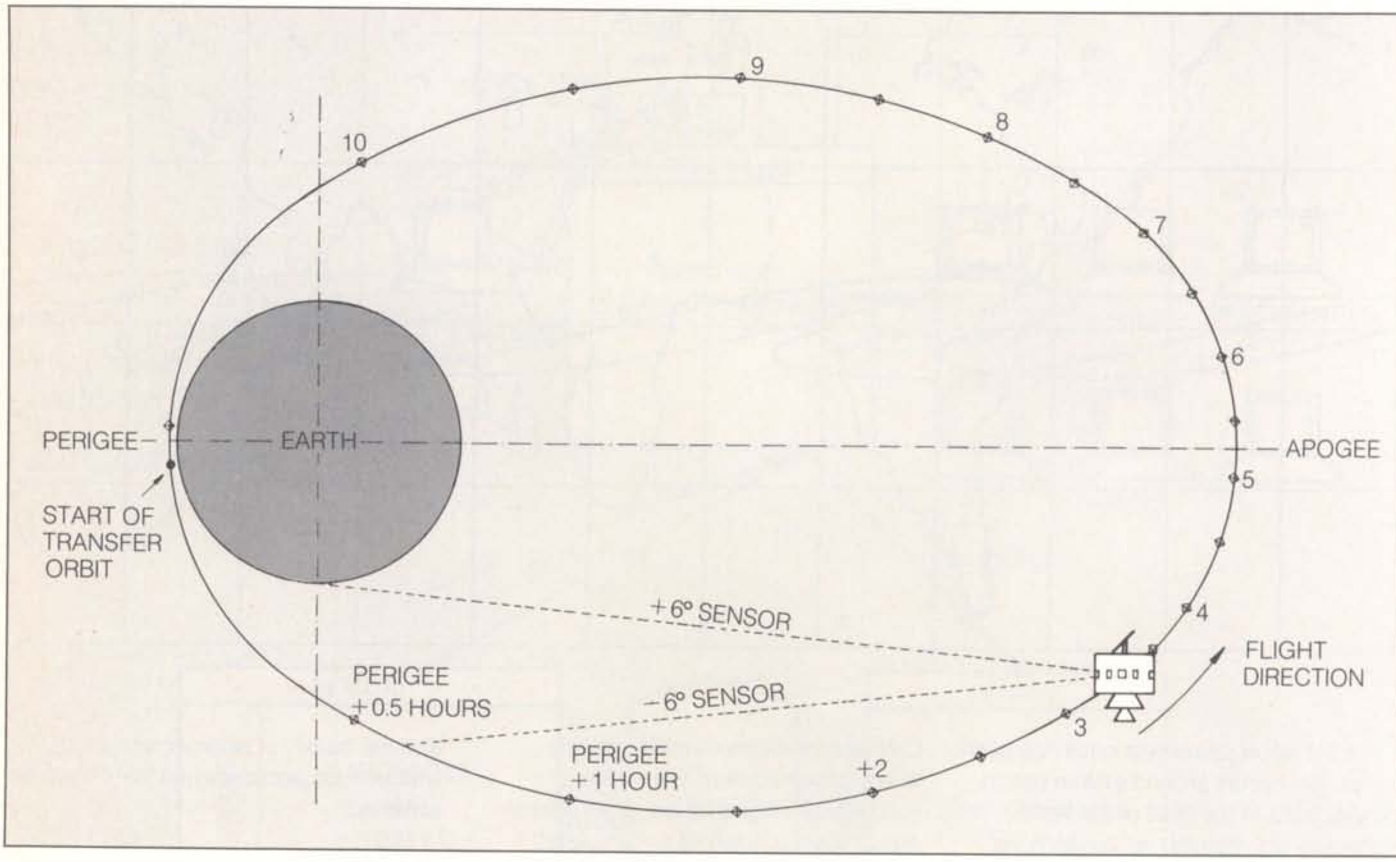
Attitude determination is performed from Sun and Earth-sensor data in the spacecraft telemetry. Depending on the spacecraft's attitude and sensor mounting angles, its infrared pencil-beam Earth sensors have Earth coverage for about 2–3 h around the apogee of the transfer orbit. Figure 4 shows, as an example, the beginning of the +6° pencil-beam sensor coverage for Sirio-2. Depending on the Sun-Earth geometry and the quality of sensor calibration, a final attitude accuracy of 0.5°–1° can be achieved.

Near-real-time monitoring is a determination of the instantaneous attitude and/or spin rate from each telemetry format as soon as it arrives at ESOC. It is particularly useful during manoeuvres, allowing the spacecraft operator to abort a manoeuvre in the case of an anomaly.

Manoeuvre preparation has an optimisation and a telecommand-generation aspect. The optimisation establishes an optimal sequence of attitude and orbit manoeuvres, such that the mission objectives are achieved with minimum fuel. The telecommand generation models the spacecraft dynamics and electronics for thruster firing.

System identification concerns the integrated identification of the mathematical-model parameters: environmental parameters, and spacecraft-actuator (thruster) and sensor characteristics.

Figure 4 — Beginning of +6° Earth-sensor pencil-beam coverage for Sirio-2



Quality control supports the planning and preparation phase to establish confidence in the reliability of the overall flight-dynamics support. In addition, selected control activities are performed during the flight.

Computer and data interfacing provides the means for smooth operations in the computer environment.

Sequence of events
The transfer-orbit planning must consider the requirements of each mission and any constraints on the ground operations, yet it must be sufficiently flexible to accommodate variations in Earth-sensor coverage times and in other parameters.

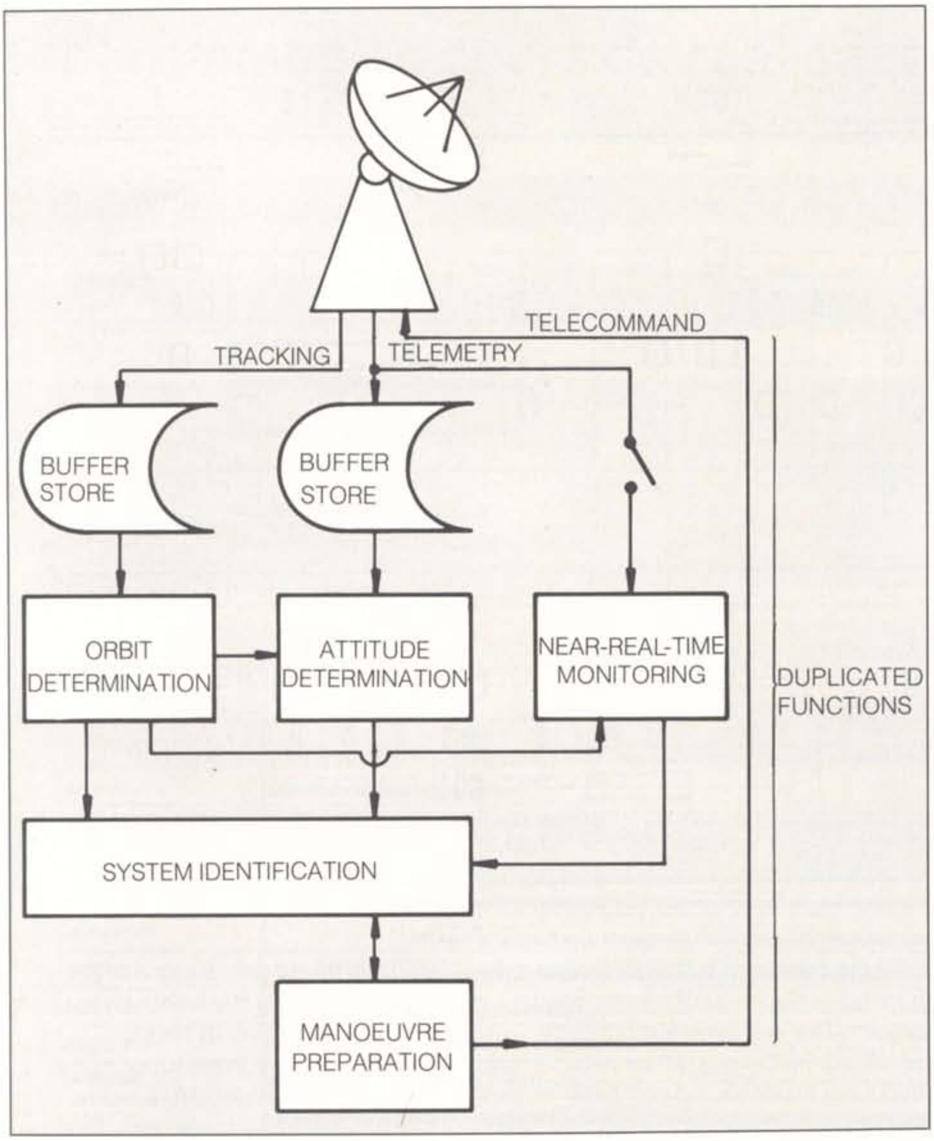
As there are two project groups involved, which naturally have conflicting interests and priorities, it is necessary to set up and plan the sequence of events as a compromise between the various interests and constraints. One of these, the time-sharing of resources, leads to a few general principles that must be applied in double-launch support:

- manoeuvres shall be carried out with only one spacecraft at a time;
- the apogee motors of the two spacecraft shall be fired at different apogees, since this is the most demanding part of the operations;
- the flight-dynamics operations – orbit and attitude determination and manoeuvre preparation and execution – are performed exclusively for one spacecraft during half the orbital revolution preceding its apogee-boost-motor firing.

Bearing these principles in mind, one has to prepare an early-orbit-phase operations time line such that the sequence, orbit and attitude determination followed by manoeuvre preparation, execution and system identification is iterated for each spacecraft throughout the transfer orbit, to provide the best possible conditions for the apogee-motor firing. This control loop is shown schematically in Figure 5.

The processing of the tracking data for orbit determination is normally not time-critical. It is convenient to process several hours of tracking at times when no manoeuvres or other demanding activities are required. After each major determination, the target direction of apogee-motor firing is updated. In the first few hours of the transfer orbit, however, there is great interest in establishing the mission's success and measuring the orbit for inputs to the attitude-determination and manoeuvre-optimisation programs. There is an analogous requirement for orbit measurement a few hours after apogee-motor firing. It is also desirable for reasons of tracking geometry to perform a last

Figure 5 — Schematic representation of the flight-dynamics control loop



orbit determination before apogee-motor firing with tracking data obtained from the current station pass.

Attitude determination utilises at least 20 min of accumulated Earth-sensor data. It is therefore performed during or immediately after the Earth-sensor coverage periods. The results are needed to prepare attitude slew manoeuvres and to confirm correct spin-axis pointing for apogee-motor firing. The critical events in the entire sequence are the attitude and orbit manoeuvres. The attitude slew manoeuvres are preferably performed within the Earth-sensor coverage periods. The necessary telecommands must be available for uplinking 30 min before manoeuvre execution.

Figure 6 shows the presently planned sequences of events for Marecs-B and Sirio-2. The events for Marecs-B are: a crude spin-up to 60 rpm, an attitude slew manoeuvre, a fine spin-up to 65.5 rpm, two further slew manoeuvres and apogee-motor firing at the third apogee pass (A3), followed by three spin-down manoeuvres for the three-axis acquisition. The manoeuvres to be executed by Sirio-2 are: a spin-up to approximately 90 rpm, three attitude slew manoeuvres, and firing of the apogee motor at the fourth apogee pass (A4).

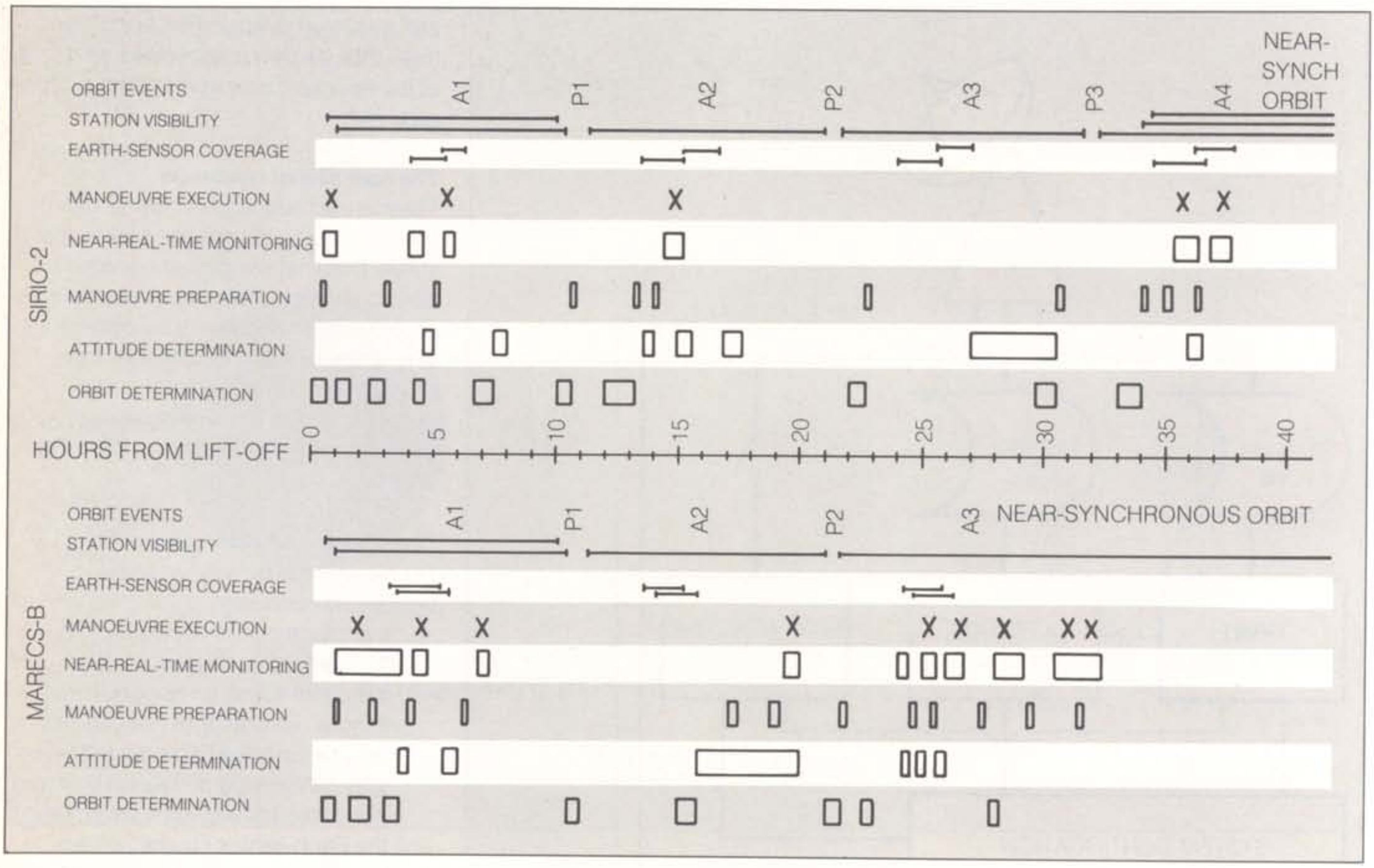
The operational challenge

The planned sequence of events can not be made too tight, because experience shows that time margins are needed to absorb delays in operations. In a double launch, delays caused by the operations of one spacecraft may influence the timing of events for the other and a priority schedule must be agreed beforehand to resolve any conflicts that develop.

Changes in event timing are often necessary even during nominal operations because:
- the orbital period depends on the transfer orbit achieved;
- the optimal time for apogee-motor firing is not exactly at apogee, but may be up to half an hour before or after, depending on launch time and measured transfer-orbit parameters;
- the Earth-sensor coverage times depend on the spacecraft's attitude. The optimal attitude for apogee-motor firing depends on the launch time and measured transfer-orbit parameters. Various intermediate attitudes result from the different slew manoeuvres;
- the number of slew manoeuvres needed to arrive at the optimal apogee-motor firing attitude depends on the performance of the on-board control system and on the quality of the intermediate attitude and orbit determinations;
- the attitude determination may need more sensor coverage data than expected, due to Earth and Sun near-colinearity or Earth-sensor blinding by the Sun.

Delays in events can also occur because of the following relatively harmless contingencies:
- an extra slew manoeuvre may be needed soon after launcher

Figure 6 — Combined events sequence for the Sirio-2/Marecs-B launch, with Marecs-B apogee-motor firing at the third apogee and Sirio-2 motor firing at the fourth (A = apogee: P = perigee).



separation if the initial solar-aspect angle is out of limits;
- the start of a nominal slew manoeuvre may be delayed due to ground-station or on-board system problems;
- bad-quality tracking data or tracking calibration may necessitate more tracking measurements and a delay in accurate orbit determination;
- low-quality sensor data or sensor calibration may delay accurate attitude assessment until more data has been collected;
- a temporary failure in a vital component in the computer system can delay operations until a repair or reconfiguration can be effected.

More severe contingencies caused by serious malfunctioning of the spacecraft or launcher can demand considerable efforts at the Control Centre in order to save the mission or to define a meaningful alternative. Such situations can only be prepared for in a general manner by providing the Control Centre with adequate expertise and computer systems capable of performing 'real-time mission analysis'.

The flight-dynamics team's challenge is one of preparing a realistic sequence of mission events, implementing it successfully, and being capable of dealing with both planned and unplanned events quickly and competently.

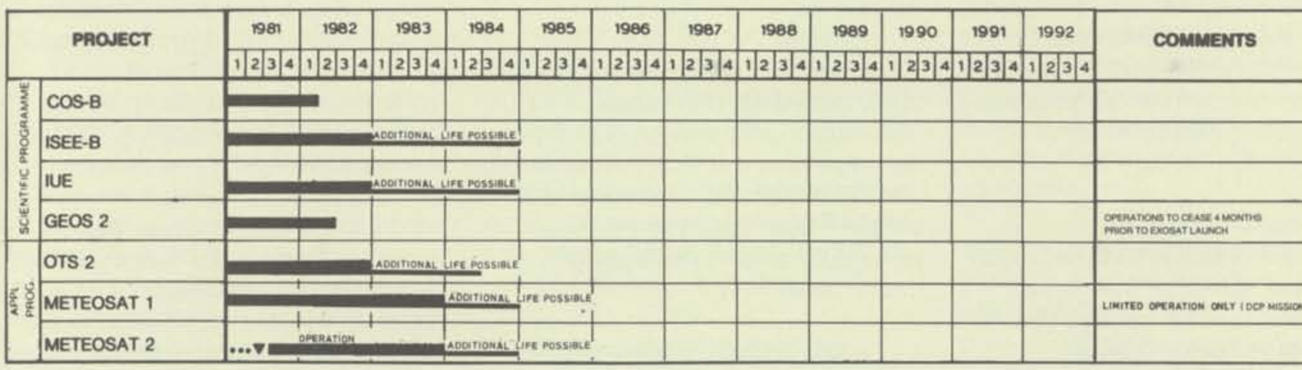
Conclusion

The forthcoming double launch will be a unique event for ESA, and a stepping stone towards future launch-support requirements associated with progressively more powerful Ariane launchers. At the time of writing (April 1982), the miriad preparations at ESOC for supporting this first launch of two ESA spacecraft have already begun. Experience gained in the support of six previous single-spacecraft launches – including the now famous Geos-1 rescue – provides a high level of confidence that the success rate can be maintained, especially with the availability of standard support facilities that have already been well tested operationally, in the hands of well-qualified and experienced specialists.

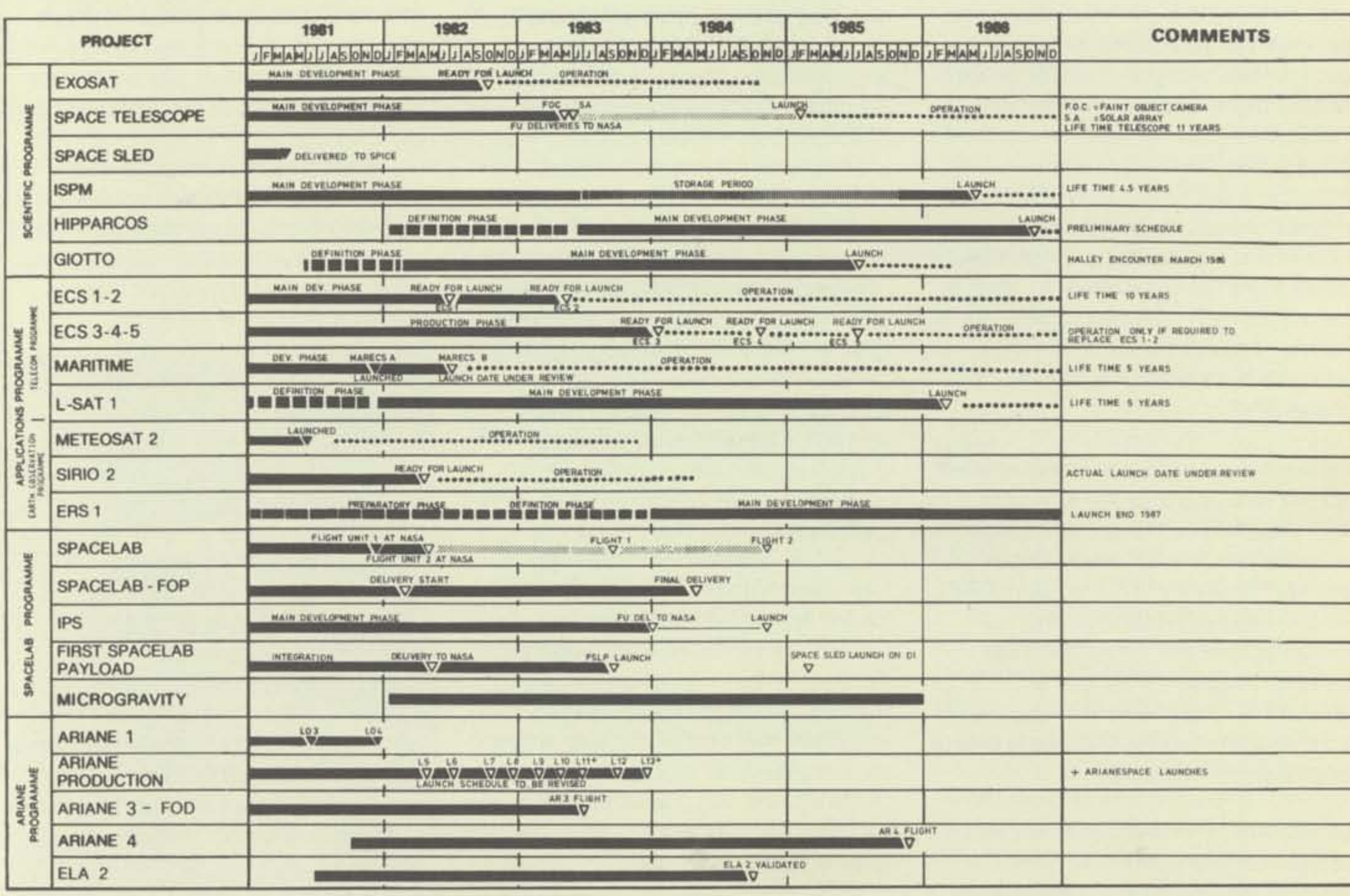
Programmes under Development and Operations*

Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status per end February 1982/Bar chart valid per end March 1982

Situation des projets décrits fin février 1982/Planning fin mars 1982

Cos-B

Lorsque, le 18 février, Cos-B a exécuté sa manoeuvre d'orientation en vue de procéder à sa dernière observation de l'Anticentre galactique, il a allongé encore la liste des records enregistrés par cette mission (la plus réussie, la plus longue vie opérationnelle, etc.). Cette date marquera en effet la fin de la plus longue période continue de pointage de la mission Cos-B. Le satellite est pointé depuis le 5 novembre 1981 sur l'objet X-3 du Cygne, l ± 80°, b + 0°, soit une période d'observation de 94 jours. Les résultats de cette observation de Cos-B, bien qu'obtenus avec une surface sensible limitée (environ 50 cm²), seront difficiles à améliorer avec les instruments de la prochaine génération, dont la couverture sera limitée en raison des orbites basses et des courtes durées de missions prévues.

Cette période d'observation particulièrement longue a été nécessaire pour pouvoir 'suivre' les forts indices — révélés par de précédentes données — d'une variabilité des sources de rayonnement gamma avec le temps. En outre, des statistiques plus précises contribueront à élucider l'émission spatiale complexe du Cygne mise en évidence par les sources de rayons gamma détectées par Cos-B, 2CG75+0 et 2CG7518+1, qui pourraient n'être en fait qu'un aspect étendu d'un même phénomène. On pourrait également procéder à des corrélations d'émissions gamma et d'autres traceurs de gaz, notamment maintenant que l'on dispose de données CO qui révèlent la présence de nuages de H_2. On peut espérer que la portée de ces corrélations sera renforcée à la suite de cette longue période d'observation.

La dernière opération de renouvellement du gaz de Cos-B a eu lieu le 30 septembre 1981 mais la quantité de gaz restante n'a permis d'effectuer qu'une vidange partielle, qui a consisté à remplacer 50% du gaz utilisé. En revanche, on a pu constater, grâce à 'l'installation de traitement rapide' (FRF), que le rendement de la chambre à étincelles s'est nettement amélioré et que le taux de dégradation reste faible.

Les données FRF relatives à l'observation actuelle du Cygne font nettement apparaître le rayonnement émis par les sources 2CG75+0 et 2CG78+1. Comme toujours, il faudra attendre le tracé manuel des trajectoires dans la chambre à étincelles pour déterminer la sensibilité maximale de Cos-B.

Une dégradation lente et continue de la surface sensible efficace de Cos-B, constatée depuis la fin de l'année 1978, a conduit les enquêteurs à examiner de façon minutieuse les programmes d'identification automatique des diagrammes — filtrage d'événements bruts précédant l'analyse manuelle — qui pourraient être 'rajustés' en fonction de l'état de fonctionnement actuel de la chambre à étincelles, permettant ainsi de récupérer une partie de la 'sensibilité manquante'.

Après la manoeuvre exécutée le 18 février, le gaz destiné à la commande d'orientation représente un potentiel de manoeuvres de ± 200°, la quantité de gaz destinée à la chambre à étincelles étant suffisante pour assurer un nouveau remplissage à concurrence de 35%, en cas de besoin.

La Collaboration Caravane a demandé que les opérations soient poursuivies jusqu'au 25 avril afin de pouvoir procéder à une longue et dernière observation de la région de l'Anticentre galactique. Le champ de visée comprendra la mystérieuse source de rayonnements gamma 2CG195+4 ainsi que le pulsar du Crabe 2CG184−5. Des résultats extrêmement intéressants, acquis récemment, montrant qu'il existe une variabilité à long terme de la forme de la courbe lumineuse du Crabe en fonction du temps, il importe que cette dernière observation soit effectuée avec la plus grande précision statistique possible. En outre, le fait que l'objet 2CG195+4, observé pour la première fois par SAS-II en 1973, n'ait pas été identifié rend indispensable ce dernier effort de recherche d'une signature de source ponctuelle.

La mission Cos-B a commencé le 9 août 1975 et le premier pointage a visé l'Anticentre. La dernière observation de l'Anticentre fournira donc de nouvelles données importantes pour déterminer empiriquement l'historique des variations de la sensibilité de détection, ce qui permettra une plus grande fiabilité dans l'analyse des données recueillies pendant toute la durée de la mission.

On trouvera dans le Bulletin no. 28, de novembre 1981, le compte rendu des six premières années de la mission Cos-B et de ses résultats.

ISEE-2

ISEE-2 continue de fonctionner de façon satisfaisante après plus de quatre ans passés dans l'espace. Comme nous l'indiquions dans le dernier Bulletin, le taux de comptage de l'expérience 'vent solaire' d'ISEE-2 a diminué en raison d'effets de fatigue qui affectent les multiplicateurs d'électrons à microcanaux. L'expérience a donc été décommutée afin de déterminer si les multiplicateurs d'électrons peuvent se 'rétablir' avec le temps. On espère que, dans quelques mois, l'expérience pourra à nouveau fournir d'autres données.

La 'communauté scientifique ISEE' est restée très active, poursuivant ses études dans de nombreuses directions. En février, en même temps qu'avait lieu la réunion du Groupe de travail scientifique ISEE, trois ateliers étaient réunis au Goddard Space Flight Centre; l'un consacré aux ondes de choc interplanétaires, le second à l'onde de choc de la Terre et le troisième à l'activité géomagnétique (ce dernier organisé en collaboration avec la communauté Geos).

Les opérations de poursuite et de récupération des données ont été légèrement réduites ces derniers temps par la NASA en raison de réductions budgétaires. La récupération des données d'ISEE-1 et 2 s'établit actuellement à 60% environ, le recoupement entre les deux satellites étant de l'ordre de 45%.

A la dernière réunion du Groupe de travail scientifique, il a été décidé de déplacer ISEE-3 vers la région éloignée de la queue de la magnétosphère. Au printemps 1983, ISEE-1 et 2 se trouveront donc dans la région de la queue de la magnétosphère proche de la Terre et ISEE-3 dans la région lointaine. La NASA s'intéresse également beaucoup (pour des raisons tant politiques que scientifiques) à l'envoi d'ISEE-3 vers la comète de Giacobini-Zinner en 1984. La 'rencontre' du satellite et de la comète pourrait se produire en septembre 1985 (c'est-à-dire six mois avant celle de Giotto et de la comète de Halley).

Cos-B

When Cos-B made an attitude manoeuvre on 18 February to begin its final observation of the Galactic Anticentre, it added yet again to the record achievements of this mission (most successful, longest operational, etc.). This date marked the end of the longest single pointing for Cos-B, which had been directed towards Cygnus X−3, l±80°, b±0° since 5 November 1981, yielding an observation lasting 94 days. Even with the modest sensitive area of about 50 cm², the depth of this Cos-B observation will be hard to better with the next generation of experiments, which will be limited in coverage by low orbits and short mission lifetime.

This particularly long observation was made to follow up the strong indications in previous data of time variability in gamma-ray sources. Furthermore, improved statistics will help to unravel the spatially complex emission in Cygnus highlighted by the Cos-B gamma-ray sources 2CG75+0 − 2CG78+1, which may in fact be a single extended feature. Correlations of gamma emission with other gas tracers represent a further effort, especially now that CO data revealing H_2 clouds are available. The significance of correlation will hopefully be improved as a result of this long exposure.

The last 'flushing' of the Cos-B spark chamber took place on 30 September 1981, when only 50% of the old gas was replaced. The efficiency of the spark chamber has, however, been seen through the 'Fast Routine Facility' to exhibit a definite improvement, and the rate of deterioration continues to be small.

The Fast Routine Facility data for the present observation of Cygnus clearly show the 2CG75+0 − 2CG78+1 source emission. As always, manual editing of the spark-chamber tracks is awaited to achieve maximum sensitivity.

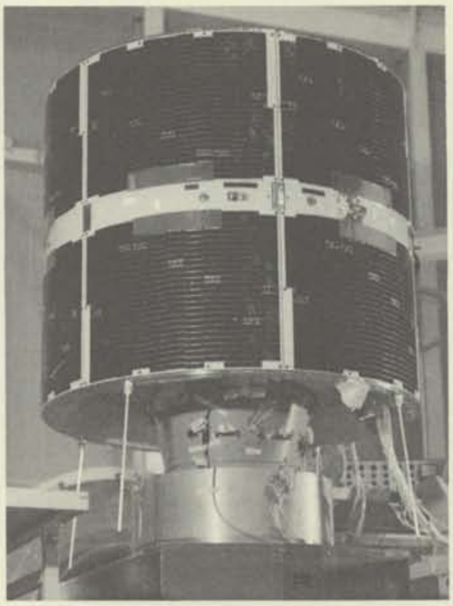
A slow deterioration in the effective sensitive area of Cos-B since the end of 1978 has caused the investigators to look carefully into the automatic pattern - recognition programmes – a crude event filter prior to manual analysis – which may be 'retuned' to the present operational state of the spark chamber, thereby regaining some of the 'missing sensitivity'.

Following the manoeuvre on 18 February sufficient attitude control gas remains for some 200° of manoeuvring and there is sufficient spark-chamber gas for a final 35% replenishment, if required.

The Caravane Collaboration have requested an extension in operations until 25 April to permit a final, long observation of the Anticentre region of the Galaxy. The field of view will include the enigmatic gamma-ray source 2CG195+4 as well as the Crab pulsar 2CG184−5. Recent exciting results showing evidence for long-term time variability in the shape of the Crab light curve make it important that this final observation be made with the highest statistical precision possible. Furthermore, no hint of identification for 2CG195+4, first observed by SAS-II in 1973, makes the final effort to search for a point-source signature essential.

The Cos-B mission began on 9 August 1975 and the first pointing was in the Anticentre. The final Anticentre observation will therefore give further important data to determine, empirically, the temporal history of variations of detection sensitivity. This in turn will make analysis of data taken throughout the intervening mission more reliable.

A summary of the first six years of the Cos-B mission and its results is to be found in the ESA Bulletin No. 28, November 1981.



Cos-B

ISEE-2

The ISEE-2 spacecraft is still operating well after more than four years in space. As noted in the last report, the solar-wind experiment's count rate has degraded because of fatigue effects in the channeltron electron multipliers. Consequently, the experiment has since been switched off to see if the multipliers will recover with time. It is hoped that the experiment will be able to provide some more data after a few months.

The ISEE scientific community has continued to pursue many lines of study. In February, at the time of the ISEE Science Working Team meeting, three workshops were held at Goddard Spaceflight Centre: one on interplanetary shocks, one on the Earth's bow shock, and one on geomagnetic activity (this last one in collaboration with the Geos community).

Tracking and data recovery have had to be somewhat curtailed recently by NASA due to their budget cuts. ISEE-1/2 tracking is now around 60%, and the overlap between the two spacecraft around 45%.

At the last Science Working Team Meeting, it was decided to move ISEE-3 to the distant geomagnetic tail. In spring 1983, therefore, ISEE-1/2 will be in the near-Earth tail, and ISEE-3 in the distant geomagnetic tail. There is also a strong interest on NASA's part (both political and scientific) in sending ISEE-3 to comet Giacobini-Zinner in 1984. The spacecraft would encounter the comet in September 1985, six months before Giotto encounters comet Halley.

IUE

IUE celebrated its fourth anniversary on the 26 January, as one of the most successful projects to date in space astronomy, providing invaluable UV data to a wide astronomical community. So far more than 1000 observing proposals have been accepted by ESA, UK Science and Engineering Research Council (SERC) and NASA Selection Committees, leading to the collection of some 25 000 spectra of celestial objects. 280 papers using IUE data have already been published in the major journals, and 120 of these have relied solely on European data.

IUE

Le 26 janvier, IUE a célébré avec succès son quatrième anniversaire. Ce satellite, l'un de ceux qui ont remporté le plus grand nombre de succès dans le domaine de l'astronomie spatiale, a fourni à une vaste communauté d'astronomes des données UV d'un intérêt fondamental. Plus de 1000 propositions d'observations ont été acceptées à ce jour par les comités de sélection de l'ESA, du SERC et de la NASA, propositions qui se sont traduites par le recueil de quelque 25 000 spectres d'objets célestes. Environ 280 documents établis à partir de données fournies par IUE ont paru à ce jour dans les principales publications, dont 120 se fondaient exclusivement sur des données européennes.

Le satellite IUE est en excellent état et sa vie opérationnelle devrait pouvoir être prolongée sans problème au-delà des cinq ans initialement prévus. Dans l'optique de cette prolongation, l'ESA et le SERC ont récemment décidé de fusionner leurs comités de sélection scientifiques respectifs en une commission européenne unique. En fait, les propositions reçues en automne dernier par les deux agences pour la cinquième série des observations IUE ont déjà été évaluées par ce comité mixte. Pour la programmation et les observations ultérieures, de même que pour le prochain appel de propositions, il ne sera plus établi de distinction rigide entre les temps d'observation de l'ESA et du SERC.

Deux conférences consacrées à l'IUE auront lieu en 1982, l'une aux Etats-Unis, l'autre en Europe. La 'troisième conférence européenne sur l'IUE', qui sera organisée sous le double parrainage de l'ESA et du Consejo Superior de Investigaciones Cientificas espagnol, se tiendra à Madrid du 10 au 13 mai. Quelque 250 astronomes se sont déclarés intéressés à participer à cette conférence pour laquelle plus de 100 textes de communications ont été soumis.

Geos-2

Six expériences sur les sept initiales de Geos-2 continuent à fonctionner de façon satisfaisante. En raison des préparatifs du secteur sol d'Exosat, l'acquisition des données du satellite a dû être limitée aux périodes de nuit. Une couverture continue de 24 heures sur 24 n'a été obtenue que trois jours par mois. La planification des expériences s'effectue en étroite coopération avec l'Association scientifique EISCAT et avec les responsables des expériences embarquées sur les satellites Arcad-3 et Dynamic Explorer. Ces satellites participeront, avec Geos-2 et ISEE, à une campagne au cours de laquelle la composition du plasma fera l'objet de mesures coordonnées réalisées dans des régimes différents de la magnétosphère. Une campagne similaire avait été exécutée en 1979, mais sans le soutien d'un satellite placé sur une orbite fortement inclinée, rôle qui est maintenant assuré par le Dynamic Explorer. Il est également prévu d'établir un relevé du profil latitudinal du renflement formé par la plasmasphère en combinant les données obtenues à l'aide de ce dernier satellite avec les mesures de plasma effectuées par Geos-2.

Les données fournies sont à la base d'un certain nombre de documents récents particulièrement intéressants sur les interactions ondes/particules. Il a été démontré par exemple que de nombreuses observations recueillies par l'instrument 'ondes' de Geos ne peuvent pas s'expliquer par une distribution maxwellienne simple des particules de plasma. Une analyse minutieuse, réalisée à l'aide des diverses expériences 'particules' lors d'émissions d'ondes fortement structurées, a révélé des distributions complexes. En fait les études sur les interactions ondes/particules à bord de Geos auront bientôt atteint le stade où elles permettront de baser les prévions quantitatives de l'environnement 'ondes' sur les seules mesures de particules. Un certain nombre de phénomènes d'ondes ont été identifiés qui peuvent avoir pour effet d'accélérer les particules soit parallèlement soit perpendiculairement à la direction du champ magnétique local. La signature d'ondes et la réponse escomptée dans les spectres de particules ont également été clairement identifiées.

OTS

Le fonctionnement d'OTS est resté satisfaisant depuis le dernier compte rendu. La période la plus chaude de l'année, le solstice d'hiver, s'est à nouveau passée sans problème et les opérations de reconditionnement des batteries, qui s'effectuent avant la saison d'éclipses, viennent d'être exécutées.

La technique des 'voiles solaires', mentionnée dans le dernier Bulletin, a continué d'être utilisée avec succès pour la commande d'orientation du satellite et continuera vraisemblablement de l'être au moins jusqu'à l'été prochain. La

Observation of a new supernova in progress in the IUE astronomy facility at Villafranca, on 24 February.

Observation d'une nouvelle supernova à la station IUE de Villafranca (24 février 1982).

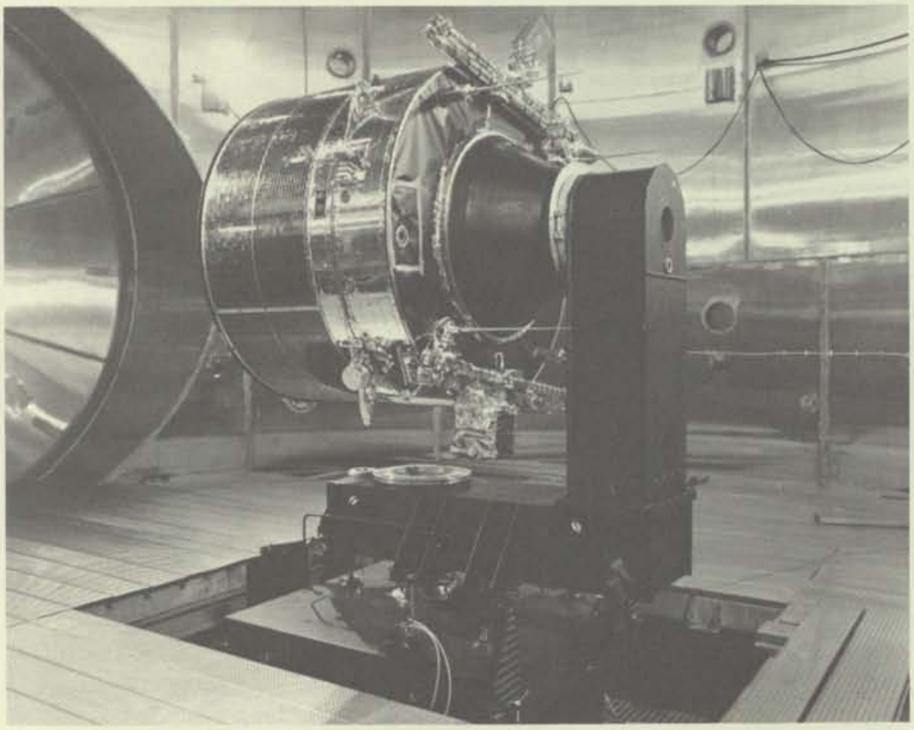
The satellite is in excellent shape and its lifetime should extend well beyond the initially envisaged five years. With such an extension in mind, ESA and the SERC recently agreed to merge their Scientific Selection Committees to form a single European Board. The proposals received last autumn by the two Agencies for the fifth round of IUE observations were, in fact, already evaluated by such a joint Committee. Future scheduling and observations, as well as the next call for proposals, will no longer differentiate formally between ESA and SERC observing time.

Two Conferences dedicated to IUE will be held during 1982, one in the USA and one in Europe. The 'Third European IUE Conference', co-sponsored by ESA and the Spanish Consejo Superior de Investígaciones Científícas, will take place in Madrid from 10 to 13 May 1982. About 250 astronomers plan to participate and more than 120 papers have been contributed.

Geos-2

Six of the original seven Geos-2 experiments are still functioning well. Because of ground-segment preparations for Exosat, Geos data-acquisition has had to be limited to night-time hours. 24-hour continuous coverage has been obtained on only three days each month. Experiment scheduling is carried out in close co-operation with the EISCAT Scientific Association and experimenters on the Arcad-3 and Dynamic Explorer satellites. These spacecraft, together with Geos-2 and ISEE, will be engaged in a campaign to measure plasma composition in different magnetospheric regimes. A previous campaign of a similar nature conducted back in 1979 did not have the support of a spacecraft in a high-inclination orbit, but this is now provided by the Dynamic Explorer. It is also intended to map the latitudinal profile of the plasmaspheric bulge, by combining the data from the Dynamic Explorer with plasma measurements from Geos-2.

Geos-2 data have formed the basis for a number of recent papers on wave-particle interactions. Many observations by the Geos wave instrument cannot be explained on the basis of a single Maxwellian distribution of plasma particles. Close analysis shows that multicomponent distributions have been identified by the various particle experiments on Geos at times of highly structured wave emissions. Wave-particle interaction studies with Geos are in fact approaching a stage where quantitative predictions about the wave environment may be made solely from particle measurements. In turn, a number of wave processes have been identified which can accelerate particles both parallel and perpendicular to the local magnetic field. Again, the wave signature and the expected response in the particle spectra have been clearly identified.



Geos

OTS

OTS has continued to operate satisfactorily since the last report. The warmest period of the year, i.e. the winter solstice, has again passed without problems, and the pre-eclipse-season battery reconditioning procedure has just been carried out.

Use of the 'solar-sailing' technique for spacecraft attitude control, mentioned in the last Bulletin, has been successfully continued, and will probably now be employed at least until the summer. Orbit control is still being executed via the appropriate thrusters.

It has been decided to continue the experiment whereby the RCS (Reaction Control System) branches are kept isolated from each other, to the point where the pressure in the branches drops to its lowest allowable working value. This will allow RCS operation to be checked over the complete operating pressure range, and will also allow a more accurate estimate to be made of remaining fuel. Present indications are that there may still be enough fuel for two to two and a half more years of operation.

The power subsystem continues to operate satisfactorily (BAPTA's, array powers, and battery performances). The thermal subsystem has maintained temperatures within limits throughout the *correction d'orbite reste assurée par des propulseurs appropriés.*

Il a été décidé de poursuivre l'expérience consistant à isoler l'une de l'autre les canalisations du système de pilotage à réaction (RCS) jusqu'au point où la pression dans la canalisation atteint sa plus faible valeur de fonctionnement admissible. On aura de la sorte l'assurance de pouvoir vérifier le fonctionnement du RCS sur toute la gamme des pressions de fonctionnement et de pouvoir également évaluer de façon plus précise la quantité d'ergols restante. Selon les indications actuelles, il resterait suffisamment d'ergols pour deux ans à deux ans et demi de fonctionnement.

Le fonctionnement du sous-système d'alimentation reste satisfaisant dans tous les secteurs: ensembles palier — collecteur (BAPTA), alimentation des réseaux et performances des batteries. Le système thermique a maintenu les températures dans les limites prescrites pendant toute la période chaude de l'année et le sous-système TTC, après une défaillance manifestement aléatoire survenue dans un bloc de huit détecteurs en d'août dernier, a continué d'assurer un fonctionnement irréprochable dans tous les autres secteurs.

Compte tenu des prochains lancements ECS, il a été récemment décidé de déplacer OTS de la position qu'il occupe au-dessus de l'équateur par 10°E, où il fonctionne depuis son lancement, à 5°E. Cette opération, qui se déroulera vers la mi-avril, libérera le créneau de 10°E pour ECS-1.

Pendant une période de trois mois, Eutelsat intérimaire a procédé à une série d'essais de liaison en direct via OTS entre les stations terriennes d'Italie et de France. Le système à grande vitesse utilisé (120 Mbit/s) est celui qui sera mis en oeuvre pour le satellite ECS. Les abonnés dont les appels avaient été acheminés via le satellite ont été rappelés après leur conversation téléphonique et il leur a été demandé de donner leur avis sur ce service. Les essais ont été très réussis et la réaction des abonnés a été particulièrement positive.

Pendant deux semaines, en décembre 1981, le quotidien britannique The Financial Times *a été 'téléimprimé' à Francfort en vue de sa distribution en Europe grâce à une liaison OTS établie entre de petites stations terriennes installées sur des toits d'immeubles à Londres et à Francfort.*

Météosat*

Secteur spatial

L'ensemble de la mission Météosat est assurée par le satellite Météosat-2, complété par le satellite Météosat-1 pour la collecte de données. Comme on s'y attendait, il a fallu pendant la première saison d'hiver procéder à une opération de décontamination pour libérer le radiomètre de Météosat-2 des fines couches de givre formées par la vapeur d'eau prise à l'intérieur des matériaux isolants avant le lancement. Deux opérations de décontamination ont été effectuées; la première, exécutée en décembre, a duré une journée et la deuxième, exécutée en février, deux journées. Météosat-1, actuellement à poste à 10°E, a été lancé en novembre 1977 et les ergols qui restent devraient assurer encore deux à trois ans de fonctionnement.

Secteur sol

C'est encore la mini-configuration qui est utilisée pour le secteur sol mais le niveau des performances est tel que le taux de disponibilité dépasse en moyenne 95%. La conversion du logiciel au nouvel équipement calcul se poursuit et tous les produits météorologiques seront disponibles à partir du 1er juillet. Le système de collecte de données a présenté un taux de disponibilité de 99%, avec toutefois une sensibilité réduite. Un contrat a été passé pour l'installation d'une nouvelle antenne, destinée à assurer le niveau de sensibilité initialement spécifié, qui sera mise en place à la station de l'Odenwald en août.

Programme opérationnel

Certains Etats membres n'ayant pas encore pris de décision quant à leur participation, la Conférence intergouvernementale n'a pas été réunie à nouveau.

Entre-temps, les groupes de travail ont achevé leur tâche dans le domaine technique et poursuivent leurs travaux sur les aspects institutionnels.

* *Compte rendu de la situation actuelle page 73.*

Exosat

Satellite

Les activités relatives au modèle de vol exécutées au cours des derniers mois se sont déroulées conformément aux plans. Des performances de référeance fonctionnelles ont été arrêtées à la mi-décembre, avant l'engagement de la séquence des essais de recette. Entre-temps, plusieurs essais et mesures au niveau système ont été exécutés avec succès (mesures physiques, compatibilité électromagnétique, alignement) et le satellite a été transporté chez IABG, Munich, pour y être préparé aux essais de vibration prévus pour la période du 26 février au 2 mars. Ces essais constituent incontestablement une étape majeure du programme du modèle de vol; ils démontreront en effet la validité de la conception mécanique du satellite et serviront en outre à la qualification de l'équipement de commande à réaction (RCE) au niveau système.

Par suite de la reconfiguration prévue pour juin-juillet, certains essais devront être répétés au cours de la période de juin à août; ils couvriront essentiellement trois phases:

- *reconfiguration des sous-systèmes de la charge utile et du véhicule spatial (AOCE, SAOM, STT);*
- *répétition des essais fonctionnels pour l'établissement des performances de référence définitives;*
- *essais d'ambiance limités, portant sur les modifications apportées à la configuration des matériels.*

La ligne d'action proposée ci-dessus semble compatible avec la lancement envisagé au début du créneau de la mi-octobre.

Le problème le plus notable au niveau des unités du satellite reste celui de la nécessaire remise en état de l'électronique de l'AOCS (système de commande d'orientation et de correction d'orbite), qui est actuellement en cours chez le sous-traitant MSDS pour l'unité de réserve, et qui devra être exécutée entre début mai et début juillet pour l'unité de vol.

Charge utile

Les douze détecteurs de l'expérience 'moyenne énergie' aux normes de vol ont été livrés à l'Europe par LND, le sous-traitant américain. Deux des huit hottest period of the year and the TTC subsystem, after what was clearly a random failure in a set of eight sensors in August last year, has continued to work perfectly in all other respects.

With the impending ECS launches, it was agreed recently to move OTS from its station above the equator at 10°E, where it has functioned since launch, to 5°E. This move will take place in mid-April, freeing the 10°E slot for ECS-1.

A series of live traffic tests have been conducted between the Italian and French earth stations, via OTS, for a period of three months by Interim Eutelsat. The full 120 Mbit/s system, as will be implemented for the ECS satellite, was used and subscribers whose calls were routed through the satellite were called back after completion of their conversations and asked their opinions of the service. These tests were very successful and subscriber reaction proved very positive.

For two weeks last December, the Financial Times was remotely printed in Frankfurt for European circulation via an OTS link between small earth stations on rooftops in London and Frankfurt.

Météosat*

Space segment

A full Meteosat service is being provided by Meteosat-2, complemented by Meteosat-1 for data collection. As expected, in the first winter season, decontamination had to be performed to remove thin layers of ice from Meteosat-2's radiometer caused by water-vapour trapped in the insulation material before launch. Two decontaminations were performed, one lasting a day in December, and another lasting two days in February. Meteosat-1, now stationed at 10°E, was launched in November 1977 and the remaining fuel is expected to last for another two to three years of operations.

Ground segment

The ground segment is still based on the mini-configuration, yet its performance is such that ground-segment availability is generally higher than 95%. Conversion of the software to the new computer system continues and all meteorological products will be available from 1 July. The Data Collection System has shown 99% availability, but with a reduced sensitivity. A contract for the installation of a new antenna to improve sensitivity to the originally-specified level has been issued, and this antenna will be installed at the Odenwald station in August.

Operational programme

As some Member States have still not decided on their participation, the Intergovernmental Conference has not yet been re-convened.

Meanwhile, the Working Groups have completed their tasks in the technical area and are continuing their work on the institutional aspects.

Exosat

Satellite

Flight-model activities in the past months have progressed according to plan. A functional performance baseline was established by mid-December, prior to entering the acceptance-test sequence. In the meantime several system-level tests and measurements have been satisfactorily performed (physical measurements, EMC, alignment) and the satellite transported to the premises of IABG, Munich to be prepared for vibration testing between 26 February and 2 March.

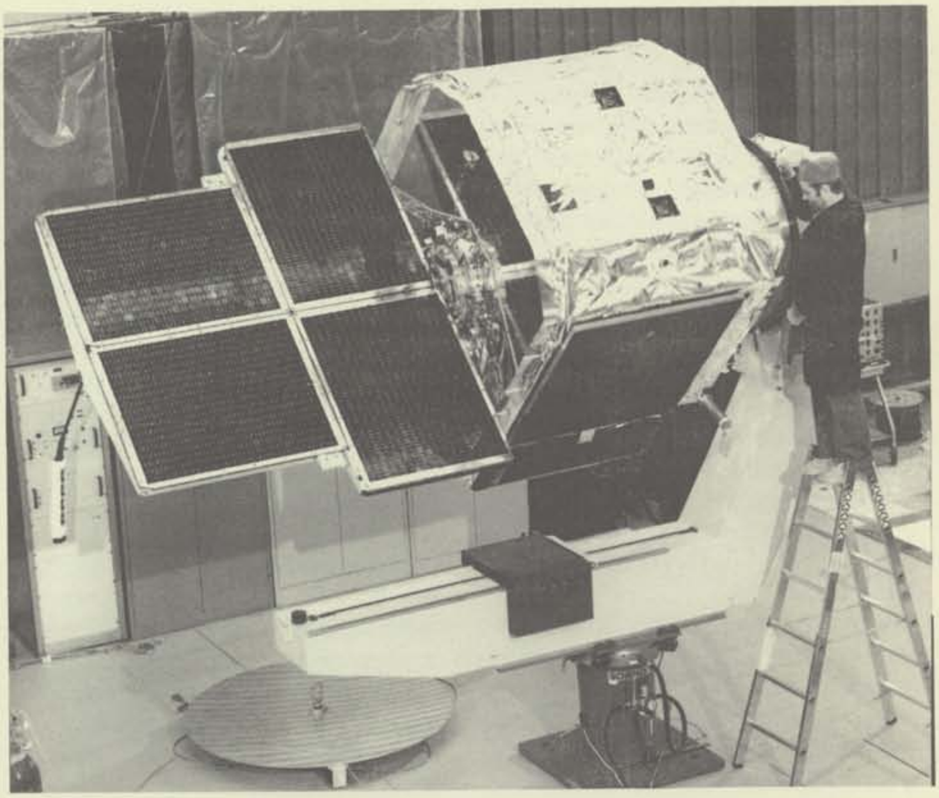
This test constitutes a major milestone in the flight-model programme as it will demonstrate mechanical integrity of the satellite and will also serve to qualify the reaction control equipment (RCE) at system level.

Following the reconfiguration work planned for June/July, some tests will have to be repeated between June and August and will cover essentially three phases:

- reconfiguration of payload and spacecraft subsystem (AOCE, SAOM, STT)
- functional retesting to establish a final performance baseline
- restricted environmental testing to verify changes in hardware configuration.

The above actions still appear compatible with a launch at the beginning of the mid-October launch window.

The most significant problem at spacecraft unit level is still the refurbishment of the AOCS-electronics,



Centre-of-gravity measurements being conducted on the Exosat flight model at MBB in Germany

Mesures du centre de gravité du modèle de vol d'Exosat chez MBB.

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* For latest status, see page 73.

détecteurs de la configuration de vol, accompagnés de leur étage électronique d'entrée et d'un boîtier électronique principal ont été intégrés au véhicule spatial pour des essais au niveau système. La totalité des équipements de l'expérience 'moyenne énergie' seront installés en juin.

Le problème du compteur proportionnel à détection de position (PSD) décelé lors des essais sous faisceau long du télescope imageur à la mi-1981 a été résolu grâce à la mise au point d'un gadget électronique baptisé suppresseur de 'pings' (décharges disruptives à haute tension), réalisé aux normes de vol, qui sera incorporé sous peu au deuxième télescope imageur. Le suppresseur de 'pings' destiné au premier télescope, qui se trouve actuellement monté sur le véhicule spatial pour les essais au niveau système, sera incorporé au télescope à la fin de la séquence des essais système en juin.

Certains effets de vieillissement à long terme ayant été observés pour les miroirs à rayonnement X produits selon une méthode de fabrication par réplique, on est parvenu à modifier le processus de production de façon à éliminer ces effets.

L'unité de vol de réserve du compteur proportionnel à tube à gaz à scintillation (GSPC) sera soumise sous peu aux opérations d'étalonnage au Département Science spatiale de l'ESA, à l'ESTEC.

Lanceur

Le point des travaux relatifs au lanceur d'Exosat a récemment été fait, et leur avancement a été jugé dans l'ensemble conforme au calendrier de lancement opérationnel. Cependant, le quatrième étage fera l'objet d'une attention particulière lors de l'examen de qualification prévu pour début mars. Sous réserve que les problèmes actuels (vérification de la compatibilité, poussée résiduelle du dernier étage après séparation) soient alors résolus, on pourrait compter sur la disponibilité de l'étage en temps utile pour un lancement en octobre.

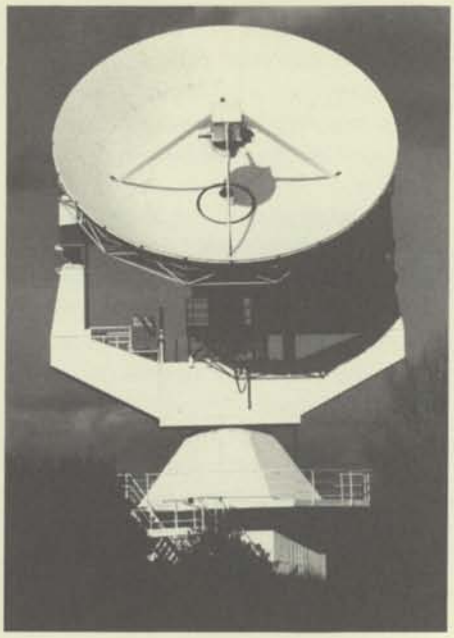
Système sol

Une première série d'essais utilisant le modèle d'identification pour procéder à la vérification du logiciel de surveillance et de contrôle du satellite a été entreprise en novembre. Des lignes de données reliant la firme MBB, où se trouvait le satellite, à l'ESOC ont été établies à cette fin. Les préparatifs ont maintenant commencé pour la prochaine série d'essais, en mai, au cours de laquelle le modèle d'identification sera de nouveau utilisé pour la qualification de la majeure partie du logiciel opérationnel.

La recette de l'antenne de la station sol de Villafranca, commencée en février, doit s'achever avant la fin du mois. La majeure partie de l'équipement de la station, qui a subi une préintégration à l'ESOC et a servi à une première série d'essais de compatibilité en août dernier, a été expédiée à Villafranca à la mi-février. Les plans prévoient l'intégration complète de la station pour la mi-juin.

La sélection des projets à retenir parmi les propositions d'observations reçues en réponse au premier Avis d'offre de participation a été reportée, car l'évaluation technique des propositions (par ex. vérification des hypothèses de sensibilité et des temps d'exposition) a pris plus de temps que prévu du fait, surtout, de leur nombre particulièrement élevé (>500). On prévoit l'achèvement de la procédure de selection pour le mois d'avril.

La préparation des opérations et de l'analyse des données a progressé de façon satisfaisante et l'équipe 'observatoire' commencera son transfert de l'ESTEC à l'ESOC début mai.



Antenne de la station sol d'Exosat à la station le Villafranca, près de Madrid.

The Exosat ground-station antenna at ESA's Villafranca del Castillo station near Madrid

Télescope spatial

Réseau solaire

L'intégration complète du modèle de développement de l'aile du réseau solaire a été menée à terme. Les derniers essais au niveau du système sont en cours.

Le premier essai dynamique au niveau système du mécanisme d'entraînement du réseau solaire et de son électronique a été exécuté, avec pour objet de déterminer le couple d'interaction entre le réseau solaire et le Télescope spatial lors de la manoeuvre d'orientation. Il est apparu que la conception actuelle permet de répondre à la plupart des impératifs, mais certaines modifications doivent être apportées pour que la stabilisation intervienne en toute circonstance dans les délais prescrits.

Presque tous les éléments du premier modèle de vol du mécanisme de déploiement secondaire de l'aile sont disponibles pour l'intégration, mais un retard est intervenu dans la livraison du modèle de vol des mâts bi-stem, un écart par rapport aux spécifications ayant été constaté aux basses températures sous vide.

Les essais de qualification en cyclage thermique des échantillons de nappe de cellules solaires ont commencé.

Chambre pour objet de faible luminosite (FOC)

L'électronique de vol a été livrée en vue de son intégration dans le modèle de vol de la FOC. Les résistances chauffantes ont été réparées.

Le modèle de vol de la FOC, comprenant le modèle structure/thermique du détecteur de photons, est en cours de préparation pour les premiers essais 'système' thermiques sous vide, prévus pour avril. Ces essais ont pour objet la qualification du système de régulation thermique de vol.

Détecteur de photons

Le modèle d'identification du détecteur de photons a été livré en vue des essais d'intégration électriques avec la FOC. De currently in progress at MSDS for the spare unit, and which will have to be applied to the flight-model unit in the period early May to early July.

Payload
All twelve, flight-standard, medium-energy experiment detectors have been delivered to Europe by LND, the US subcontractor. Two of the eight detectors to be flown, together with their front-end electronics and main electronics unit, have been integrated with the spacecraft for system-level testing. The full detector complement of the medium-energy experiment will be made up in June.

The problem with the position-sensitive proportional counter (PSD) detected during long-beam testing of the imaging telescope in mid-1981 has been overcome by development of an electronic gadget christened a 'ping quencher'. The latter has been built to flight standard and will be integrated shortly with the second imaging telescope. The 'ping quencher' for the first telescope, now integrated with the spacecraft for system-level testing, will be incorporated with the telescope at the end of the system test sequence in June.

Following detection of certain long-term aging effects in the X-ray mirrors, which are produced by a replication method, a modification to the production process which eliminates these effects has been devised and implemented.

The flight-spare unit of the gas-scintillation proportional counter (GSPC) experiment will be calibrated at ESTEC shortly by ESA Space Science Department.

Launcher
A recent review of work on the Exosat launcher showed progress to be in line with the operational launch schedule. Fourth-stage qualification will receive special attention at the qualification review scheduled for the beginning of March, by which time it is hoped that current problems (compatibility verification, rest thrust of final stage after separation) will have been solved allowing the stage to be ready in time for the October launch.

Ground system
An initial series of tests using the engineering model to check satellite monitoring and control software was conducted in November, using data lines between MBB, where the satellite was located, and ESOC. Preparations have now started for the next series of tests, in May, when the engineering model will again be used to qualify the majority of the operational software.

Acceptance of the ground-station antenna at Villafranca was initiated in February and is due to be completed before the end of the month. The major part of the station equipment, which had been pre-integrated at ESOC and used for an initial series of compatibility tests in August last year, was shipped to Villafranca in mid-February. The station is planned to be fully integrated by mid-June.

Selection of observation proposals submitted in response to the first Announcement of Opportunity has been delayed because their technical evaluation (including checking of sensitivity assumptions and exposure times, etc.) has taken far longer than expected, due in large part to the unexpectedly high number of proposals (<500). The selection process is now expected to be completed in April.

Preparations for operations and data analysis have proceeded satisfactorily, and the observatory team will begin to be transferred from ESTEC to ESOC at the beginning of May.

Space Telescope

Solar array
The development solar-array wing has now been fully integrated and final system testing is in progress.

The first dynamic system test with the solar-array drive mechanism and associated electronics has been carried out to determine interactive torque between the solar array and the Space Telescope body when slewing. Most requirements were shown to be met with the current design, but some modifications have to be introduced to meet settling-time requirements under all circumstances.

Nearly all elements of the first flight-wing secondary deployment mechanism are available for integration, but a delay has occurred in the delivery of the flight bi-stem cassettes, due to out-of-specification measurements noted at low temperatures in vacuum.

The thermal-cycling qualification tests for the blanket samples have started.

Faint-Object Camera
The flight electronics-bay assembly has been delivered for integration into the FOC flight model. The heater mats have been repaired.

The flight model of the FOC, including the structural/thermal model of the PDA, is now being prepared for the first thermal-vacuum system test, scheduled for April. This test is designed to qualify the flight thermal-control system.

Photon Detector Assembly
The engineering model of the Photon Detector Assembly has been delivered for electrical integration testing with the FOC. New magnets for the intensifier section have been manufactured.

During vibration of the intensifier section, one of the mica windows of the intensifier tube fractured. Subsequent analysis and tests verified that this failure was due to a quality problem in that particular intensifier.

The protoflight model of the camera tube has since fractured, and the reasons for this are still under investigation.

ISPM

Launcher and launch date
Following the definitive cancellation of the NASA spacecraft and the ESA decision to continue ISPM with a single, European-provided spacecraft, there has been some discussion at top-management level on the feasibility of advancing the launch date to 1985. Unfortunately, it has now been decided from the NASA side that such a move is not practicable and the launch date therefore remains at May 1986. ESA will continue to build against a completion date of mid-1983 followed by a period in storage before the launch campaign starts.

There has also been some uncertainty concerning the interplanetary transfer vehicle which will carry the spacecraft from the Shuttle's near-Earth orbit to the vicinity of Jupiter. During the course of 1981 four different vehicles have been *nouveaux aimants ont été fabriqués pour l'étage intensificateur.*

Au cours des essais de vibration de l'étage intensificateur, l'une des fenêtres de mica du tube de l'intensificateur s'est brisée. L'analyse et les essais effectués à la suite de cet incident ont confirmé que cette défaillance tenait à un problème de qualité propre à cet intensificateur particulier. Récemment, le prototype de vol du tube de la chambre s'est cassé. Une enquête est en cours.

ISPM

Lanceur et date de lancement

Après l'annulation définitive du satellite de la NASA et la décision prise par l'ESA de poursuivre le projet ISPM avec un seul satellite fourni par l'Europe, les autorités supérieures avaient eu quelques échanges de vue sur la possibilité d'avancer à 1985 la date du lancement. On vient malheureusement de décider du côté de la NASA que ce changement de date n'est pas réalisable, le lancement reste donc prévu pour mai 1986. L'ESA poursuivra ses activités en fonction d'une date d'achèvement fixée à la mi-1983, suivie d'une période d'entreposage jusqu'au démarrage de la campagne de lancement.

Le véhicule de transfert interplanétaire qui transportera le satellite de l'orbite terrestre basse de la Navette jusqu'au voisinage de Jupiter a également donné lieu à quelques incertitudes. Au cours de l'année 1981, quatre véhicules différents ont été sérieusement envisagés, mais à l'heure actuelle la base de référence est l'étage supérieur inertiel (IUS) à deux étages mis au point par l'Armée de l'Air américaine, auquel serait adjoint un petit moteur reposant sur une fusée à poudre existante.

Charge utile scientifique

Avec la supression du satellite de la NASA, tout un secteur scientifique portant sur l'étude du gaz neutre interstellaire s'est trouvé éliminé de la mission ISPM. Pour palier cette lacune, on a décidé de modifier légèrement la charge utile scientifique du satellite restant pour y inclure une version réduite d'une expérience précédemment prévue pour le satellite de la NASA. Malgré le stade déjà atteint dans la conception et la réalisation du satellite, cette modification s'est révélée possible sans incidence majeure sur les ressources ou le calendrier du satellite.

Le groupe de travail scientifique s'est réuni en février, pour la première fois depuis que le satellite de la NASA a été définitivement rayé du projet. Outre l'examen des différentes interfaces entre le véhicule spatial et les expériences, deux résolutions ont été adoptées demandant instamment à la NASA de prendre des mesures pour atténuer l'incidence de la suppression de son satellite.

Véhicule spatial

En décembre 1981, l'examen de la conception des matériels du véhicule spatial s'est déroulé devant une commission d'examen commune ESA/NASA. Celle-ci a fait le point de l'avancement du projet et donné l'autorisation de passer aux phases suivantes du développement. Cet examen a donné dans l'ensemble des résultats jugés satisfaisants et un nombre relativement réduit de recommandations ont été formulées. En février 1982, un autre examen également important s'est déroulé au Johnson Space Center et au Kennedy Space Center de la NASA: il s'agissait de l'examen de sécurité du niveau 2, étape essentielle pour l'autorisation d'un lancement au moyen de la Navette. Ici encore, les conclusions de l'examen ont été satisfaisantes.

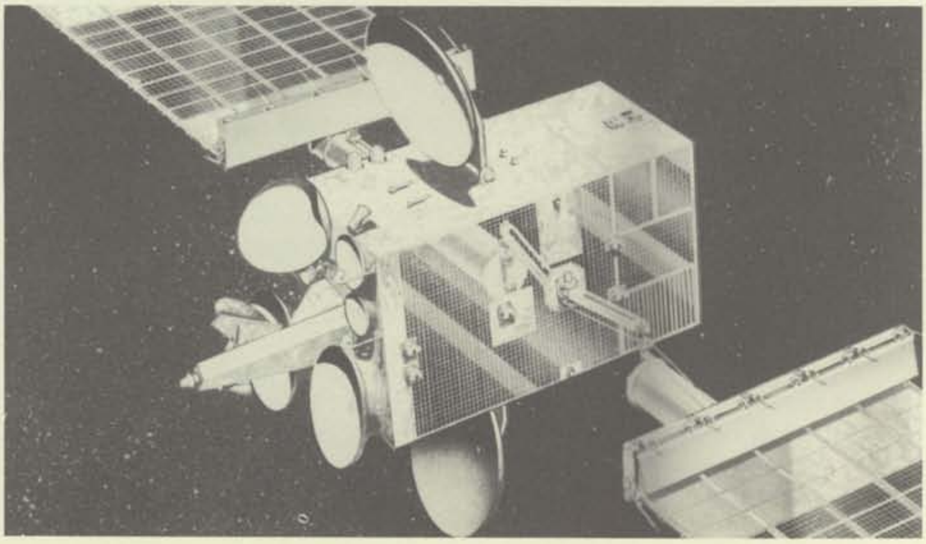
Dans le domaine technique, les travaux continuent d'avancer de façon satisfaisante et les problèmes en suspens concernant le comportement mécanique de la structure sont aujourd'hui résolus. Toutes les expériences sont maintenant intégrées au modèle de qualification du satellite et fonctionnent bien ensemble de manière générale. Le principal problème reste celui de la mise au point d'un répéteur satisfaisant. Ce point mis à part, la fabrication de toutes les unités de vol des sous-systèmes et expériences se déroule conformément au calendrier correspondant à l'achèvement de la phase C/D d'ISPM à la mi-1983.

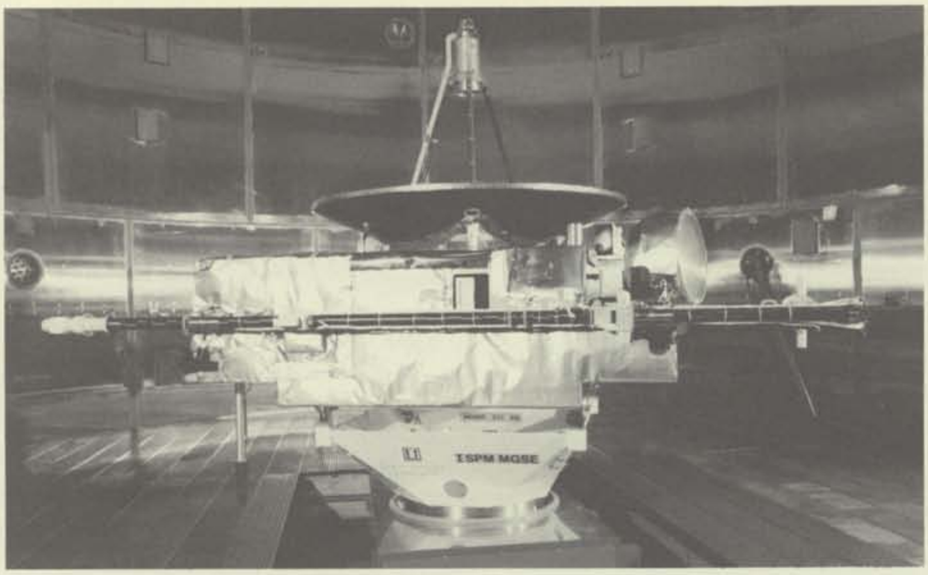
Hipparcos

A la suite de l'évaluation des offres reçues de la part de l'industrie, l'Agence a attribué, fin janvier, un contrat pour l'étude de définition non concurrentielle (phase B1) au Consortium MESH, dont le chef de file est Matra. Cette étude doit durer treize mois et sera suivie — si elle donne satisfaction — par les phases de définition détaillée (B2) et de développement (C/D).

L-Sat

A la fin de 1981, les souscriptions des Etats membres à la Déclaration relative au programme L-Sat avaient atteint le niveau requis pour la mise en route de la phase de réalisation. Des variations ont été signalées concernant les niveaux de participation de certains Etats membres, la plus importante en termes absolus étant la décision de la Suisse de ne pas participer au programme, du moins jusqu'à nouvel ordre. Cette décision implique la redistribution d'un certain nombre de tâches industrielles. Il s'agit principalement de tâches précédemment allouées à l'industrie suisse et relevant des domaines 'structure' et 'AIT' ainsi





ISPM under test in the large vacuum chamber at ESTEC

ISPM au cours des essais dans la grande enceinte de vide thermique à l'ESTEC.

seriously considered, but at the present time the baseline is the two-stage Inertial Upper Stage developed by the US Air Force plus a small boost motor based on an existing solid rocket.

Scientific payload

When the NASA spacecraft was cancelled, one area of science, that of interstellar neutral gas, no longer existed within the ISPM mission. To remedy this deficiency it was decided to modify slightly the scientific payload of the remaining spacecraft to incorporate a reduced version of an experiment previously on the NASA spacecraft. Despite the advanced status of spacecraft design and development, it has proved possible to do this without major impact upon spacecraft resources or schedule.

In February a meeting of the Science Working Team took place, the first since the final cancellation of the NASA spacecraft. In addition to reviewing the various interfaces between the spacecraft and the experiments, two resolutions were passed which urged NASA to take steps to reduce the impact of the cancellation of the NASA spacecraft.

Spacecraft

During December 1981, the Hardware Design Review for the spacecraft took place before a joint ESA-NASA review board. This examined the progress of the project to date and gave authorisation for the next phases of the development. The review was generally felt to be successful and a relatively small number of recommendations were made. In February 1982 an equally important review took place at NASA's Johnson Space Center and Kennedy Space Center. This was the Level-2 Safety Review, which is an essential step in obtaining authorisation to launch using the Shuttle. Once again, this review was satisfactory.

Satisfactory progress continues on the technical side and the outstanding problems with the mechanical behaviour of the structure have now been resolved. On the qualification spacecraft, all experiments are now integrated and generally functioning well together. The major problem area continues to be the development of a satisfactory transponder. With this exception, manufacture of all subsystem and experiment flight units is now under way and on schedule for completion of ISPM's main development phase by mid-1983.

The L-Sat spacecraft

Le véhicule spatial L-Sat

Hipparcos

Following evaluation of the industrial proposals, a contract for a noncompetitive Phase-B1 definition study was awarded in late January to the MESH Consortium, led by Matra. This study is planned to last 13 months and, upon satisfactory completion, will be followed by detailed definition (B2) and development (C/D) phases.

L-Sat

Late in 1981, the necessary level of Member-State subscriptions to the L-Sat Programme Declaration was obtained, allowing the Development Phase to start. Variations in the levels of participation of certain Member States were notified, the most significant in absolute terms being the decision of Switzerland not to participate in the programme, at least for the time being. This has necessitated re-allocation of a number of industrial tasks formerly allocated to Swiss industry (mainly structural and AIT tasks, certain items of electrical ground support equipment, and the 20/30 GHz payload oscillator). This late reallocation of work has inevitably perturbed the smooth start-up of the industrial work.

Immediately the programme declaration had entered into force, the Agency issued a preliminary authorisation for the prime contractor to proceed with the Phase-C/D (main development phase) contract on a limit-of-liability basis. The first two months of this phase have involved initiation of industrial activity in all subsystem areas. Simultaneously, detailed negotiations on various commercial/contractual aspects are being conducted between ESA and British Aerospace, the prime contractor.

The next significant programme milestone, the Baseline Design Review, was scheduled for the end of March, and it is envisaged to make a full contractual release thereafter, as soon as the above mentioned negotiations have been concluded.

A first evaluation of the Telespazio preliminary proposal for undertaking the L-Sat on-station operations has been made and plans are now being prepared for follow-up actions in this area.

Sirio-2

Once analyses, verifications and other minor tests had been performed following the flight-readiness review, the Sirio-2 satellite was shipped on 23 February from Rome to Kourou, where the launch campaign was commenced.

Electrical-system tests started in early March in the S1 integration hall at CSG *que de certains éléments de l'équipement électrique de soutien au sol et de l'oscillateur de la charge utile 20/30 GHz. Il était inévitable que cette redistribution tardive des travaux affecte la mise en route des travaux industriels.*

Dès que la Déclaration relative au programme est entrée en vigueur, l'Agence a donné au contractant principal un feu vert préliminaire l'autorisant à procéder à l'exécution du contrat de phase C/D (phase de développement principal) sur la base d'un remboursement des frais. Au cours des deux premiers mois de cette phase, des activités industrielles ont été mises en route au niveau de tous les sous-systèmes. Simultanement des négociations poussées sur divers aspects commerciaux/contractuels se déroulaient entre l'ESA et British Aerospace, contractant principal.

La prochaine étape importante du programme, l'examen de la conception de référence, étant fixée à la fin du mois de mars, on prévoit de donner l'autorisation contractuelle totale dès que les négociations susmentionnées seront terminées.

La proposition préliminaire, faite par Telespazio, de se charger de l'exploitation à poste de L-Sat, a fait l'objet d'une première évaluation et des plans sont actuellement à l'étude pour la suite à donner à cette proposition.

Sirio-2

Après que les analyses, vérifications et essais mineurs, demandés à l'issue de l'examen d'aptitude au vol, aient été effectués, le satellite a été transporté le 23 février de Rome à Kourou et la campagne de lancement a donc débuté.

Les essais électriques du système ont commencé début mars dans le hall d'intégration S1 du CSG et se poursuivront par le contrôle des deux charges utiles (MDD et LASSO).

En ce qui concerne le segment sol, des opérations de simulation sont en cours afin de valider les différents logiciels et font intervenir le Centre de contrôle Sirio-2, les trois stations MDD (provisoirement à Fucino), le Centre de contrôle LASSO, et les stations laser.

Télédétection

Après le vote de la Résolution habilitante par le Conseil le 28 octobre 1982, l'Exécutif a procédé à la rédaction des textes de la Déclaration et du Règlement d'exécution. La Déclaration est ouverte à la signature jusqu'au 15 avril 1982.

L'appel d'offres relatif à ERS-1, après ses dernières mises au point, était prêt dès la première semaine de novembre. A la demande de certaines délégations, la question a dû être reportée dans l'attente d'un accord final sur la politique industrielle pour la phase-B.

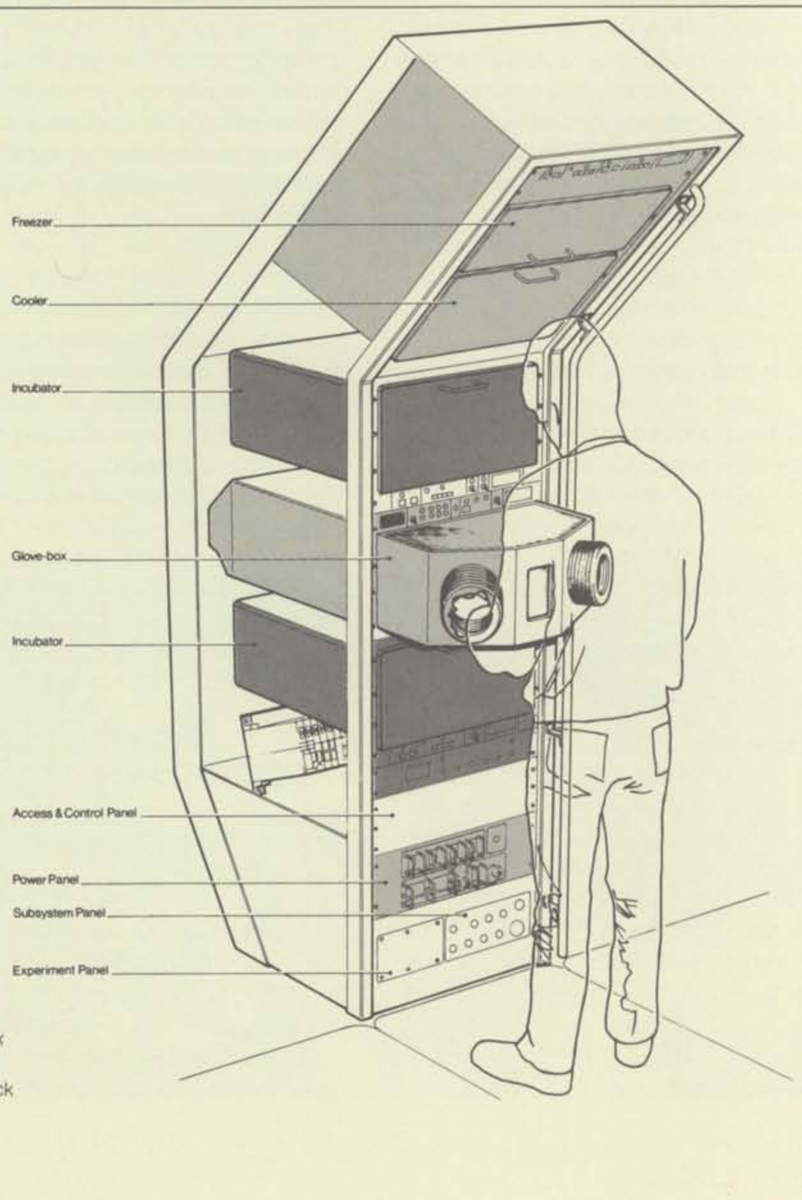
Les activités technologiques du Programme préparatoire de Télédétection (RSPP) engagées avant la fin 1981 se poursuivent et le Conseil directeur du Programme a accepté le report sur 1982 des crédits restants.

La préparation des opérations des deux expériences de télédétection de la FSLP se poursuit conformément aux plans.

Biorack

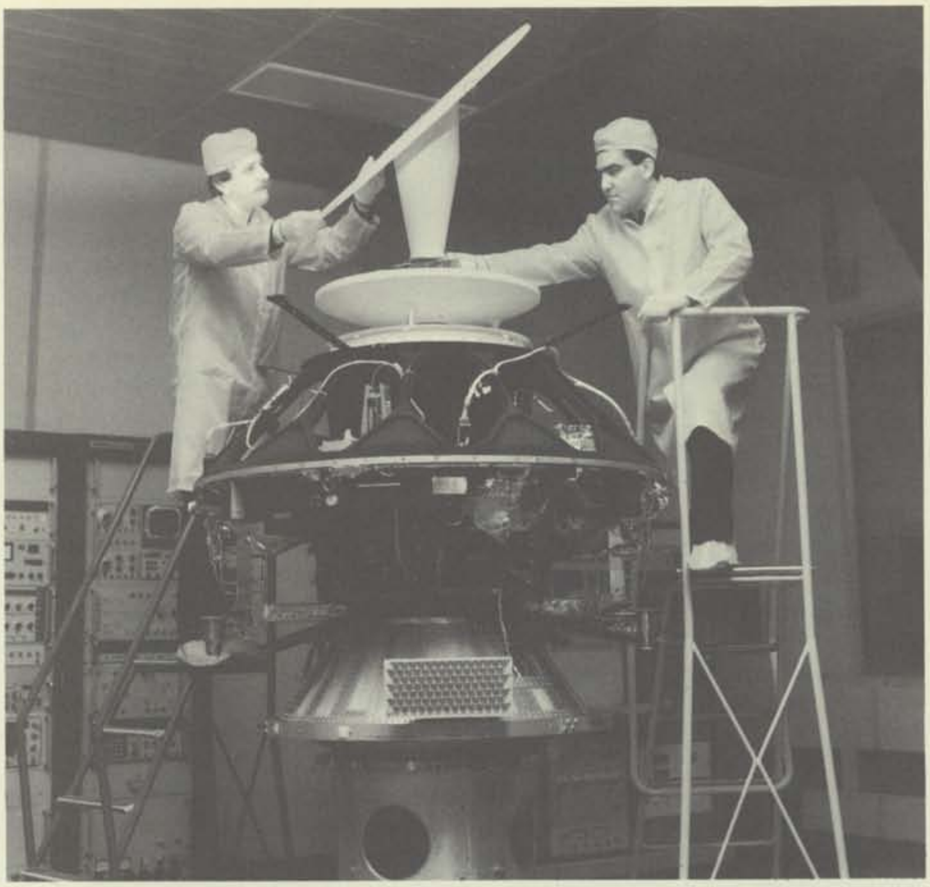
Le projet de réalisation du Biorack (bâti des sciences de la vie) a été récemment approuvé par le Conseil au titre du programme 'microgravité' de l'Agence. Ce projet a démarré officiellement en février, son but est de faire voler cette installation à l'occasion de la mission allemande D1 du Spacelab en 1985.

Le Biorack est une installation à utilisateurs multiples permettant d'effectuer des recherches biologiques sur des formes de vie telles que: des plantes, des tissus, des cellules, des bactéries et des insectes. Son but est de déterminer les effets du milieu sans pesanteur et des rayonnements de l'espace. Le Biorack comprendra: des équipements de vie et de conditions d'ambiance, des installations pour le maniement, la conservation et l'examen des substances soumises aux expériences, ainsi que des instruments pour effectuer des mesures de référence à 1 g, sur orbite. L'essentiel de ce matériel



Le Biorack

The Biorack



Flight model of Sirio-2 at CNS (Rome), shortly before transportation to Kourou for launch

Modèle de vol de Sirio-2 au CNS à Rome, peu avant son transport à Kourou.

and continued with the checking of the two payloads (MDD and Lasso).

As far as the ground segment is concerned, operational simulations are under way to validate the various software packages, and involving in particular the Sirio-2 Control Centre, the three MDD stations (provisionally at Fucino), the Lasso Control Centre, and laser stations.

Remote Sensing

Since the Enabling Resolution was voted by Council on 28 October, the Executive has prepared the texts of the Declaration and of the Implementing Rules. The Declaration is open for signature until 15 April 1982.

The ERS-1 Invitation to Tender has been finalised and was ready for issue in the first week of November. At the request of some Delegations, issue had to be postponed pending final agreement on the industrial policy for Phase-B (definition phase).

RSPP (Remote-Sensing Preparatory Programme) technological activities committed before the end of 1981 are continuing and the Remote-Sensing Programme Board has accepted the carry-over of remaining funds to 1982.

Preparations for the operation of the two remote-sensing experiments on FSLP are progressing according to plan.

Biorack

The Biorack project has recently been approved by Council as part of the Agency's Microgravity Programme. This development project formally started in February 1982 and the aim is to fly the Biorack on the German Spacelab D-1 mission in 1985.

The Biorack is a multipurpose facility for performing biological investigations on such life forms as plants, tissues, cells, bacteria and insects. It will be used to determine the effects of zero-g and the space-radiation environment. The Biorack will carry facilities for: life support; environmental support; experiment-specimen handling, preservation and examination; and also for performing 1-g reference measurements while in orbit. The heart of the Biorack is contained in a standard 'single' Spacelab equipment rack. Other special Biorack containers are mounted in the Spacelab module and on the Shuttle Orbiter's middle deck.

A recent evaluation of experiment proposals by a scientist peer group has produced a shortlist which will serve as the basis for future work to form a payload for the first mission. Current activities include the preparation of an invitation to tender for the thermal-conditioning units, breadboarding of critical system parts, and system design.

Spacelab

A major milestone in the Spacelab development programme was completed with the delivery of the first Flight Unit (FU-I) to Kennedy Space Center (KSC) in December 1981/January 1982.

The Delivery Ceremony at KSC on 5 February was attended by George Bush, Vice President of the United States, the Director General of ESA, the NASA Administrator, the Chairman of the Spacelab Programme Board, members of the American Congress and officials from ESA, European Governments, NASA and the European Spacelab Consortium.

The OSS-1 payload (NASA Office of Space Sciences) for the second ESA pallet, to fly on the Space Shuttle's third flight (STS-3), has been installed by NASA, and pallet and payload have been installed in the Orbiter bay. Launch is scheduled for 10.00 h on Monday 22 March 1982. The mission is dedicated to thermal testing of the Orbiter and subsystems, including the pallet. The Shuttle's payload-bay doors will therefore be open to the Sun for most of the mission, exposing the pallet and payload with its nine instruments, and producing a rigorous thermal environment.

Integration and test activities on the second Spacelab flight unit are underway, but a delay of three weeks seems inevitable, delivery to NASA currently being scheduled for June 1982.

The resident European team, consisting

est contenu dans un bâti simple normalisé du Spacelab. Les autres équipements du Biorack sont des conteneurs spéciaux installés dans le module du Spacelab et sur le pont moyen de la Navette.

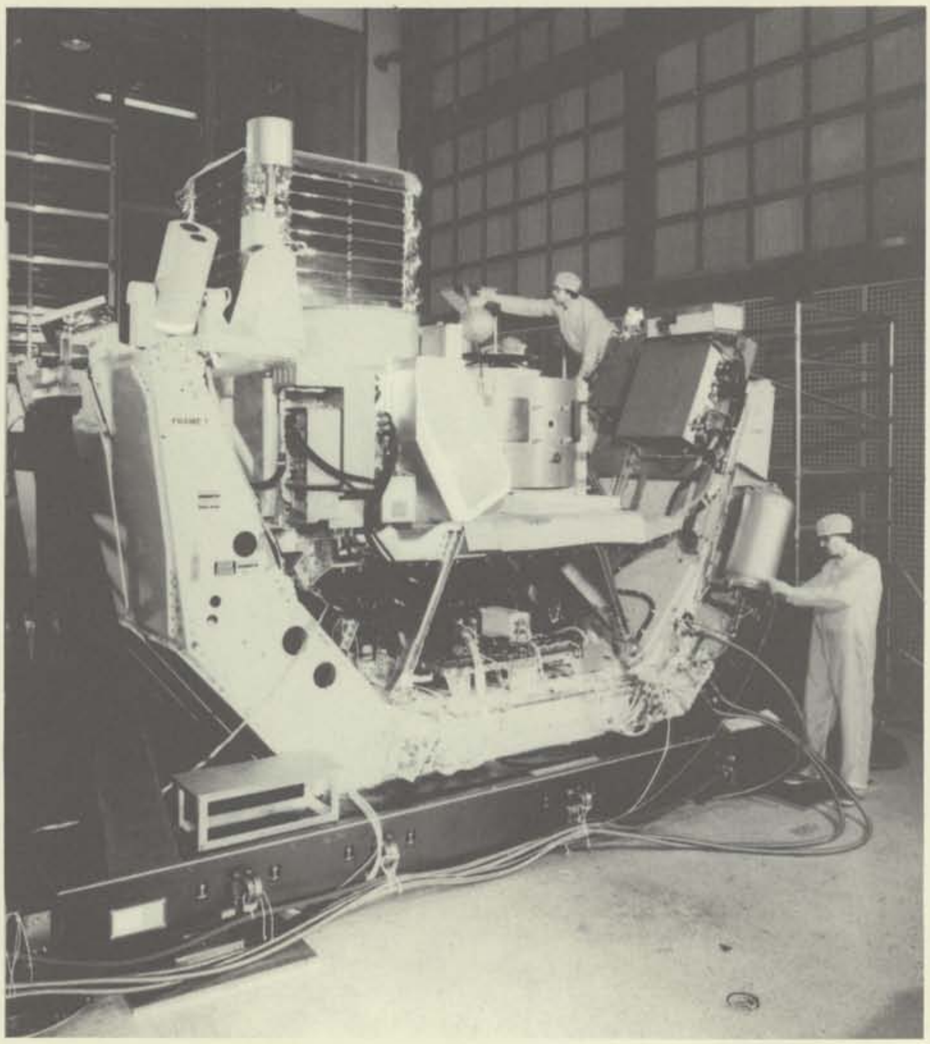
A la suite d'une récente évaluation des propositions d'expériences par un groupe de scientifiques, une liste d'expériences a été arrêtée afin de servir de base pour les travaux futurs relatifs à la constitution d'une charge utile pour la première mission. Les activités en cours portent sur la préparation d'un appel d'offres pour les appareils de conditionnement thermique, le montage de table des parties critiques du système et la conception de ce dernier.

Spacelab

Une étape majeure dans le programme de développement du Spacelab, la livraison de la première unité de vol (FU-1), a été franchie avec l'arrivée de ce modèle au Kennedy Space Center (KSC) en décembre 1981/janvier 1982.

La cérémonie de remise officielle s'est déroulée le 5 février au KSC, en présence du Vice-Président des Etats-Unis, M. George Bush, du Directeur général de l'ESA, de l'Administrateur de la NASA, du Président du Conseil directeur du Programme Spacelab, de membres du Congrès des Etats-Unis, de fonctionnaires de l'ESA et de représentants des gouvernements européens, de la NASA et du consortium européen chargé du Spacelab.

La charge utile OSS-1 ('Office of Space Science' de la NASA) — qui doit prendre place sur le deuxième porte-instruments ESA qu'emportera la Navette lors de son 3ème vol — a été installée par la NASA, tandis que le porte-instruments avec sa charge utile a été placé dans la soute de l'Orbiteur. Le lancement de STS-3 est fixé au lundi 22 mars, à 10 h 00. Cette mission est consacrée à un essai thermique de l'Orbiteur et de ses sous-systèmes, y compris le porte-instruments. Les portes de la soute contenant la charge utile seront ouvertes la plupart du temps, le porte-instruments et la charge utile seront donc exposés au Soleil et soumis à des conditions thermiques rigoureuses. La charge utile se compose de neuf instruments.



Le deuxième porte-instruments du modèle technologique du Spacelab, destiné à voler à bord du troisième vol de la Navette (STS-3) avec la charge utile OSS-1.

Second Spacelab engineering-model pallet, flown on the third Space-Shuttle flight (STS-3) with the OSS-1 payload.

Les activités d'intégration et d'essai sur le deuxième modèle de vol du Spacelab se poursuivent, mais un retard de trois semaines paraît inévitable, la livraison à la NASA étant maintenant prévue pour le mois de juin.

L'équipe européenne composée de membres du personnel de l'ESA et de son contractant est maintenant installée au KSC et collabore avec la NASA et son contractant à la solution des problèmes mineurs que posent le modèle d'identification précédemment livré ainsi que le modèle FU-1 dont le premier vol est prévu pour septembre 1983.

L'ESA et la NASA sont parvenues à un accord sur la maintenance de dépôt en Europe. La NASA utilisera les installations mises sur pied en Europe par les contractants de la phase de développement pendant un an au moins après le deuxième vol de Spacelab actuellement fixé à novembre 1984.

Les travaux touchant la conception du système de pointage d'instruments (IPS) avancent de façon satisfaisante et devraient permettre de respecter la date d'avril 1982 prévue pour l'examen critique de la conception.

Le programme de production ultérieure du Spacelab (FOP) se déroule de façon satisfaisante. Dans le cadre de ce programme, un deuxième jeu d'équipements du Spacelab représentant presque un Spacelab entier doit être fourni à la NASA, aux frais de cette dernière. Il y aura quelques retards, certaines pièces électriques, électro-magnétiques et électroniques n'étant pas disponibles et la NASA ayant demandé des améliorations. Les modifications of ESA and ESA contractor personnel, is now fully established at KSC. They are working with NASA and its contractors on resolution of routine problems arising on the previously delivered engineering model and now also on the first flight unit, scheduled for launch in September 1983.

General agreement has been reached between ESA and NASA on European depot maintenance. NASA will use the European facilities, established by the development-phase contractors, for at least one year after the second Spacelab flight, currently scheduled for November 1984.

Design work on the Instrument Pointing System (IPS) is progressing satisfactorily and the Critical Design Review is expected to take place in April as planned.

The Spacelab Follow-on Production (FOP) programme, in which a second set of Spacelab equipment, equivalent to about one Spacelab, is to be bought by NASA, is proceeding satisfactorily. Some delays will be encountered as a result of nonavailability of some components and NASA-requested improvement changes. Contractual changes were negotiated in December 1981, amounting to 1 MAU. NASA-funded improvements to Spacelab have been introduced for the first time, causing differences in FOP hardware.

IPS follow-on production is still on hold, but NASA has indicated its intention to go ahead in June 1982, subject to a successful IPS Critical Design Review.

The Spacelab Follow-on Development (FOD) programme is still in a decision phase. ESA's Council has re-set the final date for joining the programme at 15 March 1982.

FSLP

The last experiment for integration into the European payload complement was delivered in December. Because the last three experiments to be delivered (Grille Spectrometer, Very Wide Field Camera, and Lyman-÷ Emissions Measurement) arrived approximately 1-month later than planned, completion of the integration testing had to be rescheduled for February 1982. There is, however, still time to complete all the necessary activities at Bremen before shipping the payload to Kennedy Space Centre (KSC) at the end of May.

A joint ESA/NASA Programme Review was held at SPICE on 7 December. The ESA payload was judged to be in good condition, very significant progress having been made since the November 1980 Programme Review.

The refurbishment of the Material-Sciences Double Rack has continued, and re-integration is scheduled to recommence in February, leading to a 1 July delivery date to NASA/KSC.

Payload specialists Dr. U. Merbold and Dr. W. Ockels have been moved to NASA's Marshall Space Flight Center (MSFC) with effect from 1 January 1982, whilst Mr. C. Nicollier continues his training as ESA Mission Specialist at NASA's Johnson Space Center (JSC).

Definition of the Sled interfaces with the US experiment for the German Spacelab D1 flight has advanced significantly, and procurement of a single Spacelab rack has been initiated.

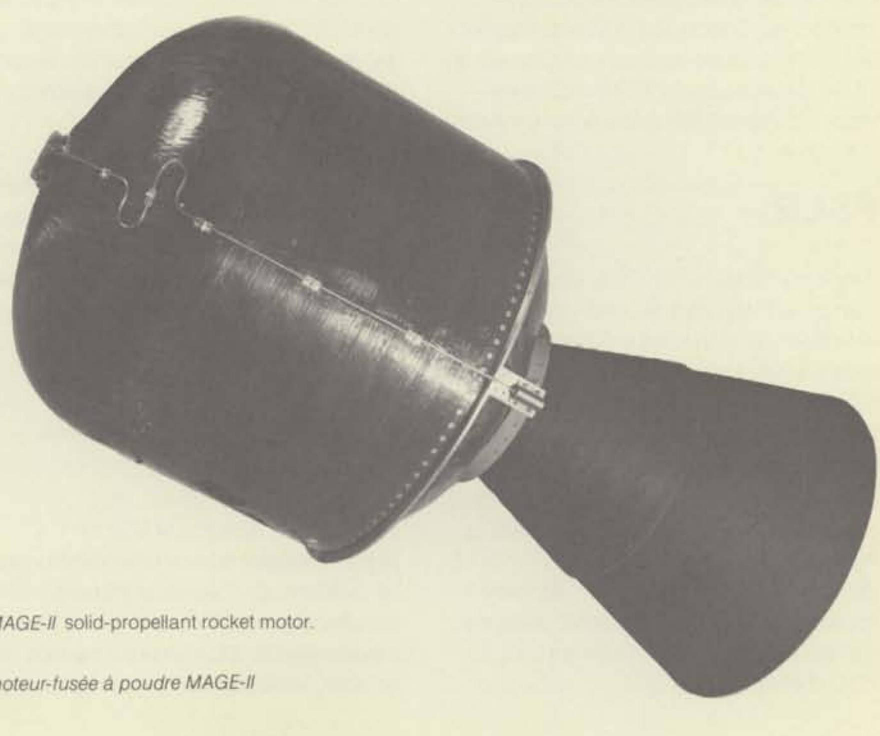
MAGE

The MAGE apogee boost motors have been developed primarily for injecting satellites into geosynchronous orbit from the transfer orbits provided by Ariane launch vehicles. This solid-propellant-type rocket motor is usually mounted in the centre of the satellite. It can also be used for injecting satellites into other than geostationary orbits or onto interplanetary trajectories.

The MAGE programme has been underway for some years and the aim is to develop a family of motors, sized for various classes of satellite. Three different sizes of motor have already been produced which can put satellites weighing between 600 kg and 1200 kg into geostationary orbit. The present status of these motors is as follows:

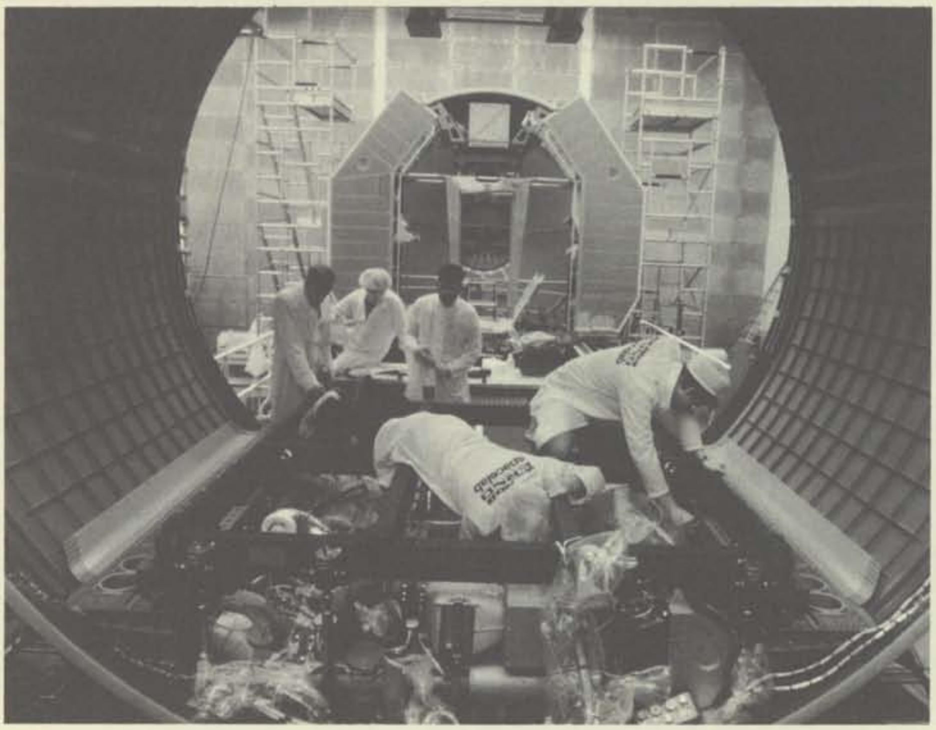
- MAGE-I (for 600–800 kg satellites) has been qualified and put the Meteosat-2 spacecraft into geostationary orbit in June 1981.
- MAGE-IS (for 800–1000 kg satellites) was qualified in June 1981 and is being considered for use on the Giotto and Hipparcos spacecraft.
- MAGE-II (for 1000–1200 kg satellites) is in a qualification test phase and its use is foreseen for ESA's ECS and the French Telecom-1 spacecraft.

The MAGE-II (approximately 1.5 m in length × 0.8 m in diameter) has recently successfully completed its third qualification test firing in vacuum. The flight and flight-spare motors for ECS-1 are planned to be transported to Kourou in May 1982, in time for the ECS-1 launch this summer. The formal MAGE-II qualification review for ECS-1 is planned for April 1982.



The *MAGE-II* solid-propellant rocket motor.

Le moteur-fusée à poudre MAGE-II



Intégration finale de la première unité de vol du Spacelab chez ERNO à Brême, avant sa livraison à la NASA à la fin de 1981.

Final integration of the first Spacelab flight unit at ERNO (Bremen) prior to its delivery to NASA at the end of 1981.

contractuelles correspondantes, s'élevant à 1 MUC, ont été négociées en décembre 1981. Pour la première fois, des améliorations du Spacelab financées par la NASA introduisent des différences de conception entre les matériels de la FOP et les matériels initialement livrés.

Le programme de production ultérieure de l'IPS est toujours en suspens mais la NASA a indiqué son intention d'aller de l'avant au mois de juin si l'examen critique de la conception de ce système est un succès.

Le programme de développement ultérieur du Spacelab (FOD) est toujours dans la phase de décision. Le Conseil de l'ESA a repoussé au 15 mars la date-limite pour la souscription au programme.

FSLP

Le dernier équipement d'expérience a été livré pour intégration dans la charge utile européenne en décembre 1981. Comme les trois derniers instruments à livrer (spectromètre à grille, chambre à très grand champ, rayonnement Lyman alpha) sont arrivés approximativement un mois après la date prévue, l'achèvement des essais d'intégration a été reporté à février 1982. Il reste néanmoins suffisamment de temps pour achever toutes les activités nécessaires à Brême avant l'expédition de la charge utile au KSC à la fin de mai.

Un examen conjoint de programme (ESA/NASA) a eu lieu au SPICE le 7 décembre. L'opinion d'ensemble est que la charge utile de l'ESA est en bonne forme, des progrès importants ayant été accomplis depuis l'examen de programme de novembre 1980.

La remise en état du bâti double des sciences des matériaux s'est poursuivie; la reprise de l'intégration est prévue pour février, la date de montage au KSC/NASA étant fixée au 1er juillet.

Les spécialistes 'charge utile', le Dr. U. Merbold et le Dr. W. Ockels, ont été mutés au MSFC/NASA au 1er janvier 1982, tandis que M. C. Nicollier poursuit son entraînement en tant que spécialiste 'mission' de l'ESA au JSC/NASA.

En ce qui concerne l'élément de charge utile Sled sur la mission D1, la définition des interfaces avec l'expérience américaine a considérablement progressé et l'approvisionnement d'un bâti simple du Spacelab a été lancé.

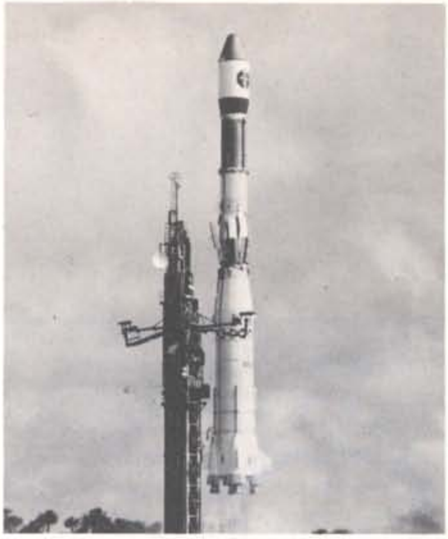
MAGE

Le moteur d'apogée MAGE est principalement conçu pour faire passer un satellite, de l'orbite de transfert résultant de son lancement, à l'orbite des satellites géostationnaires. C'est un moteur-fusée à poudre, généralement monté au centre du satellite. Un tel moteur peut également être utilisé pour injecter des satellites sur des orbites qui ne sont pas celle des satellites géostationnaires, ou sur des trajectoires interplanétaires.

Le programme MAGE a été mis en route il y a quelques années. Son but est de mettre au point une famille de moteurs de tailles différentes pour les différentes classes de satellites. Le programme a donné naissance à trois tailles de moteurs différentes pour satelliser une masse totale comprise entre 600 kg et 1200 kg sur l'orbite des satellites géostationnaires. La situation actuelle est la suivante:

- *Le moteur MAGE-I (pour les satellites de 600 à 800 kg) est qualifié. Il a mis à poste Météosat-2 sur l'orbite des satellites géostationnaires en juin 1981.*
- *Le moteur MAGE-IS (pour les satellites de 800 à 1000 kg) a été qualité en juin 1981. On envisage de l'utiliser pour les satellites Giotto et Hipparcos.*
- *Le moteur MAGE-II (pour les satellites de 1000 à 1200 kg) est entré dans sa phase d'essais de qualification. Il est prévu pour le satellite ECS de l'ESA et pour le satellite français Télécom-1.*

Le moteur Mage-II (environ 1,50 m de long × 0,80 m de diamètre) a récemment subi avec succès son troisième tir d'essai qualification sous vide. L'examen de qualification officiel de Mage-II pour ECS-1 est prévu pour avril. Il est prévu de transporter le moteur de vol et les moteurs de secours d'ECS à Kourou en mai, en vue du lancement d'ECS-1 cet été.



Ariane – l'injecteur en question!

A. Mechkak, Direction des Systèmes de Transport spatial, ESA, Paris

Venant après le spectaculaire succès du premier vol d'essai L01, l'échec de la deuxième tentative (L02) a été d'autant plus cuisant que la défaillance s'est produite là où on l'attendait le moins. En effet, les moteurs du premier étage du lanceur sont dérivés d'un moteur de plus faible performance mais qui a déjà subi des essais de mise au point (40 t de poussée alors que celle du moteur Viking-V est supérieure à 60 t au sol).

Le moteur Viking a lui-même subi plusieurs essais suite aux modifications importantes apportées pour atteindre la performance assignée; parmi ces différents tests, on relève plus de 100 mises à feu, sans que le phénomène observé lors du vol L02 ait été mis en évidence. On peut dès lors se demander pourquoi ce mode de fonctionnement défectueux est brusquement apparu sur un moteur, puis a été retrouvé systématiquement dans les essais conduits au cours des investigations qui ont suivi l'échec du deuxième lancement.

Analyse et cause de l'échec L02

Les dépouillements des enregistrements effectués par les stations sol des paramètres télémesurés à bord du lanceur, ont montré que des vibrations importantes à fréquence élevée sont apparues dès le début du vol propulsé du premier étage.

Ces vibrations avaient pour origine une instabilité entretenue de combustion, dans un des quatre moteurs de cet étage, engendrant une très forte pulsation de la pression foyer. Cette anomalie a eu l'effet destructeur que l'on connaît. Dès que l'origine du défaut a été connue, on s'est attaché à reproduire le phénomène au sol, afin d'en déterminer si possible les causes et de trouver impérativement les remèdes permettant d'éliminer tout risque pour les lanceurs futurs.

Les investigations ont été menées avec opiniâtreté et diligence par les responsables concernés. Les résultats obtenus dans un temps qui peut paraître long (un an) pour ceux qui ne sont pas au fait du problème, représentent une réelle prouesse si l'on connaît l'étendue des voies de recherches qui s'offraient au début. En effet, dans un souci d'objectivité, les responsables CNES du projet avaient retenu toutes les hypothèses qui leur avaient été suggérées, y compris celle qui a priori pouvaient paraître quelque peu fantaisistes... Cependant, grâce à l'excellent travail des différentes commissions de spécialistes, créées pour la circonstance, les efforts se sont très rapidement orientés vers le vrai fauteur de trouble, l'*injecteur*.

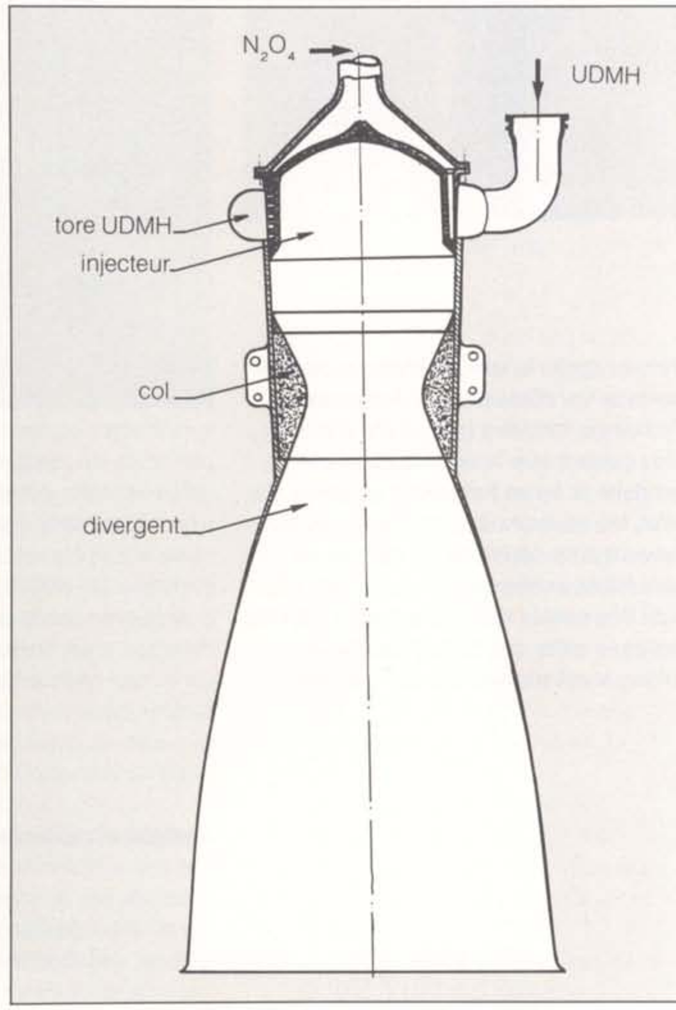
Qu'est-ce- que l'injecteur?

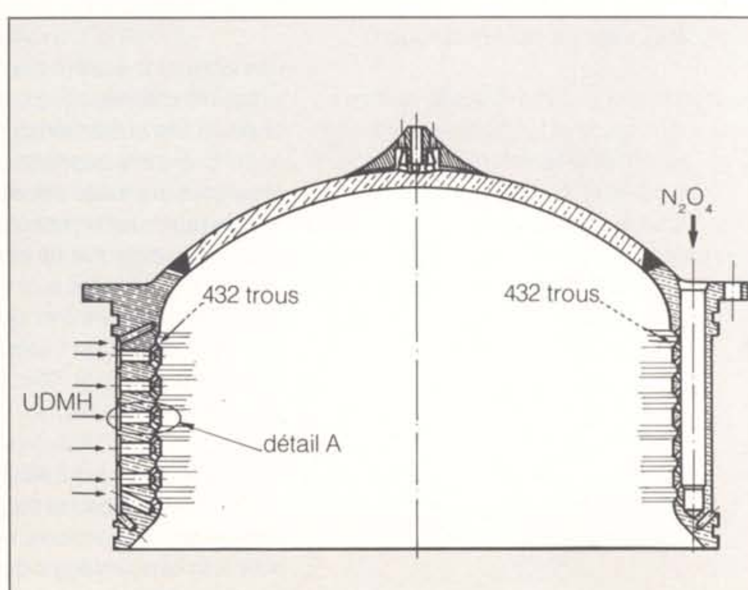
Le moteur Viking comprend les éléments suivants:

- des circuits d'alimentation en ergols (UDMH et N_2O_4)
- des circuits de pressurisation et de régulation des débits en ergols
- un éjecteur (Fig. 1) constitué essentiellement de:
  - une chambre comprenant un tore d'alimentation UDMH, un col (convergent), et une tuyère (divergent)
  - un couvercle cônique d'alimentation N_2O_4
  - un injecteur situé à l'intérieur de la chambre, sous le couvercle.
- l'injecteur: c'est une sorte de couvercle composé d'une virole cylindrique, fermée par un fond bombé (Fig. 2). La virole comporte un certain nombre de trous d'injection (environ 860 partagés en nombre égal entre trous UDMH et trous N_2O_4), par lesquels les ergols sont pulvérisés dans la chambre de

Figure 1 — L'éjecteur Viking équipé

Figure 2 — L'injecteur du moteur Viking





combustion. Ces trous sont disposés de telle façon que le jet d'un ergol rencontre à proximité de son débouché dans la virole le jet issu du trou correspondant de l'autre ergol, créant ainsi une nappe uniforme au voisinage de la paroi interne de la virole où s'amorce la combustion. On peut d'ores et déjà concevoir que la façon dont les jets des deux ergols vont se rencontrer, et par la suite, se combiner pour former le mélange détonant, va avoir une influence déterminante sur la stabilité de combustion; aussi est-ce la voie qui a été privilégiée dans la recherche des causes de la défaillance du moteur du lanceur L02.

Comme on le verra par la suite, un des facteurs d'influence essentiel de l'injecteur est la configuration du puits UDMH. Aussi est-il important d'en connaître la géométrie pour mieux saisir les renseignements qui suivront.

La Figure 3 (agrandissement A de la Fig. 2) montre que pour une position donnée des trous d'injection, selon que le puits UDMH est plus ou moins profond, l'intersection avec les deux trous d'injection se fera entièrement ou partiellement dans le cylindre du puits, ou entièrement dans l'extrémité cônique.

Facteurs d'influence sur la combustion
Pour ce qui concerne les injecteurs, il faut examiner les paramètres principaux agissant sur les caractéristiques des deux jets d'ergols pénétrant dans la chambre de combustion. On peut essentiellement distinguer:

- le débit d'ergol
- le diamètre des gouttelettes pulvérisées dans la chambre
- l'angle de l'axe du jet avec l'axe de la chambre
- la nature des ergols.

Débit d'ergol
Une des caractéristiques de l'injection est reflétée par la mesure du coefficient de débit, qui est le rapport entre le débit et la racine carrée de la pression différentielle existant entre la canalisation d'amenée d'ergol et la chambre de combustion. Les essais ont montré que pour j'injection d'UDMH, ce coefficient était fortement influencé par la profondeur du puits. Il avait semblé intéressant, afin de compenser les dispersions de fabrication, de se placer dans la zone 'plate' de la courbe.

Les essais effectués ont démontré qu'en fait, les injecteurs les plus stables étaient ceux dont la toile du puits U a une épaisseur de 4 mm.

Diamètre des gouttelettes d'ergols
Afin d'étudier le comportement des injecteurs en fonction du diamètre des gouttes des ergols pulvérisés dans la chambre de combustion, on a soumis aux essais plusieurs jeux d'injecteurs dont les trous d'injection U et N avaient des valeurs différentes.

Les résultats ont conduit à augmenter aussi bien le diamètre des trous d'injection côté UDMH que côté N_2O_4, les valeurs finales étant respectivement de 2,9 et 4,3 mm.

Angle du jet
On pouvait penser que l'angle sous lequel le jet pénétrait dans la chambre avait une influence sur la stabilité de la combustion, et que cet angle était différent selon la profondeur du puits U.

Les mesures effectuées, si elles ont bien montré quelques faibles différences, n'ont pas permis de dégager une influence radicale permettant une conclusion quelconque.

Nature des ergols
Afin de 'calmer' la combustion, on a recherché une solution consistant à ajouter à l'un des ergols, un autre liquide qui, tout en réduisant l'énergie des vibrations induites par la combustion,

Figure 3 — Détail A de la Figure 2

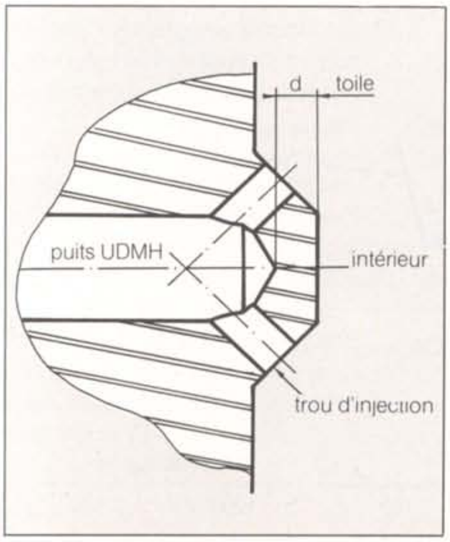


Figure 4 — Variation du coefficient de débit de l'injecteur Viking en fonction de la profondeur du puits UDMH.

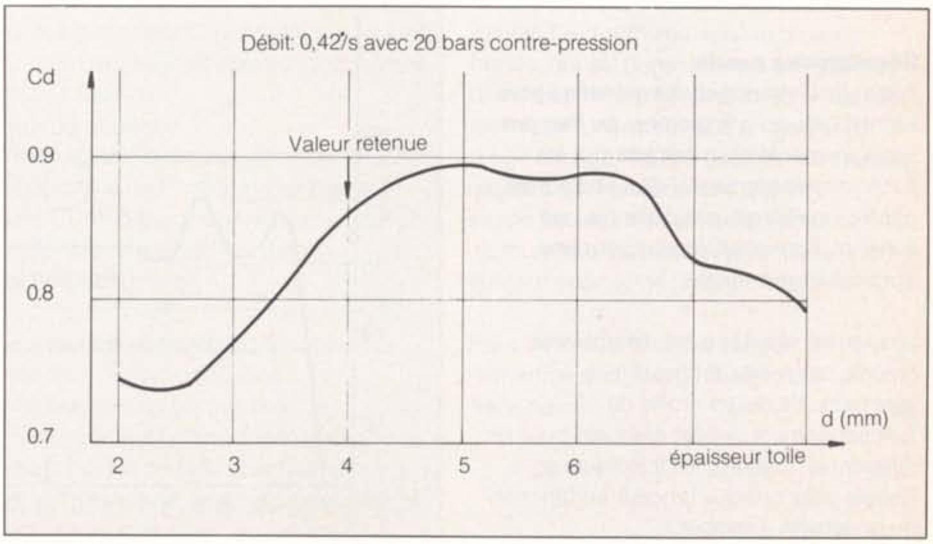
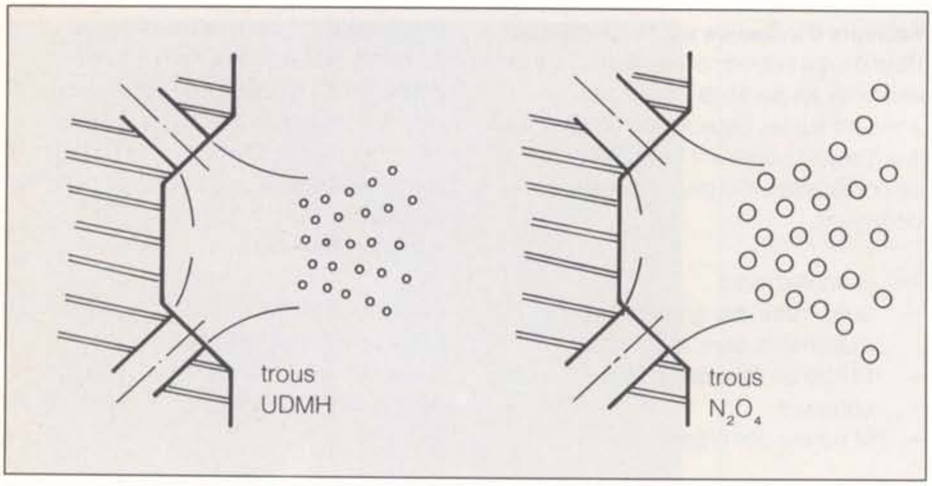


Figure 5 — Trous d'injection élargis



permettait néanmoins de conserver au mélange des caractéristiques propulsives (I_{sp}) intéressantes. Les essais ont été faits avec deux types de mélange:

- UDMH + 10% d'eau (en masse volumique),
- UDMH + 25% d'hydrate d'hydrazine (en masse volumique).

Pour un même injecteur, l'addition d'eau permettait d'augmenter d'environ 5 à 6 bars la limite haute de la pression foyer (portée de 61 bars à 66–67 bars) alors qu'avec l'hydrate d'hydrazine l'augmentation n'est que de 3 à 4 bars.

Par contre, la perte d'I_{sp} est plus élevée avec l'eau (1,7%) qu'avec l'hydrate d'hydrazine (1,2%).

Résultats des essais

A la suite d'investigations menées après l'échec L02, on a finalement pu tirer des enseignements dont certains ont été suivis immédiatement d'effet et d'autres, gardés en réserve, pourraient le cas échéant, être reconsidérés pour une application éventuelle.

Le premier résultat a été d'établir des critères de recette 'à chaud' des injecteurs. Plusieurs profils de fonctionnement ont été élaborés pour les différentes missions; les injecteurs sont choisis pour chaque lanceur en fonction de la mission à remplir.

Actions pour Ariane-1

L'objectif Ariane-1 est un fonctionnement à pression foyer de 53,5 bars avec UDMH pur. Les modifications apportées aux injecteurs après le lancement L02 ont consisté à:

- agrandir le diamètre des trous d'injection des ergols (2,9 mm pour UDMH et 4,3 mm pour N_2O_4);
- augmenter le diamètre des trous de suintement qui passe de 1 à 1,5 mm;
- réaliser avec précision un puits UDMH de profondeur bien déterminée (épaisseur de la toile: 4 mm).

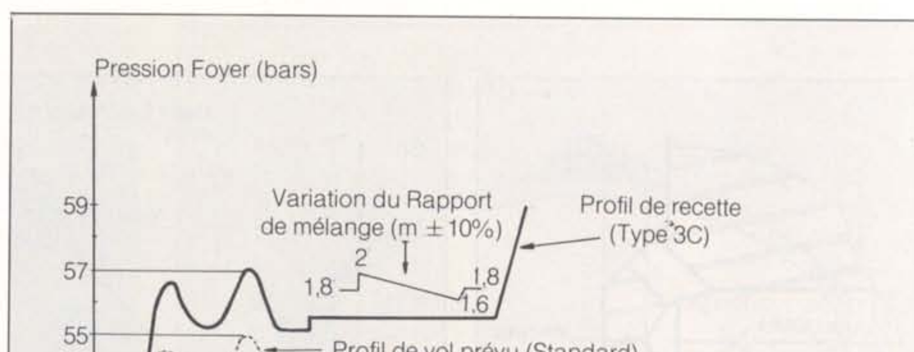
D'autre part un profil de recette à chaud des injecteurs a été établi et des critères d'acceptation ont été définis en ce qui concerne les fluctuations de la pression foyer à des fréquences déterminées et le niveau de vibration relevé sur le couvercle de la chambre.

Sur la Figure 6, les deux bosses en début de combustion sont dues à des inerties mécaniques du régulateur primaire du moteur, qui de ce fait, assure son office de façon imparfaite lors des régimes transitoires. La première bosse, appelée 'surrégime démarrage', correspond à la période pendant laquelle le régulateur passe de la position grande ouverte (à l'instant H_0), à sa position d'équilibre lorsque la pression foyer est devenue correcte.

La seconde, appelée 'surrégime PGC', correspond au régime transitoire induit par l'afflux de gaz de pressurisation chauds dans les réservoirs d'ergols. Les conditions de pressurisation (température notamment) changeant, le débit des ergols varie, entraînant un surrégime.

Afin de réduire l'effet de ces périodes transitoires, des modifications (matériels et réglages) ont été introduites sur L04;

Figure 6 — Profil de recette par rapport à profil de vol



c'est ce qui explique que le profil réel diffère quelque peu du modèle de vol standard initial. Les critères de recette retenus pour l'acceptation des injecteurs figurent ci-contre:

Fréquence (H_z)	2000	2700	5200
ΔPF chambre neuve (bar eff.)	⩽ 0,5	⩽ 0,5	
ΔPF chambre usagée (bar eff.)	⩽ 0,25	⩽ 0,5	
Δ vibration chambre (*g* eff.)			⩽ 25 *g*

Lors des essais de mise au point, il a été constaté que les niveaux de ΔPF à 2000 Hz obtenus avec une chambre ayant déjà subi un ou plusieurs tirs étaient, pour le même injecteur, d'environ moitié de ceux obtenus dans une chambre neuve. C'est ce qui explique les deux critères différents pour cette fréquence. Une chambre peut être considérée usagée après 20 secondes de tir environ.

Globalement, on peut dire que la raie 2000 Hz (en réalité la fréquence se situe entre 2000 et 2200 Hz) caractérise la chambre, alors que la raie 2700 Hz est plus spécifique du comportement de l'injecteur.

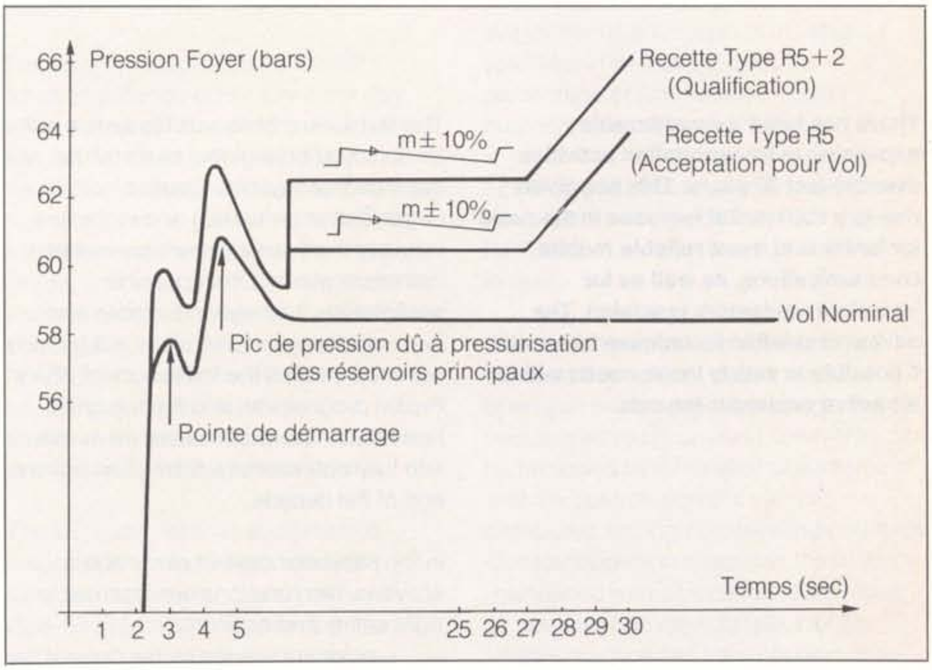
Actions pour Ariane-3

Les modifications apportées sur Ariane-2 permettent d'obtenir une marge de sécurité de 7 à 8 bars sur la pression foyer critique à laquelle une instabilité HF de l'injecteur est à craindre. Pour Ariane-3, l'augmentation de la performance du lanceur, qui passe de 1825 kg environ à 2480 kg de charge utile mise sur orbite de transfert, est obtenue notamment en accroissant la pression foyer nominale à 58,5 bars. La marge de sécurité par rapport au point critique était donc réduite dans la même proportion.

Il a été nécessaire d'appliquer une autre modification. On a décidé l'emploi d'UDMH doppé à 25% d'hydrate d'hydrazine, ce qui permet de regagner 3 à 4 bars de marge.

Les mêmes critères de recette sont conservés, avec des profils de la qualification et de recette adaptés à la mission (Fig. 7).

Figure 7 — Fonctionnement des injecteurs de moteur Viking pour Ariane-3 et Ariane-4



Les voies non explorées

Parmi les solutions proposées, certaines ont déjà fait l'objet d'essais (très limités), telles que chambre avec jeu entre col et anneau cônique et chambre en deux parties (permettant un montage plus aisé du col). Les résultats obtenus semblaient encourageants.

D'autres solutions appartiennent encore au domaine de l'inconnu, par exemple: puits UDMH approfondi, injecteur avec 7 rangées de trous (au lieu des 6 actuellement).

Les résultats très satisfaisants obtenus avec les autres modifications, l'achèvement du programme de développement Ariane-1 et le manque de crédits pour le programme Ariane-3 ont fait que pour le moment ces solutions ne sont pas envisagées.

Conclusion

L'échec du lancement L02, en permettant de découvrir les limites des moteurs Viking tels que conçus actuellement, a du même coup borné les ambitions du lanceur Ariane. La quatrième version de cette famille, qui est constituée pour l'essentiel d'une partie haute (2ème et 3ème étages) identique à Ariane-3, et d'un premier étage allongé, équipé des mêmes moteurs assistés de 4 propulseurs d'appoint à ergols liquides également équipés de moteurs Viking, semble bien être le lanceur optimal de la filière Ariane.

Pour l'avenir, il se confirme que la recherche d'une voie nouvelle est nécessaire.

Prospects for Navsat – A Future Worldwide Civil Navigation-Satellite System

C. Rosetti, Directorate of Applications Programmes, European Space Agency, Paris

There has been a considerable expansion in transportation activities over the last 20 years. This has given rise to a substantial increase in the need for better and more reliable mobile communications, as well as for improved navigatory precision. The advent of satellite techniques has made it possible to satisfy these needs within attractive economic bounds.

The first such mobile satellite system will be deployed on a global basis by the International Maritime Satellite Organisation (Inmarsat) and in the first instance it will service maritime-mobile communications. Other possible applications, namely land-mobile and aero-mobile communications, will be tried out shortly within the framework of ESA's Prosat programme, and there is great hope that these experiments will evolve into fully operational systems towards the end of the decade.

In the particular case of aero-mobile activities, two functions are essential for flight safety and economy:
- precise knowledge by the crew of the position and altitude of their aircraft at any moment
- transmission of these flight parameters to the air-traffic-control services.

The ever-increasing cost of fuel is already forcing airlines to seek optimal flight paths and profiles, particularly for long-distance flights. Such optimal patterns have a limited capacity because of the need to ensure safe separations (lateral, longitudinal and vertical) between aircraft. Consequently, at peak-traffic hours many aircraft have to follow nonoptimum flight paths. The smaller the minimum separation can be, the greater the number of aircraft that can benefit from an optimum path, but any such reduction in separation calls for substantial improvements in the quality of both communications and navigation.
This article concentrates on the navigational problems.

Existing navigation systems and alternatives

Since the advent of the first radio navigation systems, each time a new need has appeared or a new technological breakthrough has enabled an existing need to be met, a new 'black box' has been added in the aircraft's cockpit, and a new terrestrial infrastructure set up.

Over the years, these black boxes and the corresponding terrestrial networks have been compounded to a disturbing extent. In the case of airlines making long-haul (intercontinental) flights, the efficiency of use of these terrestrial systems is very low, while for general aviation the ratio between the cost of the aircraft and the cost of its avionics is in many cases disproportionate. The maintenance costs for on-board equipment are also high. Moreover, none of the terrestrial systems in use today has sufficient growth potential to meet future requirements.

While precise, real-time position determination is required for most mobile activities, geodetic applications need even greater precision, but within an acceptable time. This latter application is of the utmost importance for many developing countries, which are still not well mapped. A better understanding of the dynamics of our planet, research related to earthquake prediction, and other activities such as offshore oil exploration or seabed mining also call for precise and economic means of determining position on a global basis. The only technical tool capable of serving such a wide field of applications is the satellite.

The only satellite system under development today that has the potential for providing the necessary position-determination service to an unlimited number of passive (nontransmitting) users is the Global Positioning System (GPS/Navstar). However, GPS/Navstar is a military system possibly available to civil users only in its lower accuracy version, which does not meet their current requirements. Furthermore, the system is very expensive, both for the provider and for the users, because of the military requirements for communications security and invulnerability to jamming. Moreover, as GPS is a national/regional military system, it is not, and indeed could not be, envisaged for global usage under international management. Nevertheless, the satellite-navigation concept itself is sound and a less-expensive civil version may well be feasible.

The GPS/Navstar system
With this system the user determines his position (or sequence of positions) by trilateration, by measuring his range to a number of well-spaced satellites. Each satellite continually transmits time-tagged position signals (ephemerides) synchronised to the universal GPS system time. The user determines the time of arrival of these signals and the offset of his clock from the GPS system time. Depending on whether he wants two-dimensional or three-dimensional position determination, he will have to determine the value of three or four unknowns (x, y + time or x, y, z + time) and has therefore to solve a system of three or four equations using information broadcast by the satellites.

The GPS signals are transmitted on two frequencies (1227 and 1575 MHz) to allow corrections to be made for ionospheric delays. These signals are modulated with two direct sequence spreading codes, one at a chip rate* of 10.23 MHz for precise position determination, the other at a chip rate of 1.023 MHz providing lower precision but facilitating aquisition of the precision code. Each of the codes is further modulated with 50 bit/s information conveying satellite ephemerides, correction parameters and satellite status information to the user.

For security reasons, the satellites function autonomously. Once per day when the satellite is over a well-protected site, the satellite's clock and the navigation messages to be broadcast are corrected from a ground station. The satellites must therefore carry atomic clocks, and a sophisticated computer for internal system management, ephemeride computation, etc. This complexity and hence the need to provide a highly reliable signal even in hostile environments makes both the satellites and the navigation receivers costly.

The GPS user receiver equipment is responsible for carrier and pseudo-random code tracking and performs data-bit detection. It also performs a number of computational functions, including: receiver control; selection of the best satellite signals; corrections for propagation effects; and position and velocity determination in the desired coordinate system. The fully deployed space segment consists of 18 to 24 satellites, spread equidistantly over three orbits, mutually inclined at 60° and with a geocentric altitude of 19 652 km.

The GPS Control Segment consists of four monitoring stations, an Upload Station and a Master Control Station.

A new approach for a civil 'Navsat' system
A civil satellite-based navigation system providing very-high-precision position determination at much lower cost is perfectly feasible in the absence of military requirements. How could this be done?

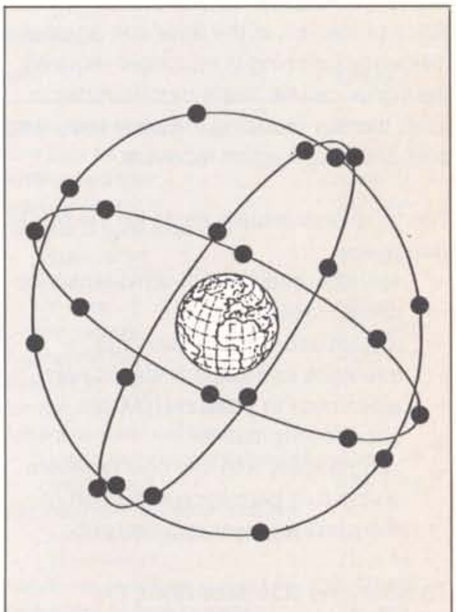
Space segment
The original GPS/Navstar constellation of 24 satellites, illustrated in Figure 1, which satisfies the requirement for continuous worldwide visibility of at least four satellites and is characterised by high reliability and very graceful degradation, can be retained.

Table 1 shows the approximate system availability as a function of missing satellites, while Table 2 gives the percentage of time for which given numbers of satellites are visible.

For 95.7% of the time, 6 or 7 satellites will be visible from any point an Earth, while for 73.5% of the time 8 or 9 of them will be in view.

The satellites themselves can be simplified if the requirement for autonomous operation is dropped. Operating frequencies (both up- and down-link) can be protected by international agreement and the control segment can be distributed among co-operating countries. Constant uplink contact can therefore be maintained with all satellites. As a result, all satellites can carry simple, highly-reliable, transparent transponders, most of the complexity being transferred to the ground segment.

Figure 1 — The basic GPS/Navstar space segment configuration, with 24 uniformly spaced satellites



* Bit rate of the spreading sequence carried by the channel.

Figure 2a – The military GPS/Navstar system

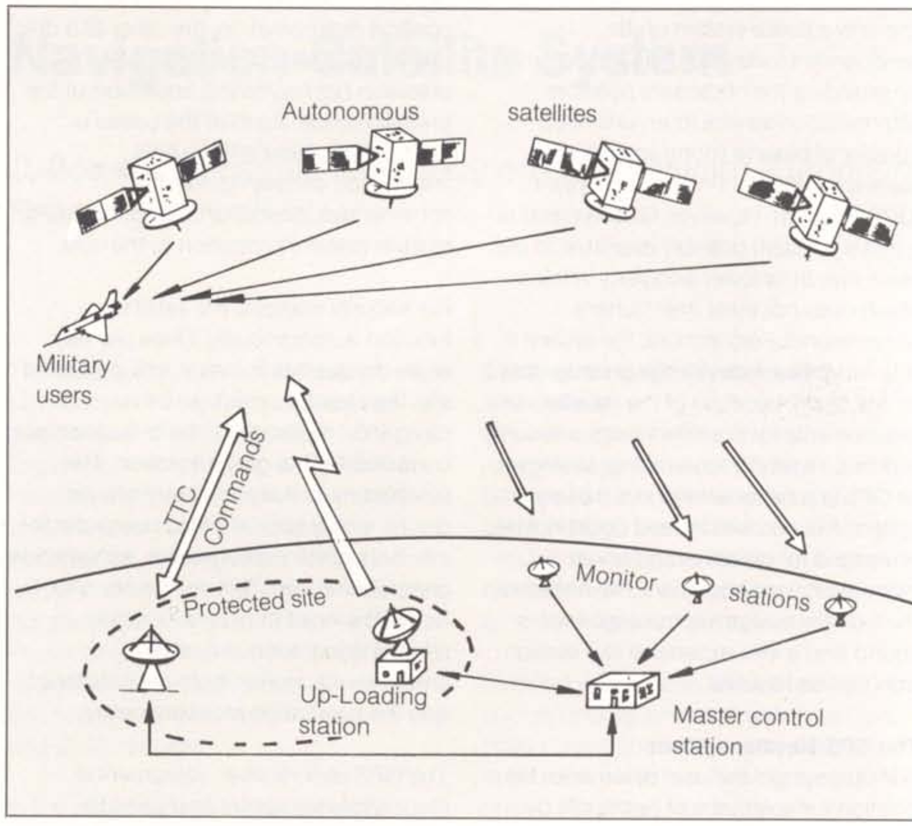


Figure 2b – A possible civil navigation system (Navsat)

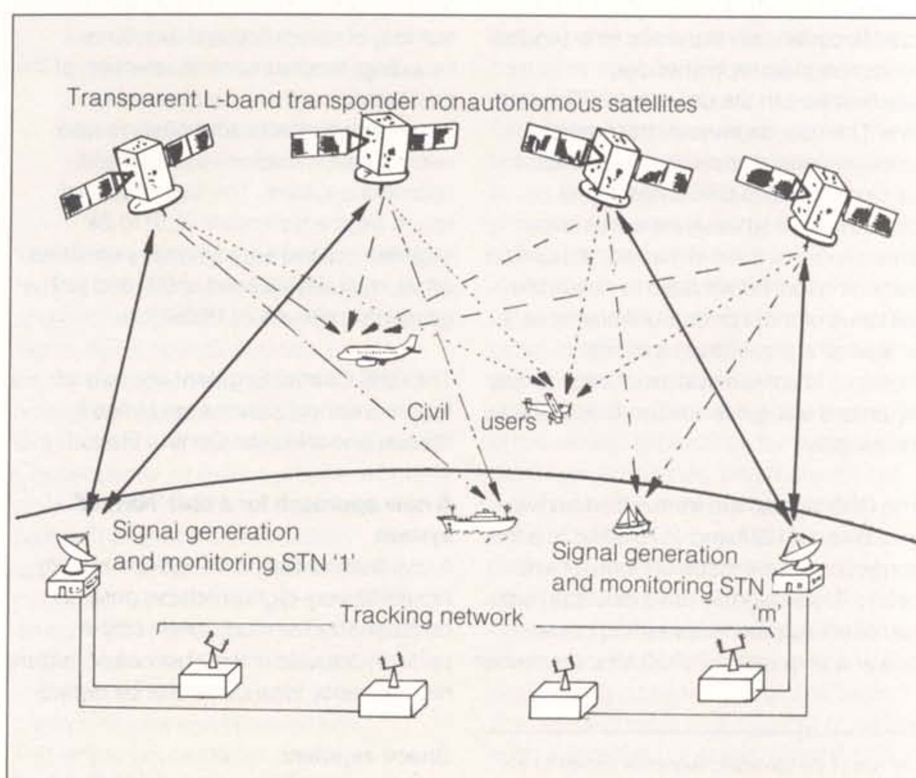


Table 1

Number of satellites missing	Approximate worst-case availability (PDOP <6)*
0	1.000
1	1.000
2	0.986
3	0.959
4	0.919
5	0.858
6	0.802
7	0.745
8	0.686

* PDOP = Precision dilution of position (tri-dimensional)

Table 2

Satellites visible	Percentage of time
11	0.0
10	4.3
9	38.7
8	34.8
7	10.8
6	11.4
5	0.0
4	0.0

The functioning of the GPS/Navstar system and a possible civil-navigation Navsat counterpart is illustrated in Figures 2a and 2b.

Signal structure

Since protection of the downlink against deliberate jamming is no longer required, the signal can be made much simpler in form, thereby reducing the complexity and cost of the navigation receivers.

The functional requirements for the signal design are:

- very accurate time-of-arrival (pseudo-range) measurement
- transmission of low-rate data
- tolerance to multipath effects even when near to ground (1000 ft)
- short time-to-first-fix
- compatibility with low-cost receivers
- a structure permitting reduction of the satellite power requirement.

To satisfy the objectives listed, the GPS/Navstar approach of transmitting continuous signals and channel sharing by CDMA (Code-Division Multiple Access) can be abandoned in favour of burst signals with TDMA (Time-Division Multiple Access) channel sharing. A provisional frame organisation is shown in Figure 3.

Each frame contains 12 time slots, each slot corresponding to one satellite. Antipodal satellites can share the same time slot. A guard period between slots greater than 17 ms is required to allow for the worst-care range difference from different satellites to the user (5034.26 km, or 16.28 ms, for the chosen orbital altitude).

Each TDMA burst will contain three elements:

- a pure carrier initial segment to assist in frequency search and carrier aquisition
- a low chip-rate (C) code to provide a coarse estimate of time of arrival
- a 10 MHz chip rate (P) code providing a precise time of arrival (1 σ range accuracy = 2 m) and not subject to multipath degradation for user altitudes above about 1000 ft.

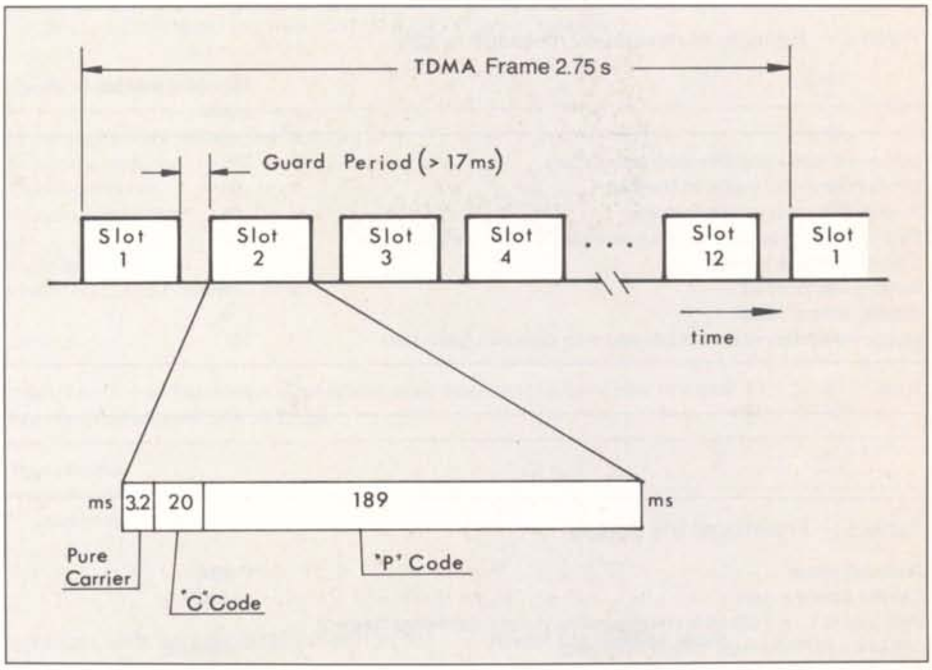
The provisional signal and link-budget concepts are elaborated upon in Tables 3–5.

Advantages of TDMA

The use of TDMA has six major advantages:

- the receiver need not know which satellites are in view (so that no 'almanac' is required)
- signals from different satellites arrive sequentially (user's receiver need not perform the sequencing)
- no range ambiguity
- no interference (common code, matched filtering)
- satellite power may be expended in bursts and therefore average power requirement is low (implying less costly satellites)
- transparent handover of satellites between uplink stations, and possibility of time-sharing uplink signal generator.

Figure 3 – Provisional TDMA frame and burst organisation



The user segment

The performance, quality and therefore cost of the user equipment may vary widely, depending on the particular requirements of a given application. The users can be classified into five main categories, as shown in Table 6.

The user requirements summarised in Table 6 must be reflected in the design of the space segment, which must be suitable for both high-precision/higher-cost and medium-precision/low-cost receivers.

The receiver consists basically of a low-gain antenna, an RF part, a computer and a control/display unit. It can measure time-of-arrival signals from different satellites sequentially and acquire data encoded as a part of the navigation signals (e.g. satellites ephemerides, ionospheric-model parameters, satellite status, etc.). The receiver can then carry out a number of computations such as: corrections for path-induced pseudo-range errors; current satellite positions; user position coordinates; filtering of solutions; and conversions into desired formats.

The cost of such a receiver will depend mainly on the complexity of the computations required, since the TDMA approach allows a relatively simple RF element to be employed.

Table 3 – Summary of TDMA analysis results

Item	Estimate
TDMA frame duration	2.75 s
Time slots/frame	12
TDMA guard time	17 ms
Burst duration	212.2 ms
Duration of burst segments:	
– pure carrier	3.2 ms
– C-code	20.0 ms
– P-code	189 ms
C-code chip rate	102.4 kHz
P-code chip rate	10.23 MHz
Data bits per burst	37
Average data rate per satellite	13.45 bit/s
Satellite oscillator stabilities:	
– long term (equipment lifetime)	4.23×10^{-8}
– short term (1 s)	1.88×10^{-9}
User equipment oscillator stabilities:	
– long term (equipment lifetime)	1.27×10^{-7}
– short term (1 s)	1.0×10^{-9}
Pseudo-range-rate accuracy (1 σ)	0.727 m/s
Time-to-first-fix (high probability)	2.89 min

Table 4 — Estimate of navigation message length

Item	Estimated number of bits
Ephemeris (assuming fifth-order polynomial)	378
Ionospheric model (same as Navstar)	64
Satellite frequency compensation	14
Zero time epoch (all parameters referenced to half-hourly updates)	42
Start-of-message marker	8
Satellite identification	5
Satellite state of health	8
Margin for additional control bits and error detection (parity) bits	181
Total	700

Table 5 — Provisional link budget

Radiated power	P dBW
Satellite antenna gain	11.5 dB
Path loss at L_1 = 1575 MHz corresponding to worst-case slant range of 18 524 km (GPS/Navstar altitude assumed)	−184.5 dB
Atmospheric loss	−1.0 dB
Receiver antenna gain	0 dB
Receiver losses (including polarisation loss)	−2.0 dB
Received power	P−176 dBW
Thermal noise (kT)	−204.0 dBW/Hz
Receiver noise figure	5.0 dB
Receiver noise	−199 dBW/Hz
Received C/N_0	P+23 dB.Hz
Margin	3.0 dB
Design value for C/N_0*	P+20 dB.Hz

* A C/N_0 = 40 dB.Hz seems adequate. The resulting radiated power requirement will be therefore 20 dBW.

Table 6 — User classifications and associated requirements

User category	Type of navigation	Level of precision
1. Marine-1 (dangerous cargo and/or precision navigation) Land-mobile	two-dimensional	absolute/high
2. Marine-2 General aviation	two-dimensional	relative/high
3. Offshore operations (drilling, sea-bed mining)	two-dimensional	absolute/very high
4. Airlines	three-dimensional	relative/high
5. Mapping Geodesy Satellite position determination	three-dimensional	absolute/very high

The control segment

The control segment of the system is relatively complex and expensive, but since the space segment represents the largest investment, its overall cost impact remains within acceptable limits.

The main functions of the control segment are:

- precise orbit determination and prediction
- continuous computation of satellite ephemerides
- continuous transmission of uplink navigation signals (pre-compensation for uplink delay) to simple transponding satellites
- precise time synchronisation between uplink stations (to within a few nanoseconds)
- coordination between uplink stations for assignment and handover of satellites from one ground station to another.

To ensure that each satellite is visible from at least one station at all times, five or six uplinks stations will be required. The TDMA signal structure makes it possible to simplify both the stations and the procedures for handing over satellites from one station to another. In fact, the transmitter , and probably also the uplink antenna, could be time-shared between the satellites in view of a given uplink station.

A satellite can be handed over from one station to another during the 11 time slots in which that particular satellite is nonoperative. Time synchronisation on a worldwide basis and with 1−2 ns precision could easily be achieved, thanks to emerging space techniques (e.g. the Lasso experiment on the Sirio-2 spacecraft).

Macro-economic considerations

To establish within what cost frame a new system could be envisaged and to have a basis for comparison, an estimate has been derived of the global annual cost of today's terrestrial navigation systems.

Capital and installation-cost amortisation, and annual operating and maintenance costs have been taken into account.

These cost estimates, summarised in Table 7, are for the terrestrial navigational infrastructure in operation today. Many regions of the world, including parts of Africa, South America, Northern Canada and some oceanic areas, presently have weak infrastructures or none at all. If a global satellite system is not to be pursued as the viable alternative, terrestrial systems will have to be improved substantially over the next 20 years. Such improvements will cost an additional $300 M per year. Alternatively, if a satellite system is adopted, the extra investment in terrestrial networks will no longer be necessary, but the existing network will have to be protected for a transition period of at least 10–15 years.

The permissible cost of the satellite system has therefore to be compared not with the running cost of the existing terrestrial network, but with the greater running cost of the improved version ($300 M per year). An attempt is therefore made in Table 8 to estimate the yearly cost of a civil Navsat system for comparison purposes, assuming a basic space segment of 24 satellites, a primary DC power per satellite of 150 W, and a satellite design lifetime of 10 years. Five uplink stations, a tracking network, and a coordination centre are taken into account, with an amortisation period for the whole system of 10 years.

Table 8 — Estimated annual cost of a civil Navsat system

Capital investment	$ M
Space segment (27 satellites launched*)	1000
Five uplink stations	125
Tracking network	50
Coordination centre	25
Subtotal	1200
Interest on capital investment (12%)	866
Subtotal	2066
Yearly capital amortisation costs, including interest (constant payments over 10 years)	207
Yearly control-segment operating cost	50
Total per year	257

* Assuming loss of four satellites over a 10 year period (100% availability)

This estimate shows that it should indeed be cheaper to introduce a highly efficient space navigation system, which would coexist for a number of years with the present terrestrial network, rather than to continue to improve the latter. The existing terrestrial navigation infrastructure could then eventually be phased out, at a saving of more than $500 M per year.

In making the above estimate, both the savings on the user's part and the benefits stemming from new types of applications have been neglected.

For the Navsat system, the predominant cost is obviously represented by the space segment. Any cost reduction in this area will therefore have a substantial impact on the yearly running costs. Such improvements are certainly possible, as pessimistic figures have been adopted in general in drawing up our estimates. Moreover, the cost of the ground stations and the annual costs for operating them have been inflated to be on the safe side. If any conclusion can be drawn here, then, it is certainly that the Navsat concept deserves at least further consideration.

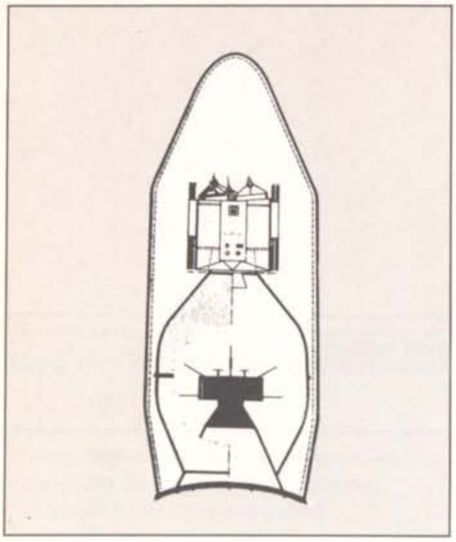
Table 7 — Annual cost of today's terrestrial navigation systems

System	Global annual cost 1981 $ US
T-Vor, Vordme, Vor, Vortac	$ 330 M
NDB	$ 25 M
Omega	$ 22 M
Loran - C	$ 80 M
ILS	$ 250 M
Total	$ 707 M

Areas for further work

In the preliminary study which provided the rough data on the characteristics of Navsat, it was assumed that only one L-band frequency would be used in order to keep receiving navigation equipment simple. Nevertheless, the requirements of a broad category of users call for very precise, absolute position determinations. It is therefore necessary to foresee a need for propagation-path delay corrections, which implies transmission on a second frequency.

The TDMA concept adopted permits such an improvement without a cost penalty, for either the user or the provider. This area will be further investigated and the concept for the low-cost receivers has also to be studied in greater detail. Little work has been done, so far, in the ground-station and tracking-network areas. The study effort will therefore be continued over the next months and it is hoped that by the beginning of 1983 a more detailed and refined knowledge of the potential of a global, civil Navsat system will be available.



The Radio-Amateur Satellite Oscar-10: An Ariane Passenger

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The radio amateurs are in the process of integrating and testing their tenth satellite, which has been built with voluntary manpower and with a scant budget of only 200 000 AU*. To be christened Oscar-10 when it goes into orbit this summer on an Ariane flight, it is a tribute to the imagination and ingenuity of the world's radio amateurs.

It was the American radio amateurs who took the initiative in the late fifties in building their own satellite, Oscar-1. The latter, which was put into orbit in 1961, just four years after Sputnik, did not relay messages like its successors, but merely transmitted a greeting in morse code for a few weeks until its batteries were depleted. Subsequent satellites in the series have become increasingly more sophisticated, with their batteries being charged by solar cells, the early transmitters being replaced by repeaters, and on-board computers being installed to look after attitude control.

Oscar-9, the last radio-amateur satellite to be launched successfully, was built mainly by the University of Surrey (UK) and carried a multitude of advanced scientific experiments, such as a magnetometer, an imaging camera, and a speech synthesiser, in addition to the telecommunications repeater.

With Oscar-10, the low orbit used previously is giving way to a highly elliptical variety, which will provide extremely wide ground coverage for several hours around spacecraft apogee.

The Oscar-10 satellite

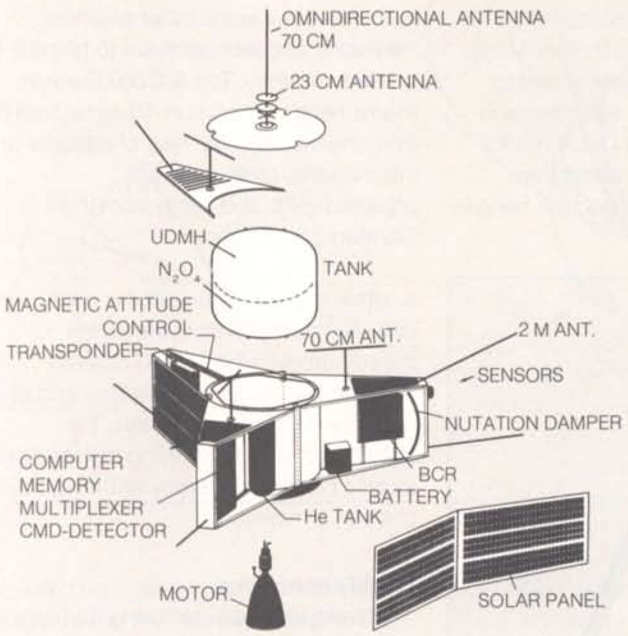
This latest satellite (Fig. 1) is a replica of the one that was lost together with the German Firewheel experiment as a result of the problems encountered during the Ariane L02 test launch in May 1980. It is spin-stabilised at 60 rpm and weighs 130 kg. The unusual three-tongued, star-shaped spacecraft body has been chosen to maximise both the solar-array surface area and the satellite's moment-of-inertia ratio. Each tongue houses a different set of electronic modules and features a 'personalised' passive thermal control system based on a mathematical model of 121 temperature nodes.

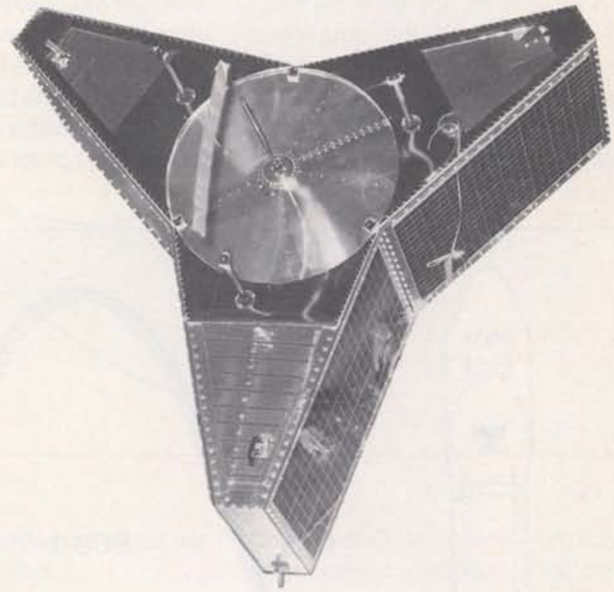
Oscar-10 carries an impressive cluster of antennas. On its upper surface, there are three dipoles for circular polarisation at 70 cm wavelength (435 MHz, 10 dBi gain), three monopoles with reflectors for 2 m operation (144 MHz, 8 dBi, circular polarisation), three quasi-omnidirectional co-linear antennas for 70 cm and 2 m transmissions along the satellite's spin axis, as well as a helical antenna working at a wavelength of 23 cm (1293 MHz). The satellite's orbit and attitude have been selected in such a way that the high-gain antennas will be pointing towards Earth around apogee, while the omni-directional antennas will be used in the vicinity of perigee.

A notable feature of Oscar-10 is the repeater developed by the project manager Dr. Karl Meinzer, in Marburg (Germany). To accommodate signals from the very large number of uncoordinated ground stations, the unit operates in a Frequency-Division Multiple Access (FDMA) mode. A novel, high-efficiency linear amplifier technology has been used which provides a similar efficiency to the conventional nonlinear transponders used for TDMA. The so-called 'HELAPS' (High-Efficiency Linear Amplification by Parametric Synthesis) repeater has an efficiency in excess of 40% for a 50 W peak RF output and a 1 MHz bandwidth with a Rayleigh multicarrier amplitude distribution.

* 1 AU = ± US$ 1.07

Figure 1 – The Oscar-10 spacecraft





This is by no means the first time that the radio amateurs have broken new technological ground; Oscar-6, for example, was the first user of CMOS technology in space.

Another remarkable feature of Oscar-10 is its programmable on-board computer, which is so sophisticated that it virtually obviates the need for a spacecraft control centre on the ground. In addition to automatically controlling the satellite's attitude in space, the computer also calculates the orbital ephemerides and transmits them to ground.

Oscar-10 is to be launched on Ariane as a co-passenger with another spacecraft, inside a spare flight model of the SYLDA, as shown in Figure 2.

The highly elliptical Molniya-type orbit (Fig. 3) will be achieved by firing a bi-propellant (UDMH – N_2O_4) perigee motor while raising the inclination in steps from 10° to about 60°. Oscar-10's apogee will be 36 000 km, and its perigee will be increased from 200 to 1500 km in the course of orbital operations.

The AMSAT Organisation

The satellite builders among the radio amateurs have formed an organisation called the Radio Amateur Satellite Corporation, or AMSAT for short. Its headquarters are in Washington DC, and there are major branches in Canada, Germany, Japan, New Zealand, South Africa and the United Kingdom.

The initiative for starting a new satellite project is usually taken by a different branch each time, and in the case of Oscar-10 it was the German branch in Marburg which took the lead. However, almost half of the design, the hardware, and the testing is the shared responsibility of other branches, and one unit – the battery-charge regulator – is provided from outside AMSAT, by the University of Budapest.

Although AMSAT is therefore a truly international organisation, it has only three salaried staff, at its headquarters. All other AMSAT participants are fee-paying members who put a part of their time and talents at the disposal of the organisation.

Contrary to popular belief, amateur satellites are not put together in sheds in back gardens; they are in fact designed and built by highly qualified personnel, mainly at various universities and research institutes. The institutes regard the activity as a form of applied research, which can lead to innovation in the various disciplines represented in a satellite. This liberal attitude on the part of scientific institutes is one of the prerequisites for the execution of the radio-amateur space programme. It is fair to say that the construction of the satellites is often tolerated rather than encouraged, and one can never be sure that such activities will be allowed to continue in the future.

Free labour does not solve all the manpower problems, however, in that voluntary effort is sometimes more difficult to coordinate than that of salaried personnel. A lot of diplomacy and

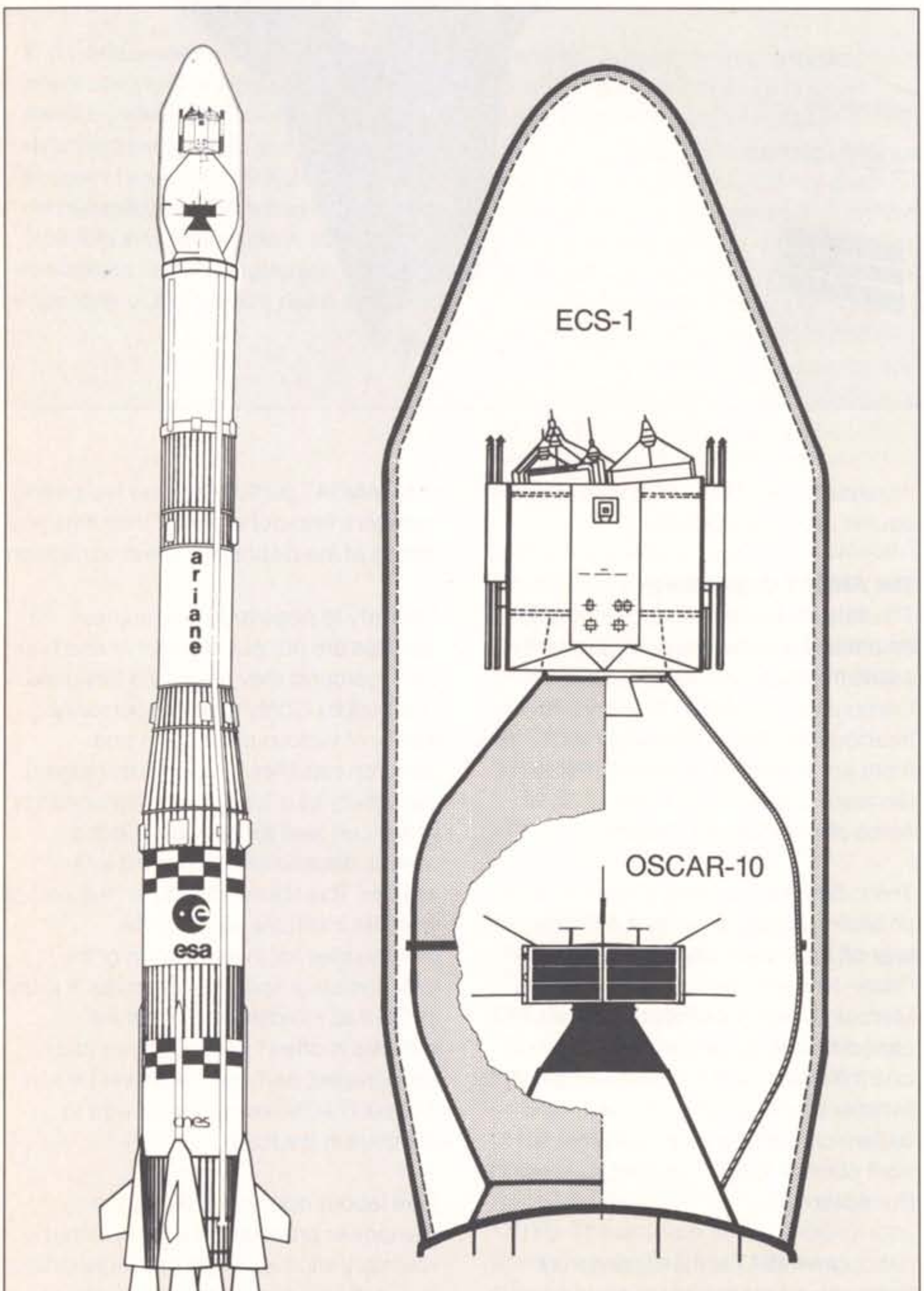
Figure 2 — Oscar-10 accommodated within the SYLDA (Système de Lancement Double Ariane) on Ariane, as would be the case for a launch with ECS-1 as co-passenger

Figure 3 — Orbital strategy for Oscar-10

persuasive talent is required of those who lead the enterprise, to ensure that the human resources are applied in the best interests of the project. At the same time, it is this overwhelming enthusiasm and dedication of the contributors which leads to the imaginative designs, high quality and timely completion of AMSAT satellites.

Sources and resources

Voluntary effort does not completely eliminate the need for a cash flow. Many units and components are donated to AMSAT by various space agencies and industries – in the case of Oscar-10, for example, the battery cells come from ESA's Sirio-2 programme, and the perigee motor from an abandoned ELDO launcher – but some other essential hardware and services have to be paid for in hard currency. The 400 000 German marks needed for Oscar-10 come mainly from the membership fees of national and international radio-amateur organisations, and partly from the German government.



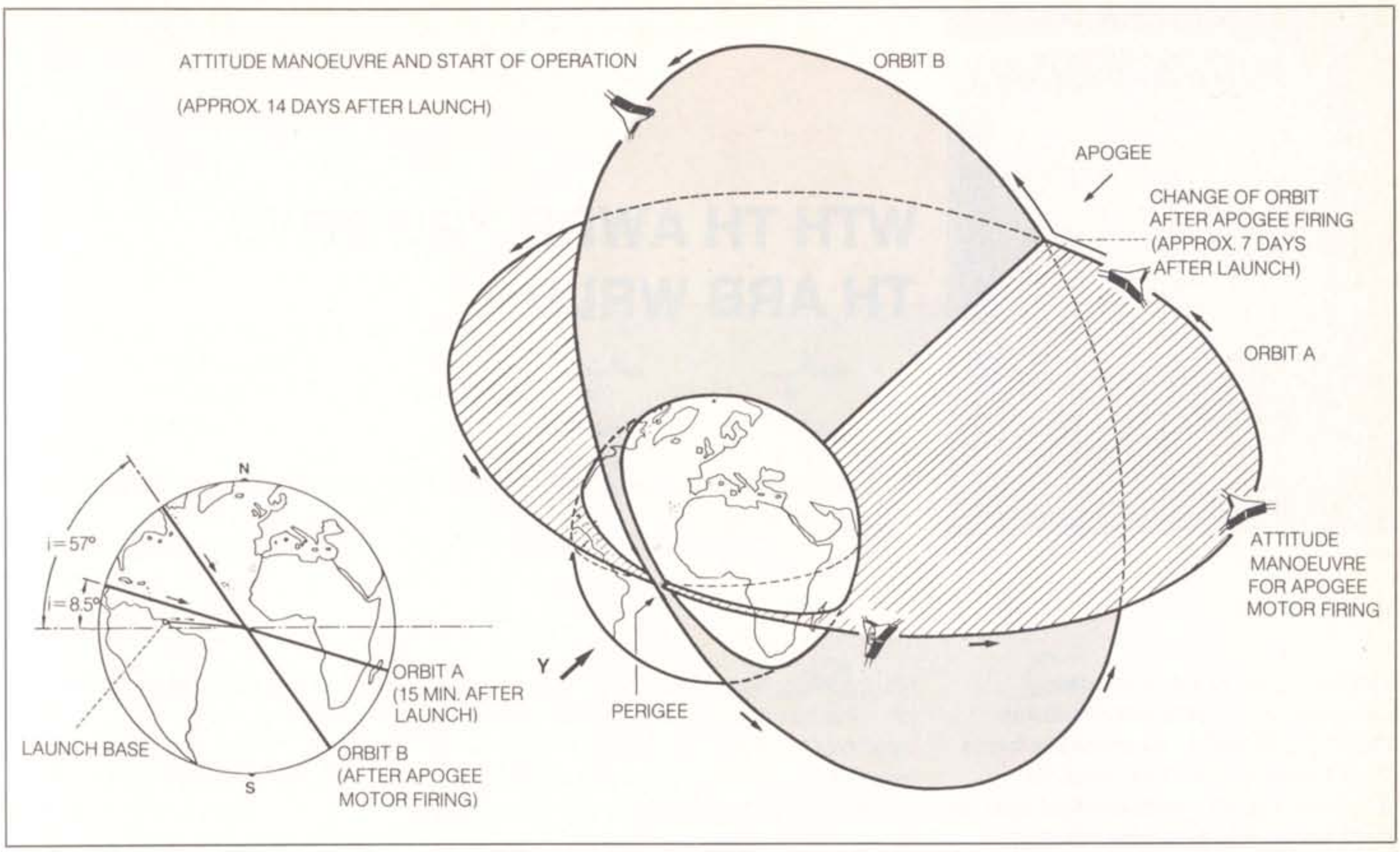
Another important resource is ham-radio communication, which allows the coordinators of the AMSAT satellite projects to converse at any time and at no cost. Teleconferencing is thus the standard method of solving technical and logistic problems, thereby reducing travel costs to a minimum.

Quality assurance

There are few manufacturing domains in which the quality-assurance requirements are as stringent as in the satellite business. Quality is assured by, for example, procuring space-qualified components, employing redundant units, working according to strict procedures, and performing independent inspections of workmanship. But QA costs money, and so the radio amateurs have had to look for alternative ways of ensuring quality in their satellites. Rather than buying expensive space-qualified components, a careful selection is made from those mass-produced commercial components that are known to be strictly quality-controlled by their manufacturers. Circuits are then carefully analysed to ensure that a minimum number of components are used, and that working points are well below specified survival limits.

Redundancy is avoided wherever possible on Oscar-10 to reduce both complexity and weight. As the batteries have caused failures of two previous amateur satellites, a spare battery, which will be kept discharged and will be conditioned only when needed, will be flown on Oscar-10.

As far as post-manufacturing inspections are concerned, the radio amateurs have



departed from traditional concepts, by merely having their various designers scrutinise each other's outputs, the emphasis being on spotting possible omissions, which may be more evident to the 'fresh mind' than to the one totally immersed in his own design work. The validity of this approach has been proved by the six-year lifetime of Oscar-6 (originally designed for 6 months) and the five-year lifetime of Oscar-7 (originally designed for 1 year).

Ground stations

It is not practicable for the radio amateurs to establish major spacecraft control centres manned around the clock, which explains why radio-amateur satellites are becoming increasingly autonomous, with on-board computers performing most of the control functions. There are, nevertheless, radio amateurs in Germany, the United Kingdom, the USA and New Zealand who, by knowing the secret telecommand codes, are able to intervene in emergency situations and also to re-programme the on-board computers whenever a change in operational modes is called for.

To familiarise these 'super-amateurs' with Oscar-10's operation, the Marburg people dispatched kits of the satellite housekeeping unit so that the 'spacecraft controllers' could assemble them and use them as training simulators.

The satellite customers are of course the radio-amateurs themselves, who are faced with the challenging task of equipping their stations with suitable antennas, transmitters, receivers and decoders (15 000 users worldwide for Oscar-7). Much of the necessary knowledge is readily obtained from various radio-amateur magazines. The AMSAT members have also devised a clever graphical overlay tool called 'Oscar-locator' for pass- and antenna-pointing predictions.

The educational value of amateur satellites does not stop at the radio operator's crowded closet. Many schools and universities have set up ground stations to give students hands-on experience with satellite technology, telecommunications and spacecraft orbit prediction.

Future projects

New radio-amateur projects are in various stages of definition in several countries. In France, the Arsène project is in a study phase, with support from CNES, industry, engineering schools and radio-amateur organisations. It is a telecommunications satellite carrying an electronically despun antenna (2400 MHz), which will travel in an equatorial, elliptical orbit (apogee 36 000 km, perigee 20 000 km). The Canadians are working on an advanced telecommunications payload, and there is every reason to believe that the Soviet radio amateurs will continue their ambitious programme which has already put six satellites in orbit.

Needless to say, the builders of future radio-amateur satellites will have to rely heavily on the continued willingness of government space agencies and industry to donate new or surplus hardware, and to accommodate the fruits of the amateurs' toils within the extra capacity of launches. This is perhaps one of the few areas in which a good deal of 'space goodwill' can still be bought for a very low price!

WTH TH AWRB YRS SRVS TH ARB WRLD

H. Orrhammar, ESA Information Retrieval Service, ESRIN, Frascati, Italy

The intelligent Arabic character generator associated with the Eurab terminal generates 156 character forms from a basic set of 52 symbols. Its development, as a technological spin-off from the work of ESA's Information Retrieval Service, is a major contribution to information storage and transfer in the Arab World, with far-reaching implications for education.

No, the editor has not fallen down on the job – the headline is in fact a westernised version of the way 'With the Eurab IRS serves the Arab World' would appear in newspapers or books printed in Arabic.

To understand how this format came about, we must go back to the Napoleonic era when printing technology was introduced into the Arab world. Prior to that time there were over 600 different character forms in the Arabic script: this posed no problem for the scribe, but it was impossible to accommodate them in the printing methods in use until quite recently! It was not only the number of different character forms, but also their positioning which caused problems. Vowel sounds, double consonants, nasalisations and accents are identified by marks above or below a consonant (diacritics), and the Gutenberg method of typesetting could not cope with them. The European specialists responsible for introducing printing therefore took the drastic step of removing the diacritics, and the Arabic script lost its short vowels!

Further reductions were made until a typesetting kit of around 200 different characters was established. As the Arabic alphabet contains only 28 consonants, and there are no capital letters, the need for 200 characters might seem strange to European minds. However, most Arabic characters have four basic shapes:

- Isolated, when it is used on its own
- Initial, when it is the first letter of a word
- Medial, when there are letters before and after it
- Final, when it is the last letter of a word.

Some of the rules for writing Arabic

In Figure 1a the character 'ba' is shown in its four different forms. Jumping ahead for a moment to the eventual solution to the problem, one can see that the character's 'body' can be slightly modified without damaging its readability, as shown in Figure 1b.

The character in Figure 1 represents the simplest and most regular group of characters. Most of the characters change shape in this way, but there are some exceptions. In Figure 2, for example, the character 'ayn' is shown in its four different forms. Here one can note that the 'body' of the character changes.

From the character shapes shown in Figures 1 and 2, it can be seen that they have certain elements in common: body, junction line and tail. This is further illustrated in Figure 3.

A third group of characters have only an isolated and a medial form, as shown in Figure 4.

The fourth group of characters change their form depending upon which character precedes them, as happens with the characters 'lam' and 'alif'. In Figure 5, 'lam' is shown in its final form with the character 'ba' before it, and in Figure 6 when 'alif' comes *after* it (remembering that Arabic reads from right to left!). Finally, in Figure 7 'alif' is shown in its initial and medial/final forms.

In Figure 6 one can see that both 'alif' and 'lam' change shape. However, these are the only two characters in the Eurab set which change form in this way, and then only when they are combined as in Figure 6. The 'alif hamza' follows the same rule as 'alif' alone (Fig. 8).

Vowel signs can never have an initial form, as they may never start a word. In Figure 9 the sign 'shadda' is shown in different positions.

In the nine examples above it has been shown that it is necessary to know the shapes of the preceding character and the two subsequent characters, before the shape of a given character can be determined.

The character itself can be divided into junction-line, body, and tail. The junction-line never changes shape, the body can change shape depending upon position, and the tail has different shapes which are related to the character to which it is added.

One unfortunate effect of the introduction of printed Arabic was to limit the ability to read to an 'educated' minority who could decipher the vowel-less system. The result, in terms of problems when trying to introduce a revival of 'full' script, is discussed later.

One man who has devoted more than 20 years to study of and research into the written language is Prof. Lakhdar at the Institute for Arabic Studies in Morocco. Supported by Unesco, which provided expert help as well as finance, he has developed a concept called 'one character, one form'. The alphabet was coded by Unesco so that it was compatible with the American Standard Code for Interchange of Information (ASCII-7), and given the name Codar-U. Twenty Arabic-speaking countries signed a resolution at a Unesco general conference in November 1976 recommending this code as a standard for information exchange in the Arab world. The code is now awaiting International Standards Office (ISO) approval.

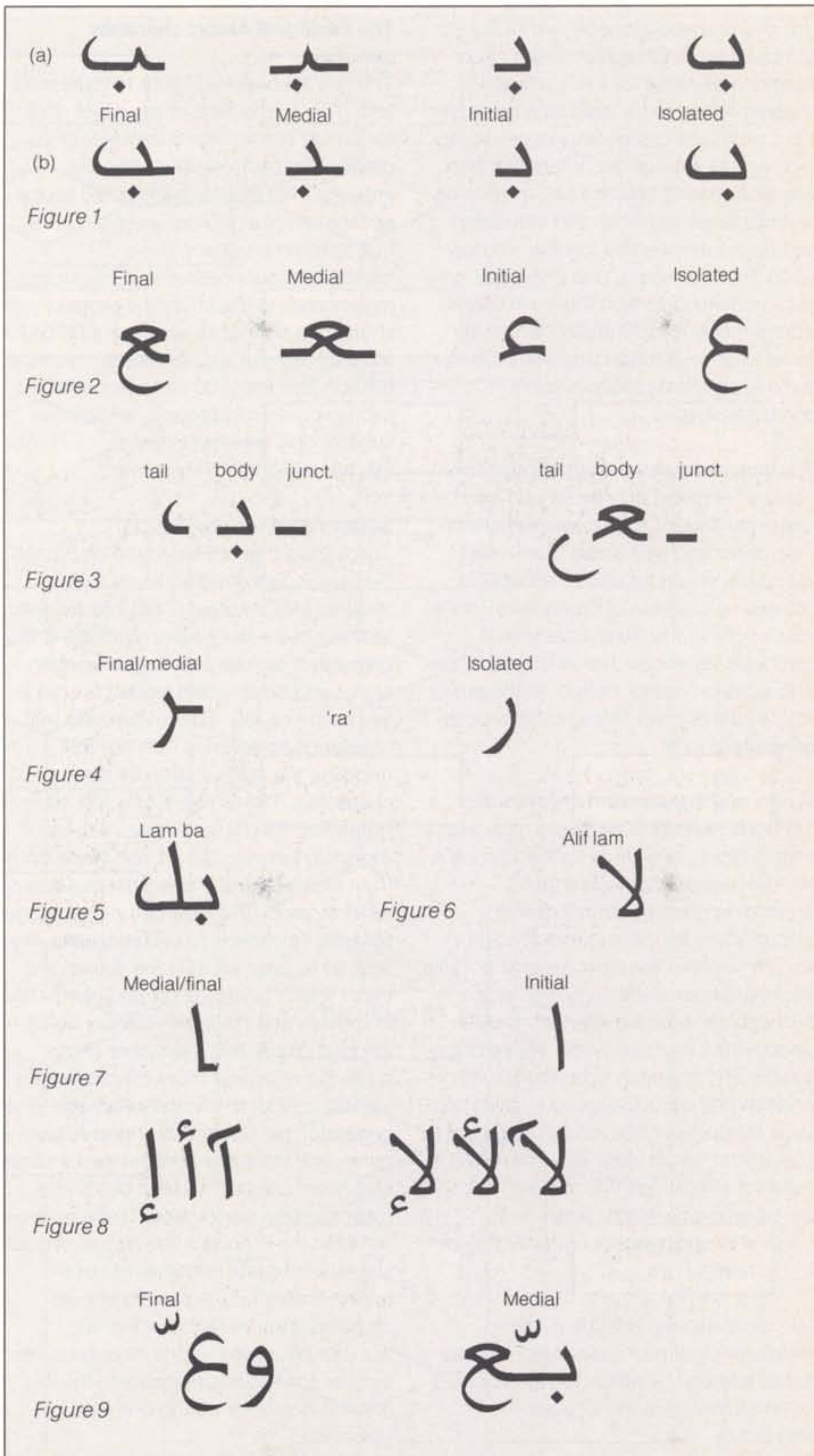


Figure 1
Figure 2
Figure 3
Figure 4
Figure 5
Figure 6
Figure 7
Figure 8
Figure 9

Use of this coded alphabet with a Eurab computer terminal represented a major milestone because for the first time it enabled Arabic to be used as a computer input/output language without ambiguity. It may seem strange that a terminal with only 52 Arabic characters can provide an unambiguous text when 200 characters had previously seemed too few. The key lies in Prof. Lakhdar's 'one character, one form' concept by which there are only 38 letter symbols and 12 diacritics to cover vowel sounds, double consonants, and some aesthetically indispensable character shapes.

The early demonstrations of Eurab soon made it clear that only those with an understanding of the reasoning behind the system and with a very open approach would be able to accept the compromise system of characters. This is why, applying the latest advances in computer, typewriter, typesetting-machine, and word-processor design, we began to think in terms of an 'intelligent character generator'.

In non-oral transmission of information, a symbol is needed to represent a phonetic sound. Going one stage further, if such a symbol has to change its shape depending on its position in a word, responsibility for making that change should lie within the machine and *not* with the keyboarder. In this way one needs only one symbol on a key, the machine deciding the eventual visible shape of the symbol on the screen according to its position in a word. Calligraphic rules had to be set up, but once established the 'transmitter' could work with minimum input yet still provide the 'receiver' with the benefits of a much more comprehensive or more correctly written text to read.

The result was the intelligent Arabic character generator associated with the Eurab terminal by which 156 forms could be generated from the 52 basic characters.

The intelligent Arabic character generator

The flow diagram of Figure 10 represents a step-by-step outline of the major rules for writing Arabic. The complexity of this diagram immediately gives one the impression of a task ideally suited for the application of a microprocessor. This is true to a certain extent, but a microprocessor needs about a hundred milliseconds to elaborate the proper shape of a character, whereas a CRT terminal, without a co-processor, needs a result in less than 500 nanoseconds. The microprocessor approach is therefore suitable only for slower electro-mechanical printing equipment.

System architecture (Fig. 11)

The signals that are fed to the character-generator chip of a traditional CRT terminal [ASCII coded (7 bit) internal line address of a row (3-4 bits normally) and chip-select signals plus cursor-symbol signal and display-field signal] are fed in this case to a four-stage n-bit-wide shift register using seven of its n bits for handling the ASCII coding for the characters. The registers are clocked in parallel at the character rate interval (normally between 0.5 – 1 μs). The output from register three is fed to the character generators. By this means, the first register will hold the 'remote future' character, the second register will hold the 'future', the third register holds the present character to display, and the fourth register holds the past characters. Two more of the n bits in the register carry the chip-select signals: one for the Arabic character generator, the other for the 'non-Arabic' generator, in which symbols like the space character, comma, full stop, digits and other symbols are located. These lines are tested at the outputs from the four register stages to establish whether or not the remote future, future, present or past characters are Arabic (see Fig. 10). Another bit is used to progress the cursor symbol, to keep this adjacent to the last entered character during normal operation.

The output from the first stage is fed to a Programmed Read-Only Memory (PROM), which decodes the vowel signs to one line, 'alif' to another, 'lam' to a third, 'ayn,ghayn' to a fourth, and 'ya' and 'ya hamza' to a fifth. These lines are then fed to a shift register (seven bits wide) for forwarding of the information to the third stage. 'Lam' alone is shifted also, to be aligned with the fourth stage.

The most significant bit is not used in the dot pattern. The next two bits hold the dot pattern for the character 'tail', and the remaining five bits hold the character body. Thus, seven bits hold the dot-pattern for a character, and are fed to a traditional parallel-load shift register for serialising the information to the CRT's Z-modulation circuitry. The two bits holding the dot pattern for the 'tail' are gated in such a way that they can be inhibited and replaced by a junction line, thus allowing easy generation of the medial form of a character. The logic controlling this is conditioned by information taken from the first and second register stages.

If, for example, the first stage holds the 'space' character and the second stage a vowel sign, while the third stage holds the Arabic character 'ba', the tail will be displayed, since a space after a vowel sign means that the character displayed is the last in a word (Fig. 9a). If on the other hand, the second stage holds the letter 'lam', the tail will be replaced by a junction-line, since it is no longer ending a word; 'ba' will then be displayed as in Figure 5.

The memory outputs from the second and third stages will under certain conditions address optional characters in the character generator (the lower 1 kbyte of the 2 kbyte character generator holds the basic body and tail of the characters, whilst the upper 1 kbyte section holds the special body shapes of some characters). The decoded 'lam' from the fourth stage can also address the special form of a character.

Figure 10 — Flow diagram for the intelligent Arabic character generator (applicable to CRT terminals, hard-copy printers, typsetting machines and photocomposition machines)

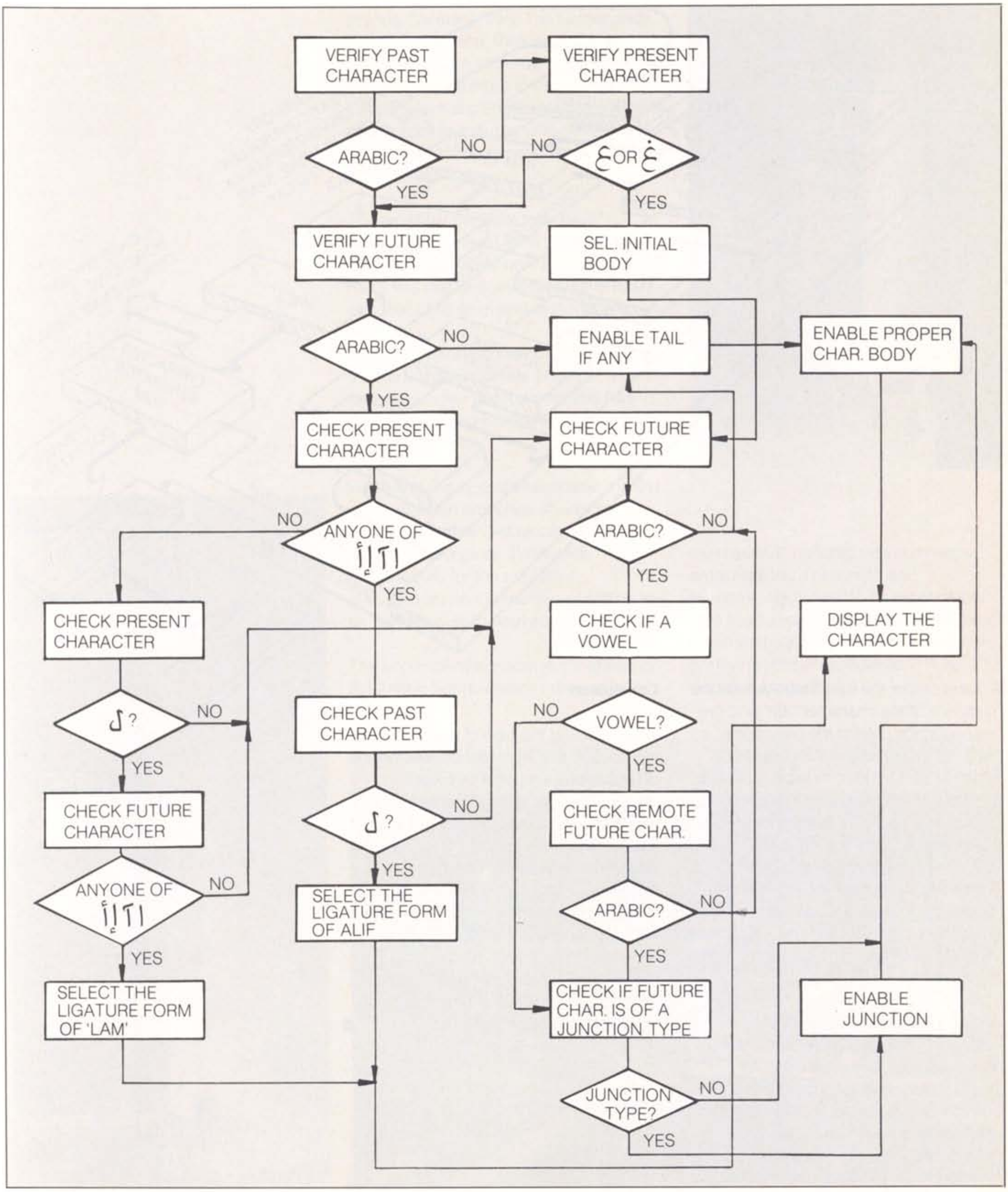
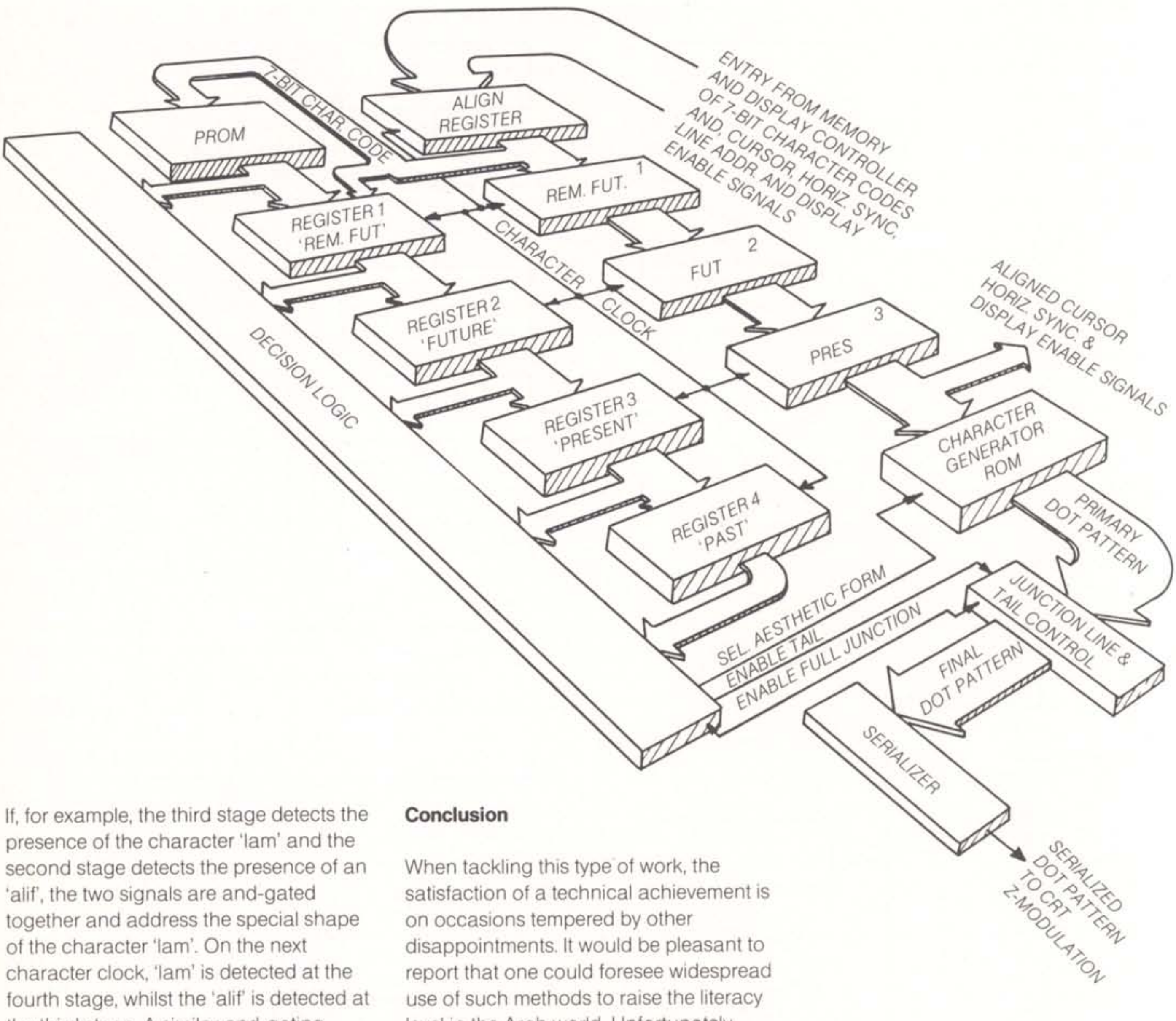


Figure 11 — Block diagram of the intelligent Arabic character generator



If, for example, the third stage detects the presence of the character 'lam' and the second stage detects the presence of an 'alif', the two signals are and-gated together and address the special shape of the character 'lam'. On the next character clock, 'lam' is detected at the fourth stage, whilst the 'alif' is detected at the third stage. A similar and-gating addresses the special form of the 'alif'. These are similar gatings for the characters 'ayn', 'ghayn' and 'ya', thereby allowing all of their different forms to be displayed.

Figure 11 is a block diagram of the intelligent character generator. The hardware structure is such that its implementation as a Large-Scale Integrated (LSI) circuit should be feasible. It is therefore hoped that European industry will take the initiative in pursuing this potentially lucrative development.

Conclusion

When tackling this type of work, the satisfaction of a technical achievement is on occasions tempered by other disappointments. It would be pleasant to report that one could foresee widespread use of such methods to raise the literacy level in the Arab world. Unfortunately history does repeat itself and there are pockets of resistance among the well-educated who see their dominant position being eroded, as when printing was first introduced. We can but hope that the eventual results follow a similar path to more universal learning.

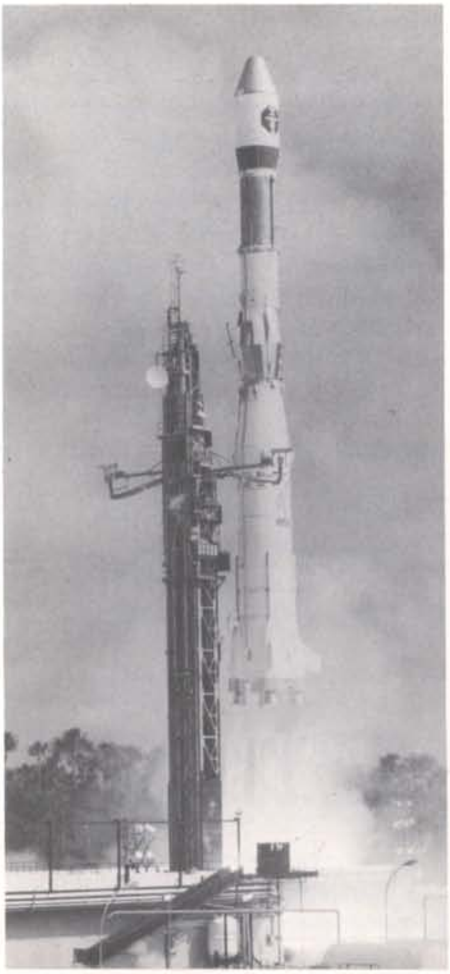
In Brief

Ariane Qualified and Fully Operational

On 25 January, following the complete success of three of its four test flights, the Ariane launcher was unanimously declared flight-qualified by representatives of the European States participating in the Ariane programme. These representatives, from Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, Sweden and the United Kingdom, took this opportunity to congratulate all those in the Agency, the Centre national d'Etudes spatiales (CNES) and European industry who have contributed to this impressive achievement.

The results of the flight tests have confirmed that the Ariane launcher has attained a degree of operational readiness that compares very favourably with that of other available launchers.

The declaration of qualification brings to a close the development phase of the Ariane launcher programme, and has firmly established Europe's independent launch capability.



In the ensuing operational phase, the first series of seven launches, known as the promotion series', will be carried out under ESA auspices. Thereafter, responsibility for the marketing, manufacture and launching of Ariane will be handed over to Arianespace.

The accompanying table is a manifest of the Ariane flights already reserved by international, national and commercial organisations. The length and multinational nature of the list of clients who have already committed to Ariane is regarded by the Agency as a particularly gratifying vote of confidence in Ariane-1 and its successors.

Ariane Manifest 1982 – 1985

Year	Month	Launcher	PAYLOAD(S)			Launcher orbit
			Spacecraft	*Mission*	*Authority*	
1982	Jul	L5 (AR-1)	Marecs-B	Maritime Communications	ESA	GTO
			+ Sirio-2	Meteo, data dissemination	ESA	GTO
		L6 (AR-1)	ECS-1	Communications	ESA	GTO
			+ Oscar-9B	Communications (radio-amateur)	Amsat	GTO
	Oct	L7 (AR-1)	Exosat or	Astronomy	ESA	Polar ellipt.
			Intelsat-V F6	Communications	INTELSAT	GTO
	Dec	L8 (AR-1)	Intelsat-V F6	Communications	INTELSAT	GTO
			or Exosat	Astronomy	ESA	GTO
1983	Feb	L9 (AR-1)	Intelsat-V F7	Communications	INTELSAT	GTO
	Apr/May	L10 (AR-1)	Intelsat-V F8	Communications	INTELSAT	GTO
			or ECS-2	Communications	ESA	GTO
	Jun/Jul	L11 (AR-1)	ECS-2 or	Communications	ESA	GTO
			Intelsat-V F8	Communications	INTELSAT	GTO
	Sep/Oct	L12 (AR-2/3)	Telecom-1A	Communications	France	GTO
	Dec	L13 (AR-3)	Telecom-1B	Communications	France	GTO
			+ Westar 6	Communications	Western Union	GTO
1984	Feb	L14 (AR-3)	Spacenet-1	Communications	Southern Pacific CC	GTO
			+ Arabsat 1	Communications	Arabsat	GTO
	Apr	L15 (AR-3)	G – Star-1	Communications	GTE	GTO
			+ (ECS-3)	Communications	ESA	GTO
	Jun	L16 (AR-3)	SPOT-1 + Viking	Remote sensing	CNES	Heliosynchr.
	Aug	L17 (AR-3)	G-Star-2 +	Communications	GTE	GTO
			Spacenet-2	Communications	Southern Pacific CC	GTO
	Dec	L18 (AR-2/3)	Available			
			or (Satcol-1) + ..	Communications	Colombia	GTO
1985	Mar	L19 (AR-2)	Intelsat-VA F14	Communications		GTO
	Apr	L20 (AR-2)	TV-Sat	Direct TV		GTO
	May	L21 (AR-3)	(Aussat + STBS-1) (or Satcol-2)	Communications		GTO
	Jun	L22 (AR-2)	TDF-1	Direct TV		GTO
	Jul	L23 (AR-3)	Giotto + (2nd passenger: (STC, SBTS-2)	Communications		GTO
	Sep	L24 (AR-2)	Intelsat-VA F15	Communications		GTO
	Oct	L25 (AR-4)	AR-4/01 (+ passengers)	Demonstration		GTO
	Dec	L26 (AR-3)	Available or (Aussat-2, SBTS-2)			

GTO: Geostationary Transfer Orbit

The ESA Microgravity Programme Gets Underway

In May 1981, the Agency's Member States agreed that a microgravity programme should be carried out on an optional basis under ESA auspices. The programme formally got underway on 15 January, some months having been needed to finalise its content in the light of the financial limits laid down.

The participating Agency Member States are Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, Sweden and the United Kingdom.

The science to be conducted in what will initially be a four-year programme, is divided over two main areas: life sciences, where researchers can study the effects of greatly reduced gravitational force on living organisms, from the most simple cells to the most highly developed ones (including human cells); and material sciences, in which the effects of microgravity on fluid behaviour, crystal growth and metallurgical systems, can be studied.

With these objectives in mind, it has been decided to concentrate, as an initial step, on three main programme elements:

(i) *Biorack*
This is a multi-user experimental facility for investigation in the fields of cell and molecular biology in the weightless environment of Spacelab. Candidate experiments include studies of plants, insects, mammalian cells and bacteria. This facility is scheduled to fly for the first time on the German national Spacelab mission, D-1.

(ii) *Fluid Physics Module*
This multi-user experimental facility, to be flown on the first Spacelab mission in 1983, is designed for the study of phenomena connected with the hydrodynamics of floating liquid zones. It is planned to improve the initial version of the Fluid Physics Module to meet a change in user requirements due to the most recent developments in microgravity sciences, and to fly this improved version on the German D-1 mission.

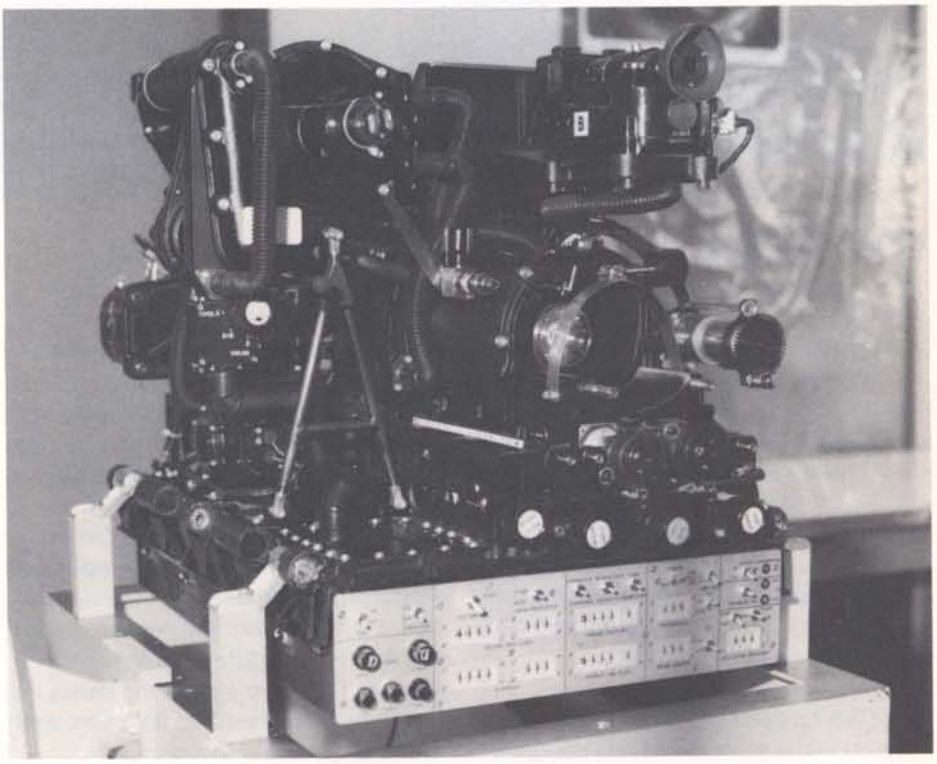
(iii) *Sounding Rockets*
The sounding-rocket programme will provide European experimenters with an opportunity to conduct solidification and fluid-physics experiments under easy-access conditions. The results obtained to date by the German and Swedish sounding-rocket programmes clearly justify the use of rockets for microgravity research.

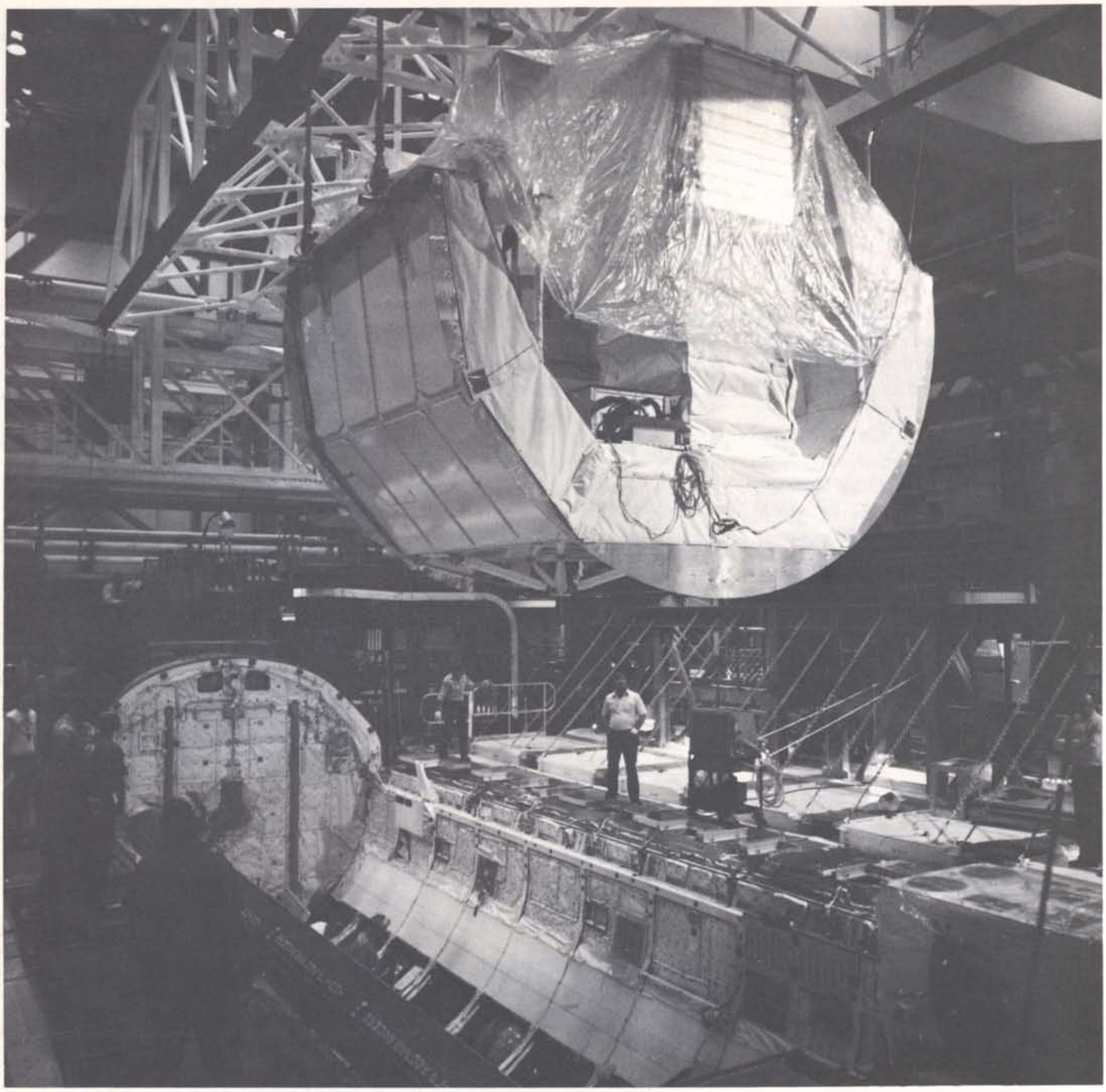
Spacelab crew members will be heavily involved with work on both the Biorack and the Fluid Physics Module; they will not only insert and remove samples from both facilities during flights but, with the Fluid Physics Module in particular, they will be responsible for observing the behaviours of liquid zones. The crew will be in direct voice contact with experimenters on the ground and will thus be able to adjust experiment operations as and when required by the investigator.

As in any new field, a considerable amount of basic research is necessary before the potential applications are known. It is hoped, however, that this research will lead to improvements that will have direct benefits for life on Earth. The growth of more perfect crystals for electronic components, improved metallurgical processes leading to new or higher quality alloys, deeper understanding of the human body which could considerably improve preventive medicine, and better insight into biological processes such as plant growth, are but some of the avenues to be explored in the coming years.

The Biorack

The Fluid-Physics Module





OSS-1 Payload

The OSS-1 payload carried on the third flight of the Space Shuttle in March, represented the most extensive and comprehensive scientific activity yet undertaken on the Shuttle. The nine OSS-1 experiments, dedicated to scientific investigations in space plasma physics, solar physics, astronomy and space technology, were mounted on one of the U-shaped pallets (2.86 m × 4.3 m) designed and built in Europe, as part of ESA's Spacelab Programme.

The OSS-1 payload was a pathfinder mission, in the sense that it was designed to provide both technological and scientific information for future Shuttle flights and thus serve as a precursor for later, more extensive space investigations.

Among the nine experiments was a 'Microabrasion Foil Experiment' – provided by the University of Kent, UK (experiment scientist Dr J.A.M. McDonnell) – designed to measure the numbers, chemistry and density of micro-meteorites encountered by spacecraft in near-Earth orbit. It is anticipated that because comets and asteroids are formed in different regions of the solar system, the particulate materials, or 'micro-meteorites', from each source should differ in nature.

The space sciences pallet OSS-1 being lowered into the payload bay of Space Shuttle 'Columbia'.

The European pallet supporting the OSS-1 payload, was the second to be flown on the Space Shuttle. The first carried the five OSTA-1 scientific experiments in the Shuttle's cargo bay on its second flight last November.

First Spacelab Flight Unit arrives at Kennedy Space Centre

The first Spacelab Flight Unit, which had been delivered to KSC aboard a number of trans-Atlantic cargo flights during December and January, had its official US 'unveiling' during a ceremony at Kennedy on 5 February 1982.

Among the guests at the ceremony were: Vice President George Bush, the NASA Administrator, the Director General of ESA, the Chairman of the Spacelab Programme Board, members of the US Congress, and officials from ESA, European Governments, NASA and the European Spacelab Consortium.

The first, seven-day flight of Spacelab aboard the Space Shuttle is scheduled to take place in September, and some 70 investigations will be conducted in five different scientific disciplines. A European team consisting of ESA and ESA contractor personnel is now in residence at KSC working side-by-side with NASA staff on preparing the first Spacelab Flight Unit for its maiden trip into space.

Meanwhile, in Europe integration and testing of the second Spacelab Flight Unit is well underway, with its delivery to NASA scheduled for June.

Vice-President George Bush (second from right) with the three European Spacelab Payload Specialists

Latest News of Meteosat-2

After performing almost flawlessly since it was put into orbit on 19 June 1981, a number of anomalies began occurring on Meteosat-2 in mid-March. The malfunctions happened as the radiometer mechanism was in retrace in preparation for the next image-taking and caused the retrace to stop. The spacecraft was temporarily placed in a standby mode to analyse the problem.

After consultation with the main contractor, a reduced mode of operation was attempted, with imaging being carried out every 3 h, allowing 2.5 h for the retrace. Although a few malfunctions have occurred in this mode, they have been adjusted for. Image quality has not been affected.

Meanwhile, an anomaly investigation has been started.

ESA to Undertake Development of More Powerful Ariane-4

At its January meeting, the Agency's Ariane Launcher Programme Board, consisting of representatives of the States participating in the Ariane programme, – Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom – authorised the development of a more powerful version of Europe's new launcher, to be known as Ariane-4. This updating of Ariane's performance marks a particularly important stage in the launcher's evolution, as it will greatly enhance its competitiveness in the space transportation systems market for the years 1986 to 1993, by further reducing the cost per kilogramme for placing payloads in orbit and providing greater adaptability to user requirements.

The decision to undertake this new programme follows upon those taken in 1980 to develop Ariane-2 and 3 (which raise the performance in transfer orbit from 1700 to over 2000 and 2400 kg, respectively), and the decision in 1981 to construct a second Ariane launch site.

The main features distinguishing Ariane-4 from Ariane-3 will be:

- Stretching of the first-stage tanks to increase the mass of propellants carried from 140 t to some 220 t.
- The possibility of adding combinations of two or four liquid or solid-propellant boosters.
- The availability of a new fairing with a diameter of 4 m and a choice of fairing heights (9.5 – 13 m) for use in combination with a new dual-launch system.

The six versions of the Ariane-4 vehicle will allow a wide range of spacecraft, with masses between 1100 and 4300 kg, to be launched in either single- or dual-launch configurations. The maximum performance of Ariane-4 will be more than twice that of the initial Ariane-1.

The development plan foresees a demonstration flight for Ariane-4 in late 1985, with operational availability early in 1986.

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table on page 82 and using the Order-Form on page 83.

ESA Journal

The following papers have been published in ESA Journal Vol. 6, No. 1:

THE EUROPEAN X-RAY OBSERVATORY SATELLITE – EXOSAT
B.G. TAYLOR, R.D. ANDRESEN, A. PEACOCK & R. ZOBL

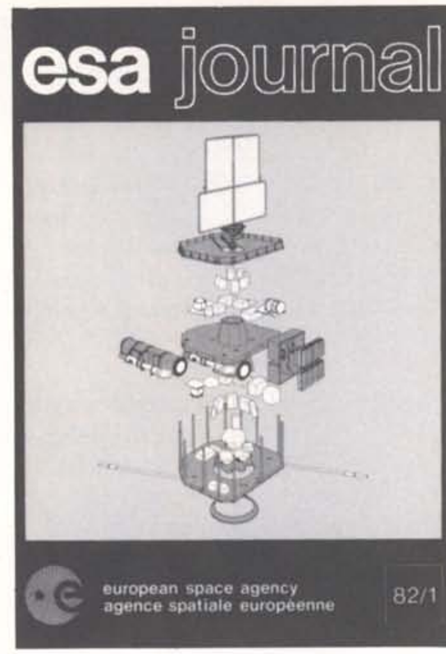
MODAL-SURVEY TESTING FOR SYSTEM IDENTIFICATION AND DYNAMIC QUALIFICATION OF SPACECRAFT STRUCTURES
N. NIEDBAL & H. HUNERS

ADAPTIVE CONTROL OF FLEXIBLE SPACE STRUCTURES
B. GOVIN & B. CLAUDINON

PLANETARY ALBEDO ESTIMATES FROM METEOSAT DATA
M. GUBE

UN OBJECTIF OPTIQUE POUR L'OBSERVATION DE LA TERRE A PARTIR DE SATELLITES
E. MATHIEU, E. SEIN & J.-P. DURPAIRE

FAST GENERATION OF CHEBYSHEV FILTER PROTOTYPES WITH ASYMMETRICALLY-PRESCRIBED TRANSMISSION ZEROS
R.J. CAMERON



Special Publications

ESA SP-161 // 470 PP PLASMA ASTROPHYSICS - PROCEEDINGS OF AN INTERNATIONAL COURSE & WORKSHOP HELD AT VARENNA, ITALY, 27 AUG. - 7 SEPT. 1981 (NOV. 1981)
GUYENNE, T.D. & LEVY, G. (EDS.)

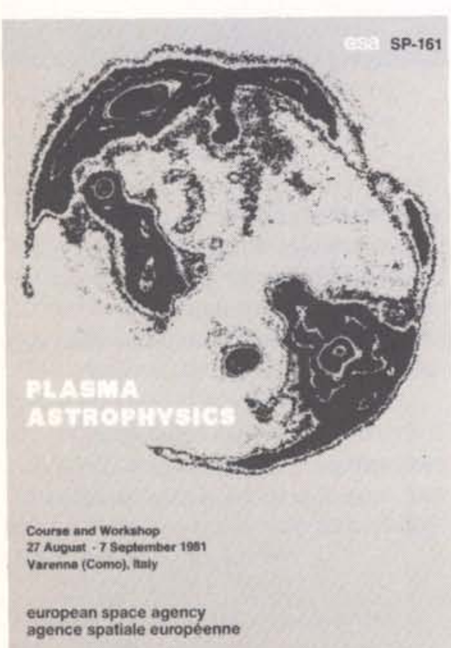
ESA SP-163 // 239 PP PROCEEDINGS OF THE SECOND ESA PRODUCT ASSURANCE SYMPOSIUM, ESTEC, NOORDWIJK, THE NETHERLANDS, 10-12 NOVEMBER 1981 (JAN. 1982)
BURKE, W.R. (ED.)

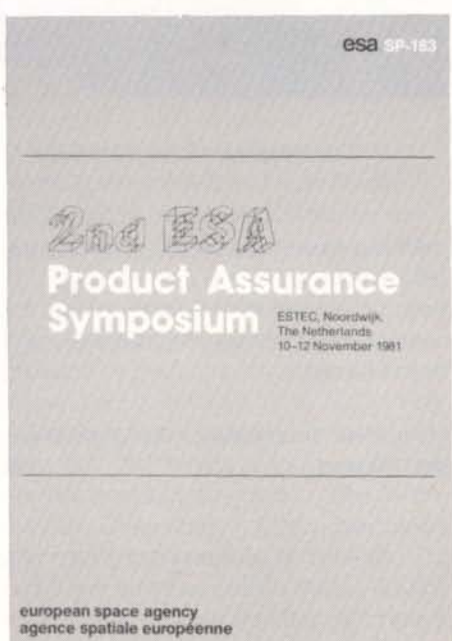
ESA SP-164 //273 PP THE SOLAR SYSTEM AND ITS EXPLORATION (NOV. 1981)
BURKE, W.R. (ED.)

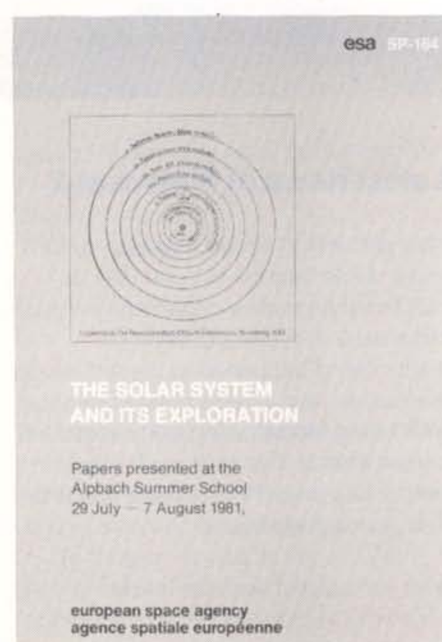
ESA SP-174 // 85 PP THE COMET HALLEY DUST AND GAS ENVIRONMENT (NOV. 1981)
BATTRICK, B. & SWALLOW, E. (EDS.)

ESA SP-1012 // PP VOL. I: 290; VOL. II: 534; VOL. III: 260. SPACE ACTIVITIES IN THE EIGHTIES - THE PROGRAMMES AND THE INDUSTRY (NOV. 1981) VOL. I: SURVEY OF SPACE PROGRAMMES (1975-1980); VOL. II. DETAILED PRESENTATION OF THE EUROPEAN SPACE INDUSTRY (1981); VOL. III: OUTLOOK OF SPACE INDUSTRY OUTSIDE EUROPE (1981)
DONDI, G.

ESA SP-1036 // 80 PP RECENT ADVANCES IN SPACE STRUCTURE DESIGN-VERIFICATION TECHNIQUES (OCT. 1981)
EUROPEAN SPACE AGENCY







Scientific & Technical Reports

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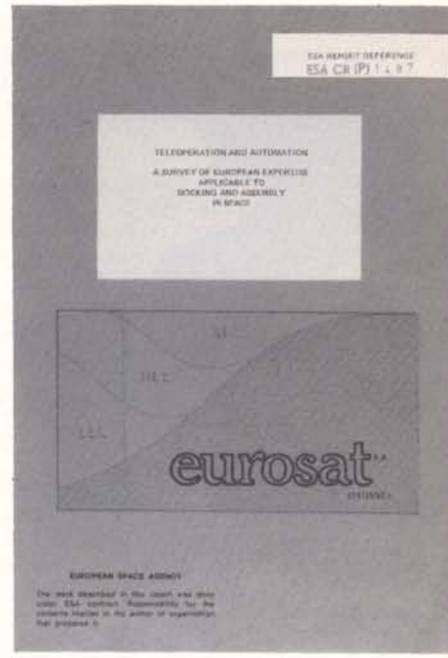

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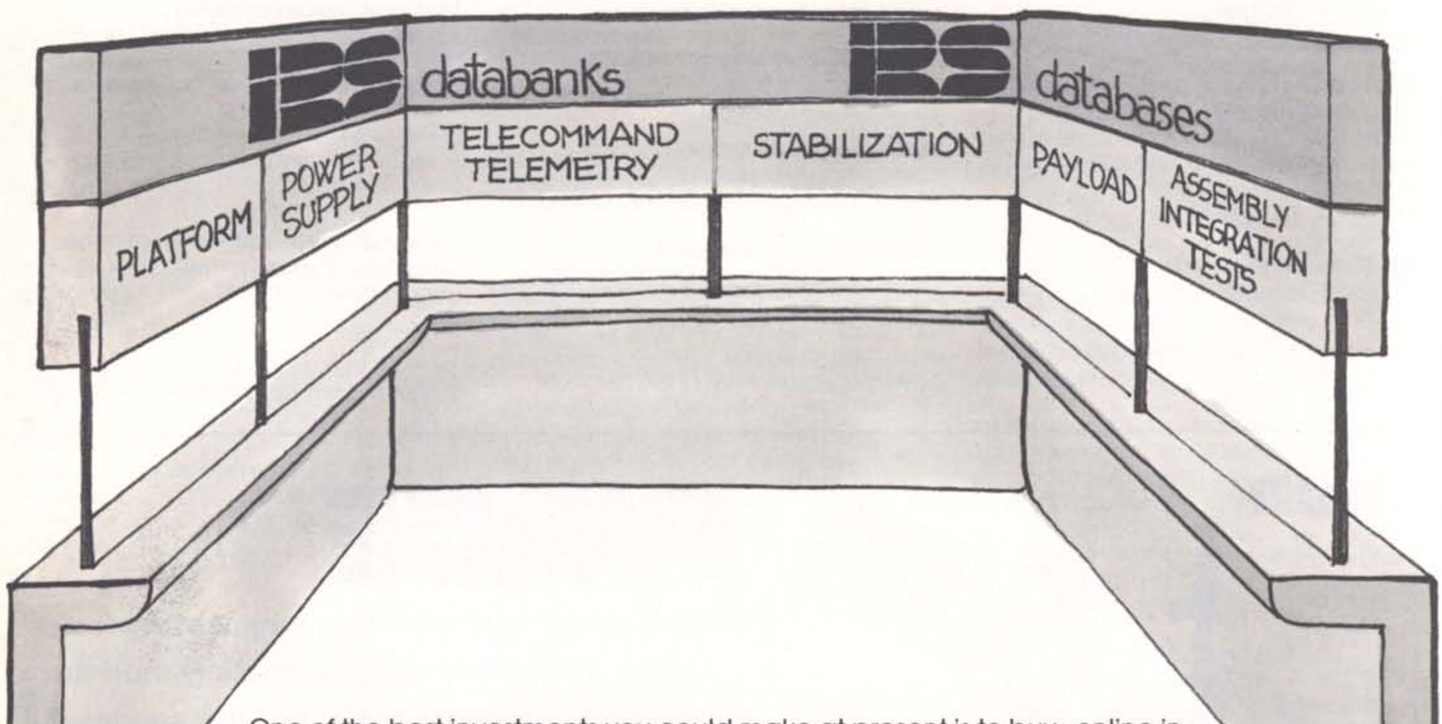

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