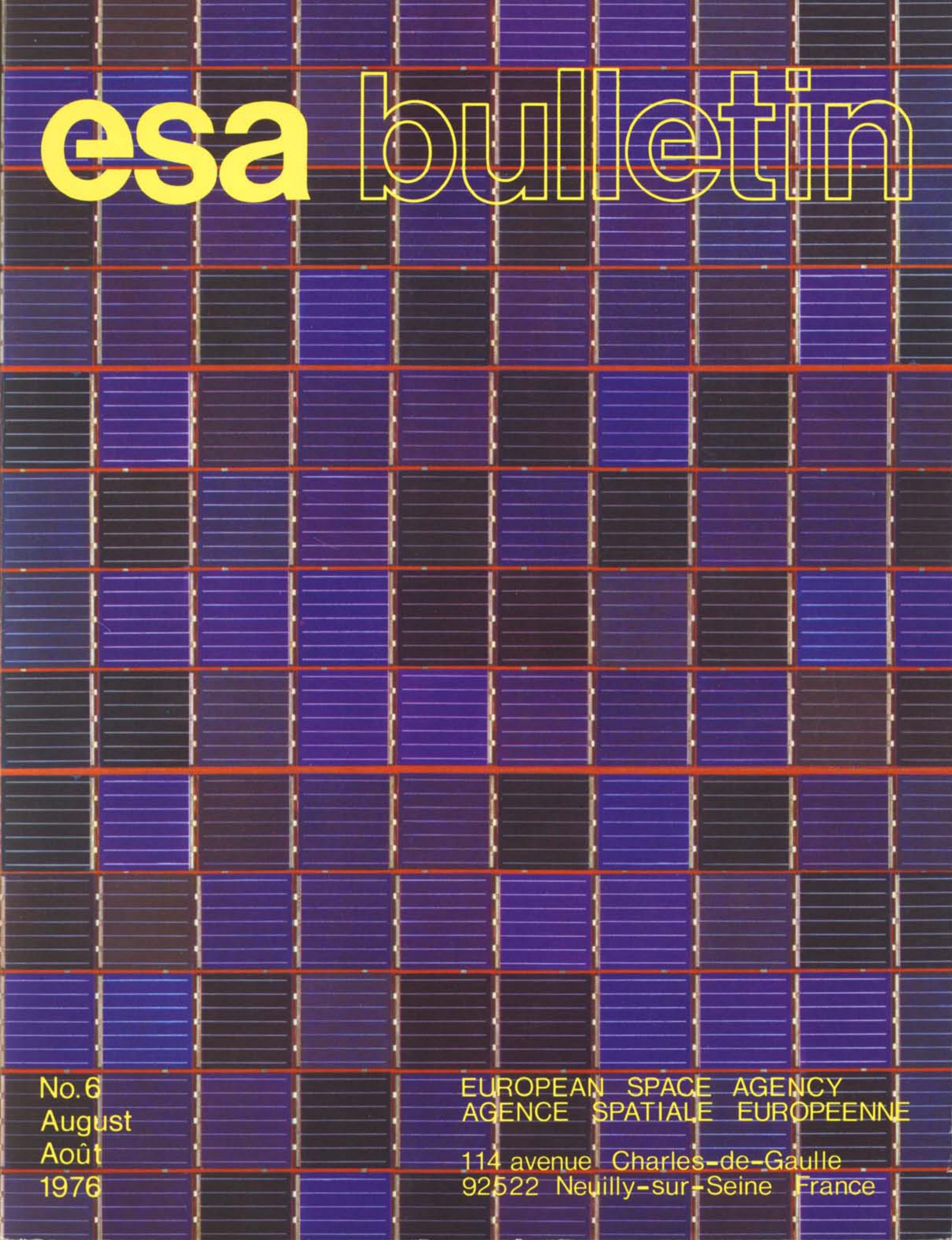

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1976

EUROPEAN SPACE AGENCY
AGENCE SPATIALE EUROPEENNE

114 avenue Charles-de-Gaulle
92522 Neuilly-sur-Seine France

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

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

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;

(b) by elaborating and implementing activities and programmes in the space field;

(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;

(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

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

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

The ESA HEADQUARTERS are in Paris (Neuilly-sur-Seine).

The major establishments of ESA are:

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

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

EUROPEAN SPACE RESEARCH INSTITUTE (ESRIN), Frascati, Italy.

Chairman of the Council for 1976: Dr. W. Finke (Germany).

Director General: Mr. R. Gibson.

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

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

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;

(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;

(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;

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

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

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

Le SIEGE de l'ASE est à Paris (Neuilly-sur-Seine).

Les principaux Etablissements de l'ASE sont:

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

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

L'INSTITUT EUROPEEN DE RECHERCHES SPATIALES (ESRIN), Frascati, Italie.

Président du Conseil pour 1976: Dr. W. Finke (Allemagne).

Directeur général: M. R. Gibson.

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For availability of ESA scientific and technical publications, *see page 55.*

All requests for *general* information on ESA activities (literature, photographs, films, etc.) should be addressed to the Public Relations Branch, ESA, 114, avenue Charles-de-Gaulle, 92522 Neuilly-sur-Seine, France.

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CONTENTS/SOMMAIRE

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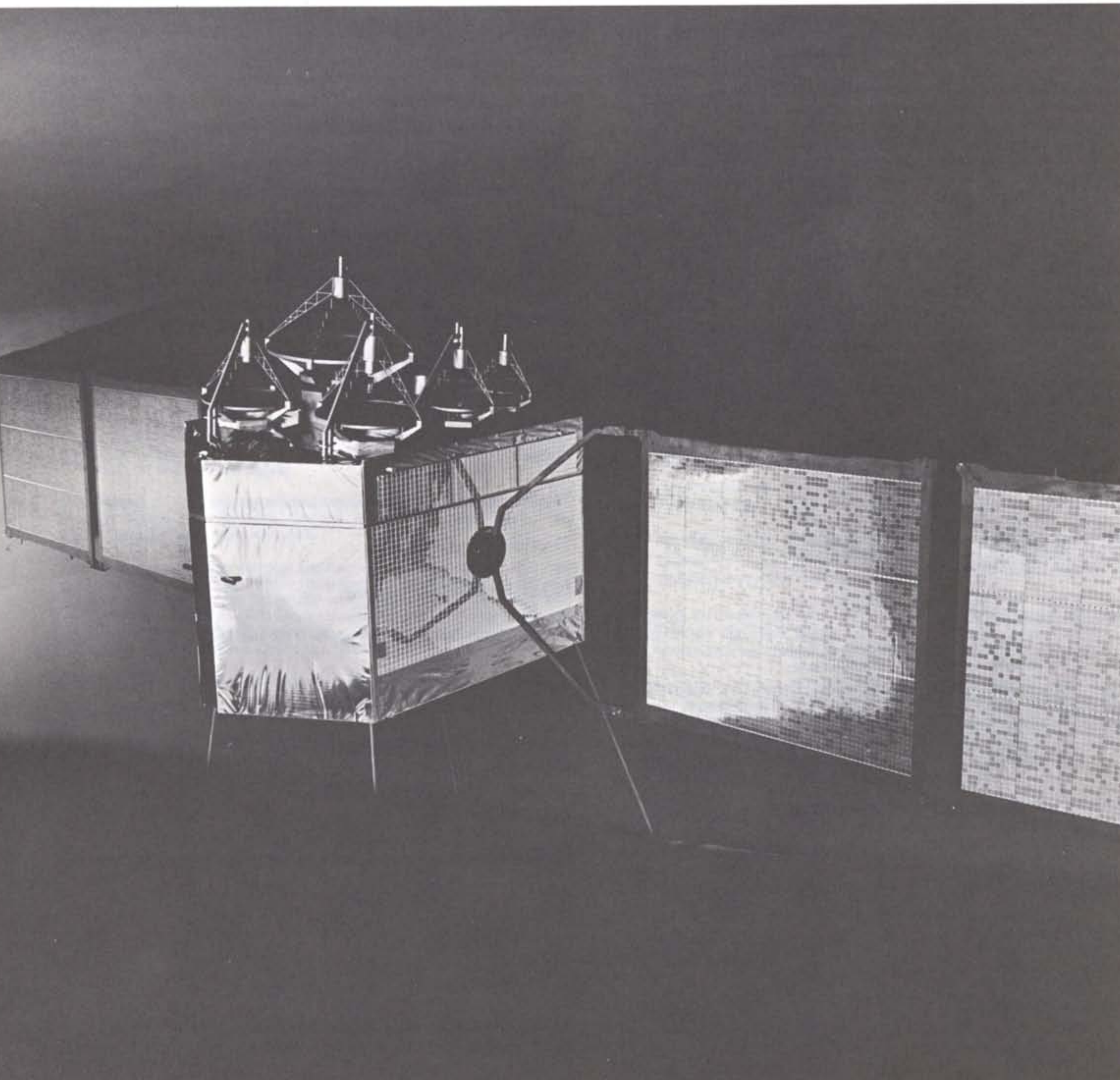


The Changing Role of Europe in Space*
La mutation de l'Europe spatiale

A. Lebeau, Director of Planning and Future Programmes / Directeur des Programmes futurs et des Plans, ESA, Paris

The establishment of the European Space Agency in June 1975 was an event that passed almost unnoticed in political and economic circles. In an issue devoted to the construction of Europe, a major business newspaper did not even mention it. Was this because the Agency grew up outside the EEC, and moreover, within a larger framework? Was it because attention in this field is usually concentrated elsewhere? Or was it because Europe is fascinated by its hesitations and failures rather than by its successes? And yet the European Space Agency does exist with a budget for 1976 of two thousand three hundred million francs and the future of Europe in space lies in its hands.

It is not only important but also necessary that Europe masters space technology, as it is one of the major technological developments of our time. Failure to acquire this technology would mean remaining dependent on others in innumerable fields. Without space there can be no telecommunications of the future, no global television broadcasting, no maritime and air navigation, no data transmission, no weather and crop forecasting, no surveillance of the oceans, no means of prospecting for mineral deposits and no military information. All these things would have to be bought or acquired. What would this dependence cost? It is as much a political problem as an economic one; if it does arise, it will do so tomorrow and by then it will already be too late.

DEPENDENCE – AT WHAT PRICE?

Europe therefore needed its own space agency. An independent capability in this field is only conceivable at European level. All thoughts on this matter, all analyses of the situation converge to the same conclusion, whether they focus on the amount of effort required in relation to national economies, on the needs generally expressed in terms of the geographical area of Europe, or above all, on the size of the captive market essential for the stability of industrial activity. What is really involved is the creation of an independent European capability in space applications. Independence here does not mean isolation or refusal to co-operate, but refusal to accept uncontrolled dependence. The need for an organisation as a proof and a guarantee of European solidarity arose from this aim.

The European Space Agency was born out of an increasing awareness of what was at stake and of the constraints, of an analysis of previous failure and success, of a compromise

* Translated from the French, published in 'Le Monde des Sciences et des Techniques', 31 March 1976.

La création de l'Agence spatiale européenne, en juin 1975, est passée un peu inaperçue des milieux politiques et économiques. Dans un numéro qu'il consacrait à la construction de l'Europe, un grand quotidien économique n'en faisait aucune mention. Est-ce parce que cette Agence s'est construite en marge des Communautés, dont elle déborde d'ailleurs le cadre? Est-ce parce que, dans ce domaine, l'attention se concentre, par habitude, sur ce qui se fait ailleurs? Est-ce parce que l'Europe est fascinée pas ses hésitations et par ses échecs plus que par ses succès? Et pourtant, l'Agence spatiale européenne existe, elle dispose, en 1976, d'un budget de 2,3 milliards de francs, et l'avenir spatial de l'Europe est entre ses mains.

Il est important, il est nécessaire que l'Europe acquière la maîtrise des techniques spatiales. Elles sont l'une des grandes mutations techniques de notre époque; une incapacité de les maîtriser serait synonyme d'un état de dépendance dans d'innombrables secteurs. Sans espace, demain, pas de télécommunications, pas de diffusion de la télévision, pas de navigation aérienne et maritime, pas de transmission de données, pas de prévision du temps et des récoltes, pas de surveillance des océans, pas de prospection des ressources minières, pas d'information militaire. Tout cela, il faudrait l'acheter ou l'obtenir. Quel serait le coût de cette dépendance? C'est un problème politique autant qu'économique, mais, s'il se posait un jour, ce serait demain, et il serait trop tard.

LE PRIX DE LA DEPENDANCE

Il fallait donc une agence spatiale européenne. L'existence d'une capacité spatiale autonome ne se conçoit sainement qu'à l'échelle de l'Europe. Toutes les réflexions, toutes les analyses se rencontrent sur ce point, qu'elles concernent l'ampleur de l'effort nécessaire en regard des disponibilités des économies nationales, les besoins qui s'expriment en général à l'échelle de la zone géographique européenne et, surtout, l'ampleur du marché captif qui est indispensable pour stabiliser l'activité industrielle. Ce qui est en cause, en définitive, c'est la création d'une capacité européenne autonome dans le domaine des applications de l'espace; autonomie ici ne signifie pas isolement ou refus des coopérations, mais refus d'une dépendance incontrôlée. La nécessité d'une organisation qui soit le témoin et le garant d'une solidarité européenne découlait de ce dessein.

* Point de vue paru dans *Le Monde des Sciences et des Techniques* du 31 mars 1976.

where a sense of solidarity finally triumphed over diverging national interests. But the birth of the Agency was not an end in itself, at best it was a step and the difficulties lie before us.

The coming years will be characterised by a marked evolution of space activities; the Agency, therefore, must know how to adapt itself and be able to do so; for this purpose, it will need the same solidarity that led to its establishment.

This development will profoundly affect its relations with national space institutions, with industry and with space users.

The supporters of national programmes and institutions have, in the past, often found themselves opposed to those who support a European organisation and programme. This approach to the question has the apparent simplicity of a two-sided argument. But it is also an outdated argument because, under its Convention, the Agency is required to co-ordinate space activities in the Member States and integrate these activities gradually into the European programme. It is a new and difficult task that it faces and one that it must carry out while preserving, at the same time, the unity of the European programme, a balance in its relations with the Member States, and the existence of national space entities.

Who can really believe that an integrated European programme can be built on the ruins of national institutions? These offer a reserve of skills and strength, a source of variety and material investment that cannot reasonably be dispensed with.

Consequently, two complementary approaches should be used. On the one hand the gradual rationalisation, co-ordination and integration of all space activities in Europe, and on the other the organisation of the national entities' participation in the preparation and implementation of the European programme. This evolution must be mastered if the political solidarity which created the Agency is to be transformed successfully into institutional solidarity.

The success of this difficult evolution is an imperative at the very moment when the nature of space activities is undergoing a change which profoundly affects relations between the Agency, industry and the bodies that are to use space applications. In the middle sixties we witnessed a move from pure scientific research towards the development of space applications. Similarly, in the coming years, the move will be from research and development towards operational uses. This is particularly the case for telecommunications and meteorology. Whilst these prospects hold a promise of fulfilment, they also contain certain threats.

L'Agence spatiale européenne est née de la conscience progressive de l'enjeu et des contraintes, de l'analyse des succès et des échecs qui l'ont précédée, d'un compromis où le sentiment de solidarité l'a finalement emporté sur les divergences nationales. Mais cette naissance n'est pas une fin, elle est au mieux une étape et les difficultés sont devant nous.

Les années qui viennent seront marquées par une très profonde évolution des activités spatiales; il est donc nécessaire que l'Agence sache et puisse s'adapter; elle a besoin pour cela de la solidarité qui conduisit à la créer.

Cette évolution va affecter profondément ses relations avec les institutions spatiales nationales, avec l'industrie et avec les utilisateurs de l'espace.

Les partisans des programmes nationaux et des institutions nationales se sont souvent opposés, dans le passé, aux partisans d'une organisation et d'un programme européens; cette approche offre les séductions d'un débat simple dans lequel chacun peut choisir son camp. C'est aussi un débat dépassé. La Convention de l'Agence lui donne mission de pourvoir à la coordination des activités spatiales dans les Etats membres et à leur intégration progressive au sein du programme européen. C'est une tâche nouvelle et difficile qui s'impose à elle, et qu'elle doit conduire avec le souci de préserver tout à la fois l'unité du programme européen, l'équilibre de ses relations avec les Etats membres et l'existence des entités spatiales nationales.

Qui peut croire, en effet, avec quelque réalisme qu'un programme européen intégré puisse s'établir sur les décombres des institutions nationales? Celles-ci constituent un réservoir de compétence et de dynamisme, une source de diversité et un investissement matériel dont il ne peut être raisonnable d'envisager la disparition.

Il faut donc que s'opèrent deux démarches complémentaires, d'une part une rationalisation, une coordination et une intégration progressives de l'ensemble des activités spatiales en Europe, d'autre part l'organisation d'une participation des entités nationales à l'élaboration et à la mise en oeuvre du programme européen. Il dépend de la maîtrise de cette évolution que la solidarité politique qui a créé l'Agence se transpose en une solidarité institutionnelle.

Cette difficile évolution s'impose alors même que la nature des activités spatiales connaît une mutation qui affecte profondément les relations entre l'Agence, l'industrie, et les administrations utilisatrices des applications de l'espace. De même qu'on

était passé, vers le milieu des années 60, d'une activité purement scientifique à une activité progressivement orientée vers le développement des applications, on va passer dans les années qui viennent, d'une activité de recherche et de développement à une activité d'utilisation opérationnelle. C'est le cas notamment pour les télécommunications et pour la météorologie. Cette perspective recèle tout à la fois une promesse d'aboutissement et des menaces.

THE USERS

To achieve success, European industry must first develop an efficient structure that will enable it to meet Europe's requirements cost-effectively and to seek outside markets for its space products. Success also requires that when the time comes for operational use, the will that led to the development of Europe's space capability will, similarly, lead the user administrations to meet their needs with systems designed and made in Europe.

The two aspects of the problem are, moreover, inseparable. In the field of telecommunications, for example, where an extensive world market is emerging, Europe's industrial capability will only be credible in the eyes of outside customers if Europe itself meets its own needs with its own products.

There must, therefore, be solidarity between the highly diverse members of the European partnership; and who can fail to see the difficulties entailed in this endeavour? Looking at the user administrations, there are no structures capable of managing European programmes, national interests do not coincide, much weight is given to short-term considerations and immediate profitability. As for industry, there is the problem of reconciling commercial competitiveness and the balance of work in the various Member States; there is the problem of satisfying all the hungry appetites stimulated by the prospects of commercial gain. These are all rocks on which European solidarity may founder.

It is clearly, in the long term, in the interests of the States of Europe, that there should be a Europe in Space and a European space industry. However, there are also many short-term opposing interests in a Europe where solidarity and national egoism co-exist. The existence of a European Space Agency is nonetheless a reality, its structures are sound and the future can be viewed with firm resolution. In the words of Beaumarchais, *'The difficulty of success is but a spur to enterprise'*. □

LES UTILISATEURS

Le succès exige d'abord que se dégage une structuration efficace de l'industrie européenne qui permette à la fois de satisfaire les besoins européens au meilleur compte et de rechercher à l'extérieur, des marchés pour les produits spatiaux européens. Il exige aussi qu'à l'heure des utilisations opérationnelles, la volonté de développer une capacité spatiale soit relayée par la volonté des administrations utilisatrices de satisfaire les besoins européens avec des systèmes conçus et fabriqués en Europe.

Les deux aspects du problème sont d'ailleurs indissociables; dans le domaine des télécommunications spatiales par exemple, où émerge un large marché mondial, la capacité industrielle européenne ne sera crédible, pour des clients extérieurs, que du jour où l'Europe aura pourvu elle-même à la satisfaction de ses propres besoins.

Il faut donc que se crée une solidarité entre des partenaires européens très divers; et qui ne voit les difficultés de l'entreprise? Du côté des administrations utilisatrices, le manque de structures capables de gérer des programmes européens, la diversité des intérêts nationaux, le poids des préoccupations à court terme et de la rentabilité immédiate. Du côté des industries, la difficulté à réconcilier la compétitivité commerciale et l'équilibre des activités dans les divers Etats membres, les appétits urgents des uns ou des autres dès qu'apparaît la perspective de gains commerciaux, autant d'obstacles sur lesquels peut éclater la solidarité européenne.

C'est bien entendu l'intérêt à terme de tous les Etats que l'Europe spatiale et que l'industrie spatiale européenne se fassent, mais à cet intérêt à terme s'opposent beaucoup d'intérêts immédiats dans une Europe où coexistent la solidarité et l'égoïsme des Etats. Il reste cependant que l'Agence spatiale européenne existe, que ses structures sont solides et que l'avenir doit être envisagé avec résolution. Comme le dit Beaumarchais: 'La difficulté de réussir ne fait qu'ajouter à la nécessité d'entreprendre'. □

European Flexible Solar-Cell Blanket on the Canadian/US Communications Technology Satellite

K.K. Reinhartz, Department of Development & Technology, ESTEC, Noordwijk, The Netherlands

P. Paulsen & R. Buhs, Space Technology Department, AEG-Telefunken, Hamburg, Germany

The Communications Technology Satellite (CTS), developed jointly by Canada and the United States and launched successfully on 17 January last, is presently the most powerful communications satellite in operation. Its primary objectives are to demonstrate the feasibility of high-power colour television and sound broadcasting to small, low-cost earth stations, and to flight-test advanced-technology subsystems.

Europe's contribution to this international co-operative space project, through a bilateral agreement between the Canadian Department of Communications and ESA, has been to supply two 20 W travelling-wave-tube amplifiers and a special low-noise parametric amplifier, and to develop the flexible solar-array blankets that provide the satellite's power.

The solar generator carried by CTS represents one of the more advanced subsystems carried on board the spacecraft. The two flexible solar-cell blankets, each 1.3 m wide, 6.5 m long and together weighing 13.8 kg, carry a total of 25 272 cells and are designed to deliver 1.3 kW of power at the beginning of the mission under normal sun illumination, with a minimum output after two years of operation of 0.95 kW at summer solstice, when the sun-earth distance is a maximum and the sun's angle of incidence 23°. Only by developing such a lightweight solar generating system was it possible to meet the power requirements of the satellite whilst still satisfying the mass and volume constraints imposed by the Thor-Delta 2914 launch vehicle.

During launch, each solar-cell blanket was to be folded 30 times, concertina fashion, and held between two rigid plates. Foam layers were inserted between the folds to avoid cell damage due to the mechanical loads during launch. After attitude acquisition in geostationary orbit, the blankets were deployed from the spacecraft with a BI-STEM boom (Fig. 1) and held in tension by the solar-array mechanical assembly.

The blankets themselves were developed by AEG-Telefunken under contract to ESA, the Agency and the Canadian Communications Research Centre (CRC) being jointly responsible for their design. The solar-array mechanical assembly was designed and built by SPAR Aerospace, under contract to CRC. The fact that development, qualification and manufacture of the first prototype/spare flight blanket was completed on schedule only two years after the first technical contacts between CRC and ESA is a reflection of the excellent spirit of co-operation of all those involved, both in industry and in the government agencies.

DESIGN

The CTS array is the first flexible, foldable solar array to be used on a geostationary spacecraft and has served as a test bed for a number of new technologies being developed as part of ESA's Supporting Technology Programme. The most difficult design problems were imposed by the extreme thermal cycling to be expected and the very stringent mechanical-interface requirements. The thermal requirements stemmed from the very low heat capacity of the lightweight solar-cell blanket and the long eclipse periods to be endured in geostationary orbit. Typical predicted blanket temperatures were +55°C in sunlight and −185°C at the end of eclipse, with an occasional minimum of −210°C. Approximately 90 such cycles had to be considered per year. The most severe mechanical requirements originated from the very tight limits on overall dimensions, leading to an extremely high packing density for both solar cells and wiring.

The major components of the solar blanket are shown in Figure 2. The substrate is a laminate of 25 μm kapton foil and 35 μm glass-fibre cloth. The total thickness of the composite is 65 μm, and its weight 87 g/m^2. By using a special polyester adhesive, the substrate remains flexible even at −200°C. To facilitate manufacture and integration and to reduce the cost of spare units, each blanket substrate has been divided into eight separate sections, interconnected by a piano-type hinge, with a thin stainless-steel rod as a hinge pin. Five sections of each blanket are identical.

The 20 × 20 × 0.20 mm^3 silicon solar cells used have an initial efficiency of 12% at 25°C. To protect them against low-energy particles they are covered with very thin (0.10 mm) cerium-doped microsheet. They are series and parallel interconnected with silver-mesh strips, welded in position. This represents the first application of welded-solar-cell interconnection technology, developed in Europe under ESA contract, to an Agency project and a very extensive test programme was conducted to establish sufficient confidence in the manufacturing processes.

The basic building block of the solar array is a 3 × 9 cell module. To supply CTS's communications experiments, 18

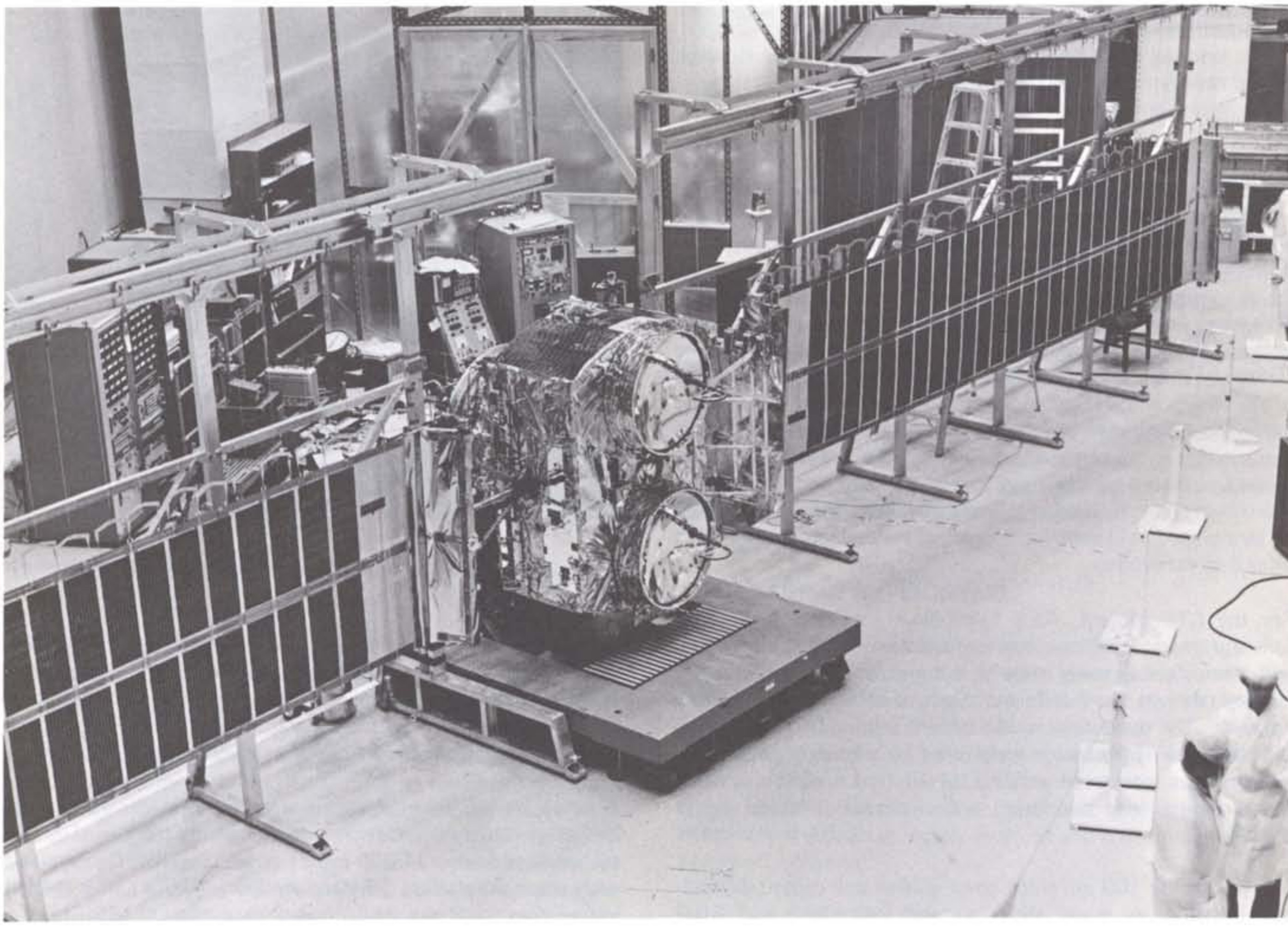


Figure 1 — Deployment testing of the flexible solar arrays on the CTS spacecraft.

such modules are connected in series and 42 in parallel, giving a minimum of 770 W (66 V) after 2 years. The housekeeping functions of the spacecraft are powered by a separate part of the solar array, comprising 9 modules in series and 20 in parallel. It supplies a minimum of 168 W (29 V). Figure 3 shows the geometry of each blanket.

The power generated by the solar panels is transferred from the cell modules to the spacecraft through flat, kapton-insulated, flexible cables located at both blanket edges. In addition, a flat, 40-wire cable in the centre of the blanket is used to transfer signals from a number of solar-array experiments. The gap between conductors is typically only 0.3 mm, in order to minimise the area occupied by the cabling. The wiring selected also has to meet the severe thermal-cycling requirements without any deformation or delamination.

DEVELOPMENT AND TESTING

All design and production activities were supported by an extensive development and test programme, conducted jointly by AEG-Telefunken and ESTEC. This programme was necessary because of:

– the introduction of new materials and technologies
– the unusual mechanical requirements during array stowage and deployment
– the severe environmental requirements.

Concerning the new materials and processes, three main problems had to be solved during the development phase:
– welding of silver-mesh interconnectors
– application of 100 μm-thick cover glasses
– use of kapton/glass-fibre substrate.

The most intensive investigations were related to the welding process. Welding had been used by AEG-Telefunken for the Helios sun probe but the design and environmental requirements of the Helios and CTS missions were very different. All welding parameters, such as electrode pressure, welding time, voltage and current had to be optimised in view of the use of silver-mesh instead of plated-molybdenum interconnectors and the extreme thermal-cycling requirement. These investigations were supported by pull tests and micro-sectioning of welded joints before and after thermal cycling.

For the CTS project, AEG-Telefunken introduced the first fully automatic welding machine for solar-cell integration. The unit comprises a power supply, a fixed welding head, and a moving table to carry different types of solar-cell and module supports. The movement of the table is numerically controlled and the welding process is monitored by a control unit which measures the integrated welding current as a function of time, comparing it with maximum and minimum allowed values (Fig. 4).

The use of the 100 μm-thick cover glasses also caused difficulties initially, as many slides showed hairline cracks after welding the interconnectors to the rear of the cells. By modifying the cover adhesive curing process and optimising the welding parameters, the incidence of hairline cracks could eventually be reduced to affect less than 3% of the covers. It was further shown through particle-irradiation and acoustic-noise tests that hairline cracks in cover glasses would not cause any measurable power loss in orbit.

The kapton/glass-fibre substrate chosen for CTS had previously been tested in the course of the development of a roll-up solar array. The mechanical parameters of the substrate were verified by a repetition of the measurements, with special emphasis on CTS requirements. New requirements included a series of folding and deployment cycles before (and after) launch and the high stowage pressure on the blanket.

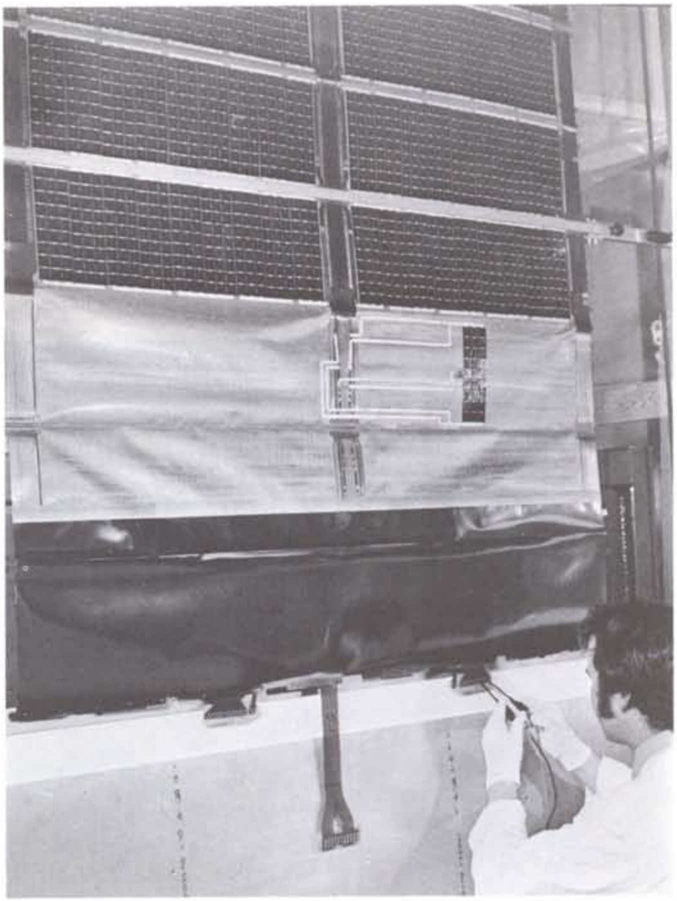


Figure 2 – Detail of the flexible solar-cell blanket with solar-cell test patch.

Ability to withstand the severe orbital temperature cycling was seen as the most important test requirement. Following the thermal analysis, the cycling qualification limits were defined as -220°C and $+100^\circ$C with temperature gradients simulating the orbital sun/eclipse transients as far as practicable.

A total of 435 thermal cycles were performed on modules, including substrate and representative wiring sections. The test sequence consisted of 200 cycles down to -185°C in vacuum with solar simulation, 35 deep cycles (-220°C) in a helium atmosphere, and an additional 200 cycles (-185°C) in a nitrogen atmosphere. This approach was chosen because the limitations of existing test facilities did not allow simultaneous fulfilment of all test conditions as regards vacuum, temperature range and temperature change rates.

QUALIFICATION AND ACCEPTANCE

For qualification of the blanket design, one complete solar-panel assembly (approximately 2000 cells) was tested. It was first subjected to 30 folding and deployment cycles at temperatures between $+70^\circ$C and -70°C. A heat-balance test and 50 thermal vacuum cycles between -170° and $+60^\circ$ were then performed in DFVLR's 2.5 m diameter solar-simulation facility at Porz-Wahn. The thermal-cycling test was completed with

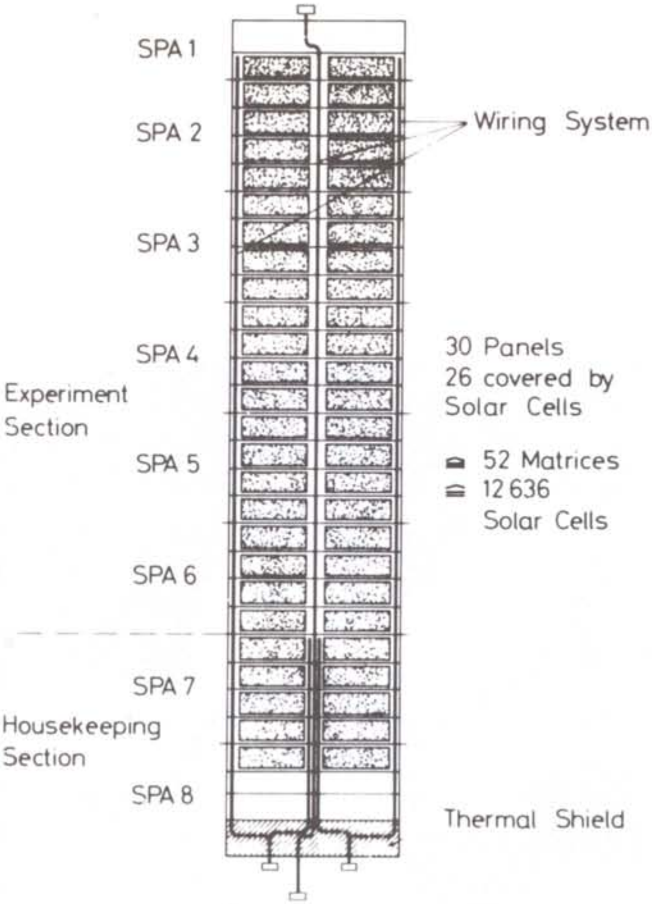


Figure 3 — Geometry of the flexible solar-cell blanket.

150 additional cycles in the HBF 2 thermal vacuum facility at ESTEC.

As part of the qualification test programme, a repair technique for the welded modules was also tested as repair is a problem, particularly as it may have to be carried out under field conditions, i.e. at the testing or launch site. Two 3 X 9 modules in different parts of the blanket were replaced at ESTEC, prior to a thermal-cycling test, by first separating the module from the flexible substrate and then bonding in a new welded module and connecting the electrical leads to the bus bars by hand soldering.

Visual inspections and repeated electrical performance measurements in ESTEC's Large-Area Pulsed Solar Simulator did not show any degradation of performance during qualification testing.

Acceptance testing on the prototype and flight blankets was carried out as part of the integrated deployable solar-array system test programme by CRC. Mechanical testing consisted of three-axis sinusoidal and random vibration at qualification levels according to the protoflight test concept followed by an array deployment. No solar-cell breakages occurred and no changes in electrical characteristics were measured. Thermal cycling was carried out in a 9 m thermal vacuum tank at NASA's

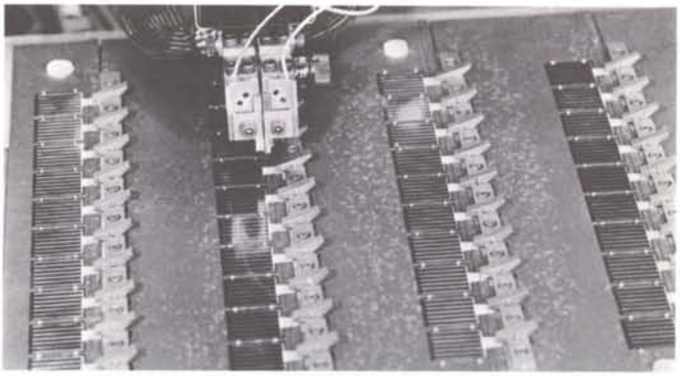


Figure 4 — Automatic solar-cell welding facility.

Lewis Research Center in Cleveland. Following vacuum deployment, the solar array was subjected to 15 simulated eclipse and sun cycles. A bank of lamps in front of the blanket was used to simultaneously heat the solar array and provide illumination for electrical-output measurements. Blanket temperatures during cycling were approx. -140°C at the end of a 72 min cold phase, and $+100^\circ$C during the hot phase. No solar-cell breakages or damage to other components occurred.

Electrical performance measurements before and after thermal cycling did not show measurable degradation. The temperature distribution across the blanket was again verified by using the data from the blanket's temperature sensors.

SOLAR-ARRAY EXPERIMENT

To monitor the electrical performance and degradation of solar cells on a flexible solar array in geostationary orbit, and to verify the thermal analysis, one 3 X 9 cell test module (see Fig. 2) and five thin-film platinum-resistance thermometers have been mounted on the blankets of CTS. An electronic control unit built by RFE in Germany scans the current/voltage curve of the solar-cell test module and the output of the temperature sensors at regular intervals and transmits the data to a telemetry channel.

ORBITAL OPERATIONS

The CTS spacecraft was launched from Cape Canaveral on 17 January 1976. After injection into geostationary orbit and attitude acquisition, the solar arrays were deployed on 1 February 1976. No anomalies occurred and the blankets were completely unfolded and in nominal tension 4 min after beginning deployment.

The performance of the blankets is very close to that predicted, the operating temperature of the cells varying between 52° and 42°C, depending upon season. The minimum temperature recorded at the end of the longest eclipse is -188°C, and the maximum rate of change of temperature recorded so far after leaving eclipse is 75°C/min. The solar array has survived its first eclipse season without any malfunction and continues to provide the CTS spacecraft with the requisite power. □

Exploratory Journey Out of the Ecliptic Plane*

D.E. Page, Space Science Department, ESTEC, Noordwijk, The Netherlands

Our picture shows how nonuniform the solar atmosphere generally is (Fig. 1). Moreover, the coronal streams that are seen stretching out to engulf the Earth change their structure from hour to hour. Yet, in spite of all the effort that has gone into space research, we have never managed to explore the solar environment beyond the narrow and totally unrepresentative strip traced out by the Earth's orbit. (The plane in which the Earth's orbit lies is referred to as the ecliptic plane. The solar equatorial plane is tilted at 7° to the ecliptic plane in such a way that in March and September the Earth makes its maximum solar latitude excursions of 7°).

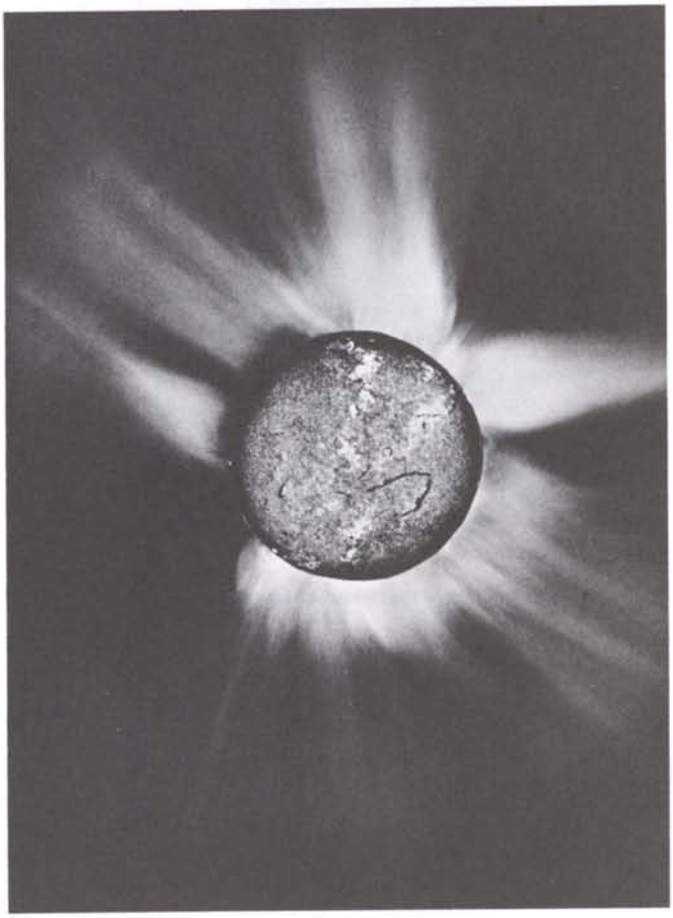


Figure 1 — Montage of an eclipse photograph of the solar corona and a photograph of the visible surface of the Sun (out of eclipse, near the same time) in the light emitted by atomic hydrogen (courtesy of the Space Environment Laboratory, NOAA, Washington, DC and the High Altitude Observatory, NCAR, Boulder, Colorado).

An exploratory journey out of the ecliptic to higher solar latitudes is essential if we are to understand the astrophysics of the nearest star — our Sun — and explain how its behaviour so dramatically affects the Earth.

Our ignorance falls into three categories and arises largely because the Earth, and all spacecraft so far flown or planned, never depart more than 7° from the solar equatorial plane.

UNREPRESENTATIVE SAMPLING OF SOLAR RADIATION

We sample only a tiny fraction, within a narrow angular strip, of the radiation emitted by the Sun. The Sun continuously ejects a gusty supersonic plasma flow, called the solar wind, which fills interplanetary space and entwines the Earth and planets with solar magnetic field lines dragged along with it (Fig. 2). At times of localised eruptions the Sun emits, in addition, penetrating nuclear particles with energies of millions of electron volts. These are accompanied by enormous blast waves in the plasma and frequently by ultraviolet, X, and even potentially lethal gamma-ray bursts. The effects at the Earth show up as the brilliant auroral lights, magnetic storms big enough to upset national electricity grids, and ionospheric disturbances that distort our radio communications. The large-scale structure of the solar wind may produce similar terrestrial effects, and there is now very convincing evidence — although the physical mechanism is not understood — that the Earth's global weather is markedly affected too.

The performance of the Sun and its variability are truly awesome. Normally the auroral lights, marking the latitude to which the solar wind has managed to penetrate the Earth's shielding magnetic field, are seen around the polar circles, but we know of cases when auroras appeared close to the equator — for example, on 25 September 1909 and 14 to 15 May 1921 at Jakarta, Singapore, and Samoa. The ferocity with which the Sun must have behaved on these occasions is difficult to comprehend. It could be that at such dramatic times the active sunspot belt, normally limited to solar latitudes between about

* A more detailed and fully referenced description can be found in *Science,* **190** pp. 845–850.

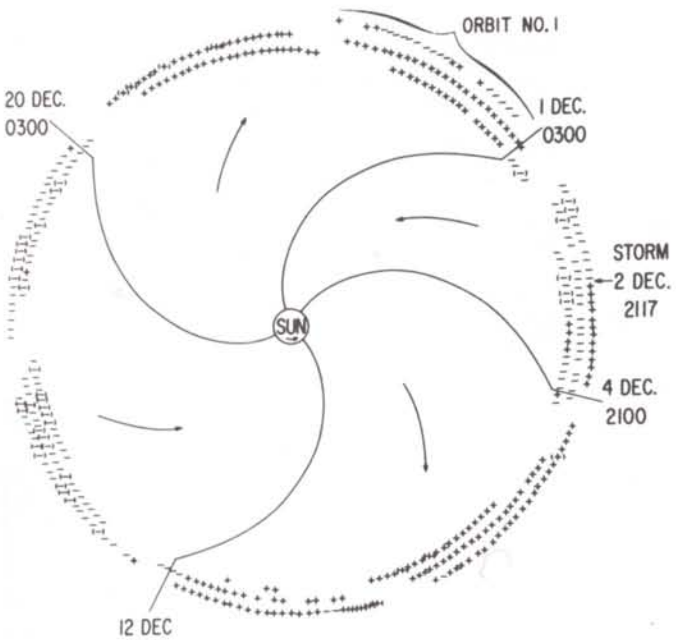


Figure 2 — The solar magnetic field is dragged out by the solar wind to entwine the Earth. The field takes up the 'garden hose' spiral configuration because the Sun rotates. The sector structure of alternate positive and negative field polarities is so far without explanation — probably because the third dimension is unknown. (Figure after Wilcox and Ness).

40° and 10°, had moved a bit lower, and the Earth experienced the full radial plasma blast which it normally misses by staying within 7° of the solar equatorial plane. Just as an underwater swimmer might locate dirty patches above him by looking toward the light, so by looking through the solar wind toward cosmic radio stars we can get some crude idea of the structure in the wind. Indeed, it is very inhomogeneous and shows marked variations with solar latitude. Above about 40° solar latitude, things appear calmer, but the flow could be much faster. The variations with latitude are linked with the fundamental mystery of the 11-year sunspot cycle.

It is clear that our ability to sample the solar radiation is extremely limited and that what we do see is totally unrepresentative of what might be found at other latitudes. Our space efforts in this field thus far are equivalent to trying to map the Earth's magnetosphere with a single spacecraft fixed in a circular equatorial orbit just below the radiation belts.

HELIOSPHERIC DISTORTION OF GALACTIC COSMIC RADIATION

We do not know the structure or size of the heliosphere carved out by the solar wind, so we cannot tell how it affects galactic cosmic radiation on its way to the Earth. Since, except around the Earth, we have a poor idea of the radiations and field emitted by the Sun, we are obstructed in our studies of the Sun as a star. Astrophysics loses out again because, for the same reasons, we are unable to establish the nature of the true primary interstellar cosmic-ray spectrum. If we could travel to high solar latitudes we could get to understand the interplanetary cavity that hinders the radiation reaching the Earth and, at the same time, come closer to directly measuring the unmodulated cosmic radiation. We must make the journey because the modulating plasma and field parameter changes seen in the ecliptic plane during a solar cycle are totally inadequate to explain the cosmic-ray changes seen over the same period.

A NARROW AND INTERRUPTED VIEW OF THE SUN

Because we look at the Sun from a fixed angle, we have a poor idea of the three-dimensional structure of many solar features. Two basic experimental problems arise in studying solar features: (i) We do not know the third dimension in most cases and therefore can only guess about the field configurations, absolute size, total energy, and so forth of objects such as the recently discovered coronal holes — especially since these exist predominantly close to the solar poles. (ii) Our attempts to study the evolution of features are frustrated when every 13 days the centre of interest disappears behind the western solar limb. A continuous bird's-eye view of the Sun from polar latitudes would provide the third dimension and allow study of solar features from their moment of birth until they disappear or are dragged away into interplanetary space.

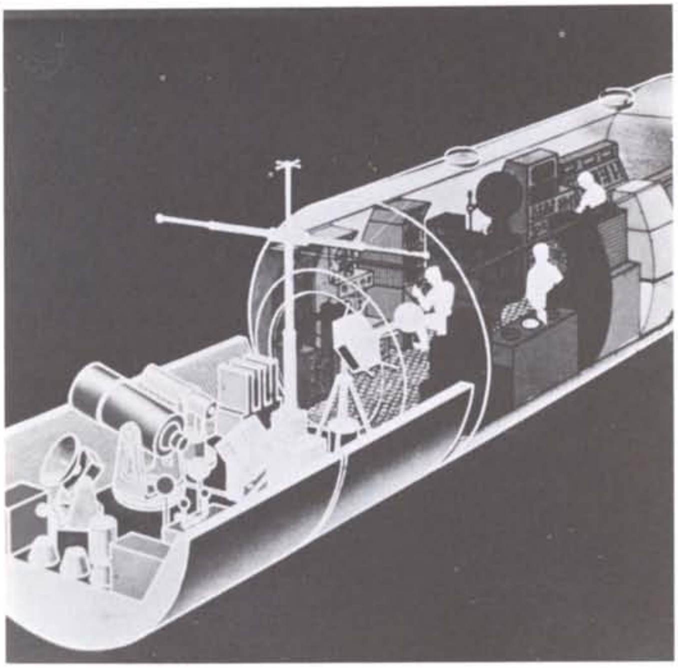
It is seen, then, that a journey out of the ecliptic is not just a crazy venture away from the plane of the planets toward 'empty' space. There is ample evidence that there is much to be seen and gained if only we can get there. We stand today like the European sailor-explorer of the Middle Ages who was confident of reaching riches in the Indies if only he could find his way. Like him, we could well stumble on a new world during the journey.

□

The Spacelab Instrument Pointing Subsystem

J. Colin Jones, Spacelab Project Office, ESTEC, Noordwijk, The Netherlands

Many of the scientific experiments to be performed on Spacelab missions require accurate and stable pointing significantly better than that provided by the Orbiter vehicle. The purpose of the Spacelab Instrument Pointing Subsystem (IPS), currently under development by Dornier System, is to provide a fine-pointing facility that satifies these requirements and is capable of adaptation to the diverse dimensions, weights, operating modes and interfaces of the many potential Spacelab instruments.



The requirements for the IPS come from a substantial fraction of the disciplines planning flights on Spacelab, i.e. astronomy, solar physics, high-energy astrophysics and earth observations. These disciplines investigate radiation over a large part of the electromagnetic spectrum, ranging from the far-infrared, through the visible and ultraviolet regions, up to X-ray and gamma-ray energies. They are all aiming for very high spectral resolution, and to this end will be making use of the unique capability of Spacelab to carry larger and more sophisticated instruments than could be flown at reasonable cost on conventional satellites. Sensible application of this instrumentation, however, dictates that it be pointed very accurately and with high stability towards the objects or regions under study.

Current planning for Shuttle missions in the 1980's indicates that some 25% of all Spacelab flights will be stellar astronomy or solar physics payloads, and the majority of these will include more than one instrument requiring accurate pointing. In this situation, the development of a standard pointing system of adequate performance, with the flexibility to adapt to re-use with widely varying payloads, offers the advantages of:

(i) significantly reducing the overall cost, as well as risk (for payload and Spacelab), incurred by developing separate pointing systems for each major instrument
(ii) providing a facility that has a standard well-tested interface with other Spacelab subsystems
(iii) improving the ease and reliability of integrating pointing experiments with Spacelab
(iv) providing identical interchangeable IPS units which can be integrated simultaneously with Spacelab subsystems
(v) providing a pointing capability on a short-lead-time basis for users technically or financially unable to develop one independently.

Having decided that it is appropriate to provide a single pointing facility for use by many payloads, the requirements of each of the instruments must be brought together and a refined set of requirements imposed upon the IPS design. Although the design definition of many potential Spacelab payloads is not very advanced, data on instrument requirements, as well as they are currently known, have already been tabulated by NASA and by ESA and these therefore represent the total envelope of all potential user requirements at this time. The task then is to determine whether it is possible to satisfy all of the requirements with one design at reasonable cost; if not an analysis must be made to minimise the number of payloads falling outside the capabilities of a real, achievable design. This activity has been pursued jointly by ESA and NASA during the past two years as the IPS design has evolved, and the current design concept now satisfies the majority of requirements.

PAYLOAD REQUIREMENTS

The physical properties of the potential payloads vary widely and this represents a considerable challenge in defining a payload-to-IPS mechanical interface and a payload-to-Pallet clamping mechanism for the launch and landing phases. Also,

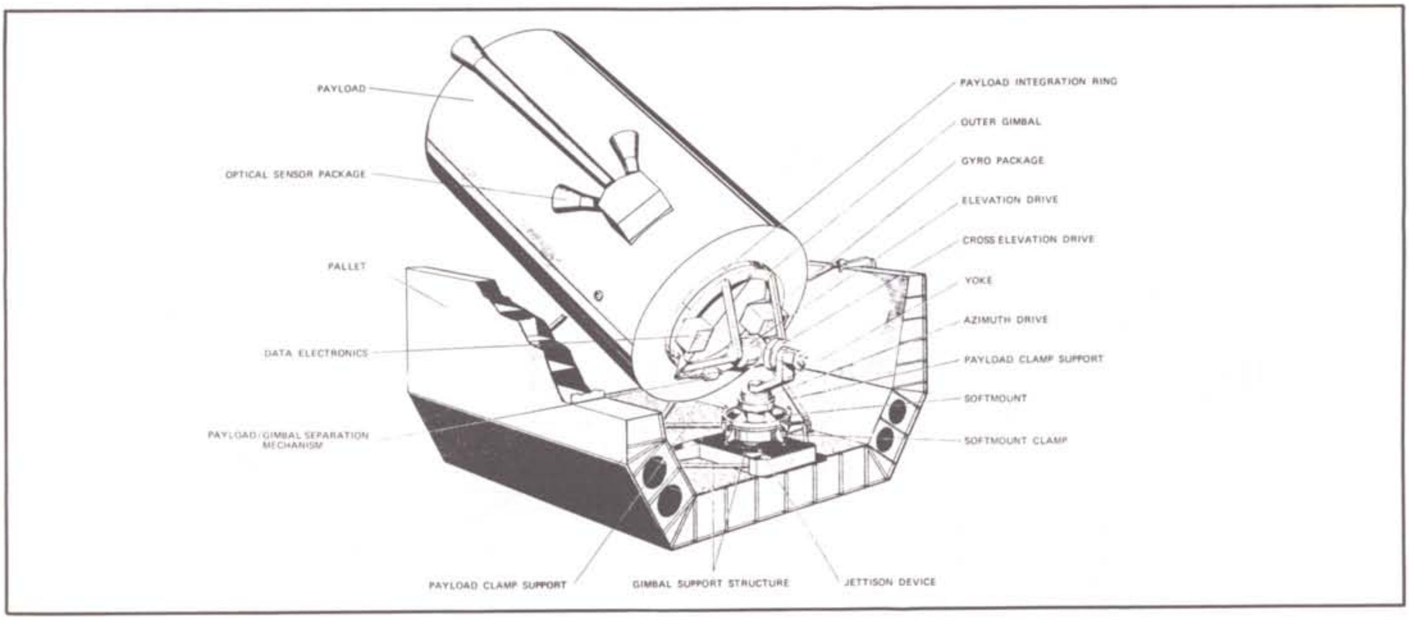


Figure 1 — Instrument Pointing Subsystem

since the payload may consist of a large single instrument, or a cluster of instruments, or a single, small rocket-class instrument, a similar wide diversity exists in the mass and moment-of-inertia parameters. This results in a need to be able to change the control system parameters over a wide range so that performance can be optimised for each mission. While acknowledging that more extreme cases for each physical parameter do exist, the IPS has been designed to accommodate, as a minimum, payloads of up to 2000 kg, 4 m long, and 2 m in diameter.

The pointing performance requirements of the payloads exhibit as much diversity as their physical characteristics, but the problem this presents to a pointing facility is no longer one of adaptation, but simply satisfying the most stringent requirement in each of the parameters (e.g. line-of-sight range, absolute pointing accuracy, pointing stability, etc.). There is, however, a danger in attempting to design to the worst-case requirements in each performance parameter on the assumption that they must be achieved simultaneously, since it is unlikely that any particular payload requires all of these performance parameters to be achieved simultaneously.

An equally difficult problem with pointing-performance parameters is the measurement and test arrangements necessary in 1 g to predict performance in orbit. Given the Shuttle-system scenario in which hardware is repeatedly returned to earth and available for repair, modification, and improvement, the exorbitant costs associated with complete zero-gravity simulation testing are judged to be unjustified. Hence the performance specification for the IPS has been written at two levels:

(i) 'design' values, intended to determine the sizing, quality, characteristics, etc. of IPS components such that the desired performance is achieved an orbit
(ii) contractual 'requirements', which are less stringent performance values to be verified during qualification testing in a 1 g environment.

Even with this bi-level approach, proof of all 'requirements' values by test is not always possible and computational analyses for interpolation and extrapolation of test results are still necessary. Complete verification of IPS performance must inevitably await orbital operation.

The operating modes of the different scientific disciplines vary considerably. Solar-astronomy instruments, for example, will require manual control capability, infrared astronomy and high-energy astrophysics instruments will require long periods of single-point or slow-scan mapping, while earth observations

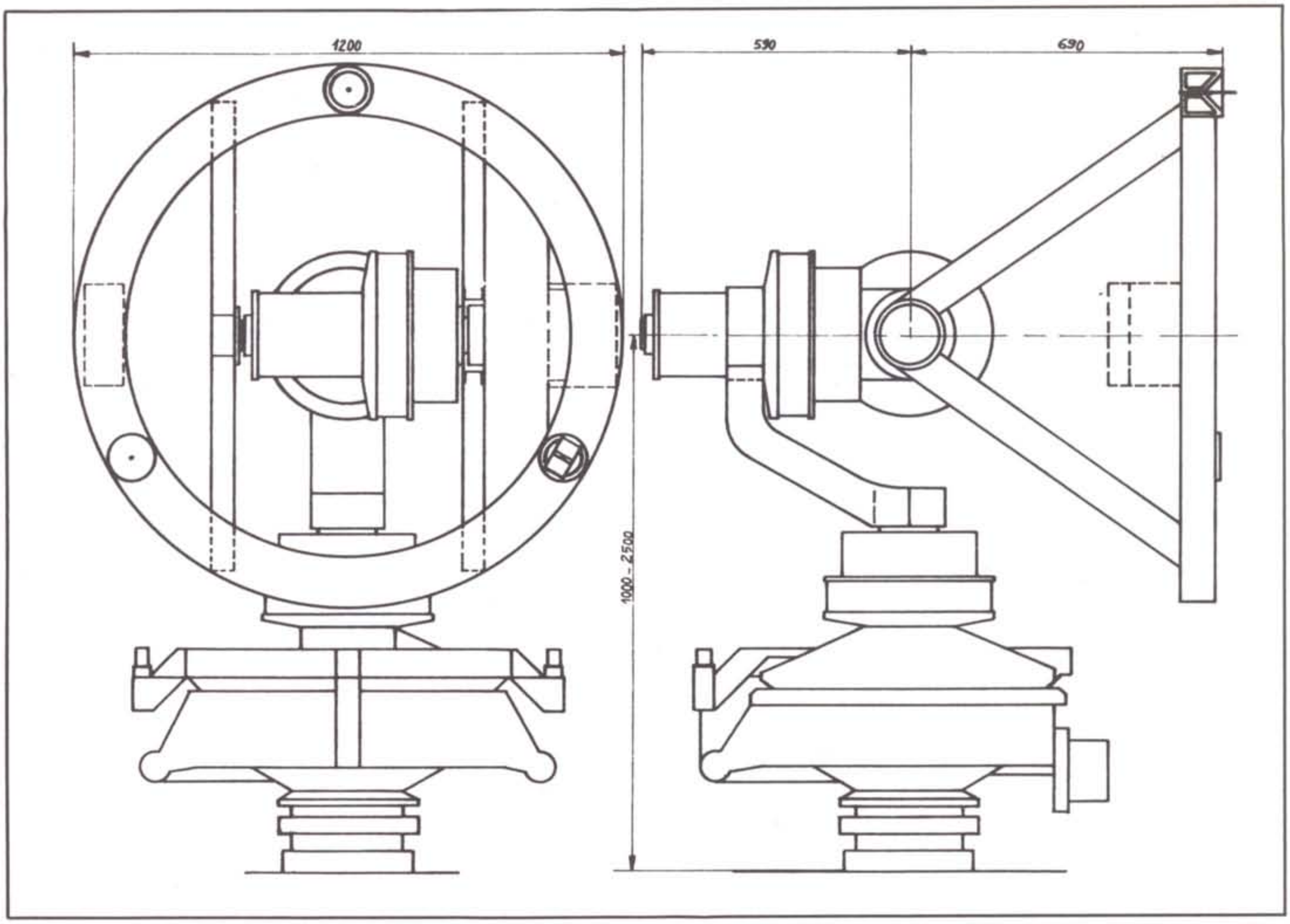


Figure 2 — Gimbal system

will require high angular rates and accelerations. To perform in all these modes requires the kind of flexibility only reasonably achievable with computer software, and for this reason maximum use has been made of Spacelab's computers. This not only allows an optimum set of IPS operating software for the particular type of scientific mission to be programmed in the computer before launch, but also allows changes to be made in orbit when unexpected events occur.

DESIGN

The pointing system evolved during the study phase to meet these diverse requirements is an unusual one. A three-axis gimbal system is mounted between one end of a payload and the Pallet, as shown in Figure 1. This technique offers a very compact system, able to accommodate the wide variety of physical payload dimensions, but in principle it is sensitive to disturbances of the Orbiter, because of the large offset between the payload centre of gravity and gimbal centre of rotation. To reduce this effect, the entire gimbal system rides on a 'soft mount' of springs and dampers, which acts as a mechanical filter for Orbiter disturbances, such as may occur in response to a crew member pushing off from a wall.

The movement of payload and soft mount under such disturbances may be visualised as follows: one can safely assume that the payload does not move instantaneously when the Orbiter is being displaced, but that in the first instance the soft mount tilts by whatever angle is required so that the pointing of the payload remains essentially undisturbed. The springs of the soft mount then tend to return to the undeflected state, pushing gently at the pivot point of the gimbal system to cause a motion with a characteristic frequency of a few hundredths of a Hertz.

Hence, the g-level of any disturbance is attenuated by several orders of magnitude by the soft mount. The attitude control loop of the IPS, the bandwidth of which is a few Hertz, then responds to this disturbance by trying to minimise the pointing error. The mount is so 'soft' in fact that the servo loop, while controlling and correcting a pointing error, does not displace or move the payload centre of gravity, but only the pivot point of the gimbal. In other words, the centre of rotation due to the servo loop control is the centre of gravity of the payload and not the pivot point, and the payload mounted on the IPS behaves almost like a free flyer.

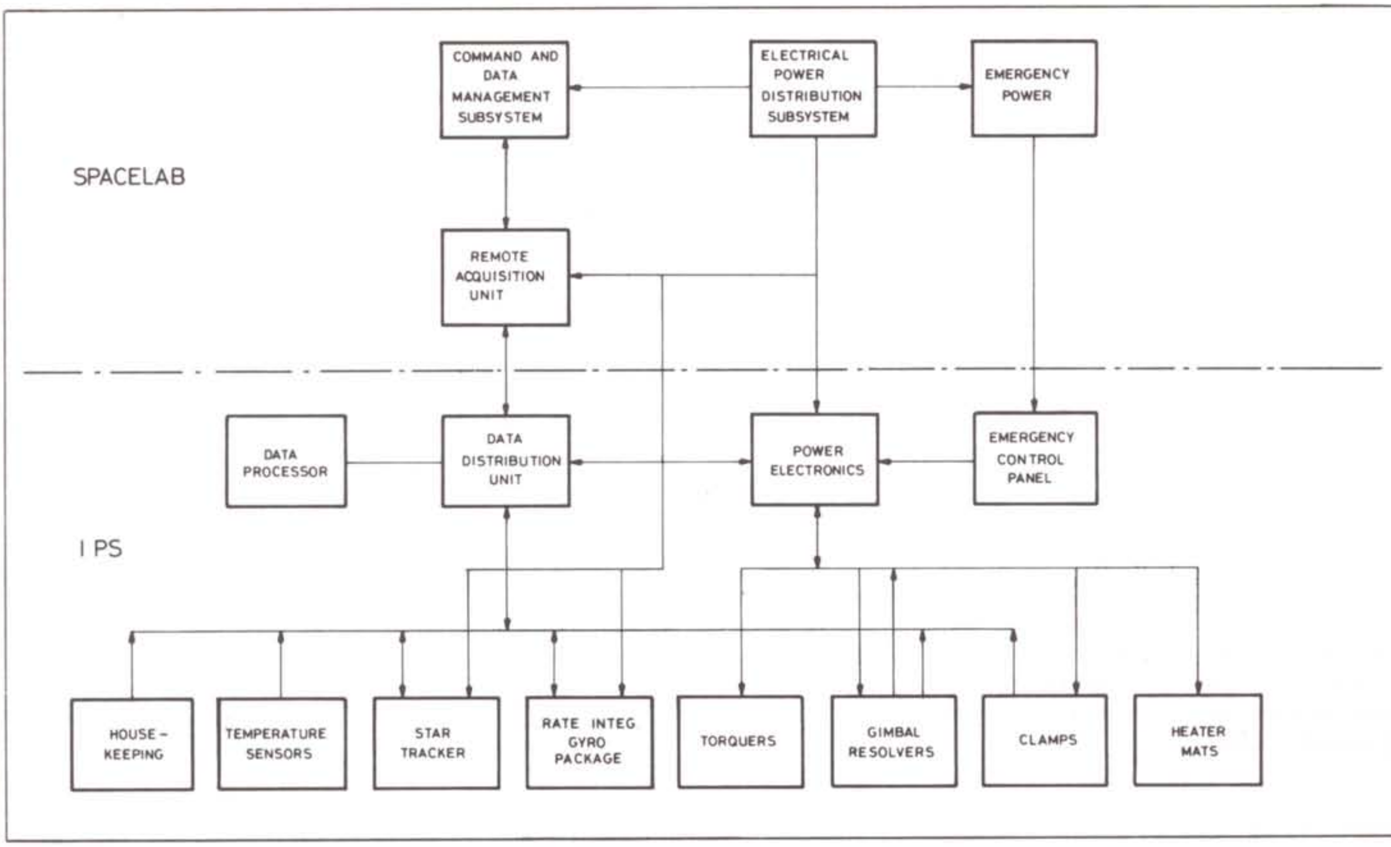


Figure 3 — Electronics block diagram

GIMBAL SYSTEM

The gimbal system, which represents the basic structural hardware of the IPS, is shown in Figure 2. The three identical drive units are arranged in such a way that their axes intersect at one point, the order of the axes from payload to Pallet being elevation, cross-elevation and azimuth. The gimbal structure itself is minimal, consisting only of an inner gimbal and an outer gimbal, to which the payload is attached by the payload-mounted integration ring. During ascent and descent the soft mount will be clamped to form a rigid connection between gimbal structure and Pallet. A replaceable column between the soft mount and support structure can be changed between missions to adjust the gimbal point of rotation for a particular payload.

PAYLOAD CLAMP SYSTEM

The clamp system is designed to hold the payload during ascent and descent at three points. From these three attachment points, the loads are distributed via struts which may be replaced to match individual payload dimensions, but the same clamp mechanisms will be used for all missions.

ELECTRICAL SYSTEM

Overall control of the IPS during normal operations is exercised from the Spacelab control console using the keyboard and CRT display of the Command and Data Management System (CDMS). Software packages covering all normal IPS functions, from pre-launch checkout through to pre-landing payload retraction, reference guide star tables and the planned observational sequence, are stored in the CDMS. This provides the necessary flexibility for the different missions and also allows the operator to modify planned operations during orbit to achieve an improved scientific return.

The closed-loop stability control functions are performed in a dedicated data processor, shown in the electronics block diagram, Figure 3.

Special emergency power functions are provided as part of the power electronics and are located in a dedicated IPS emergency control panel. These functions consist of an alarm to inhibit the gimbal system from any angular range or rate outside the allowed zone, controls to allow the payload to be returned to the stowed position under manual control, and as a final resort the jettisoning of the complete IPS/payload system if a safe (clamped) landing configuration cannot be achieved.

ATTITUDE SENSORS

Stabilisation data are provided by a gyro package containing three orthogonal gyros and one skewed gyro for redundancy.

The pointing-error signal is derived from an optical sensor package which, for a stellar mission, consists of three identical fixed-head star trackers, one bore-sighted with the payload for lateral axes data, the other two skew mounted at 12.5° or 45° to provide roll data. For a solar mission, the bore-sighted star sensor is replaced by a sun-sensor, and the skew angle of the two roll-star sensors is 45°.

The control system can also be configured to accept stabilisation and pointing-error data from the payload, for those earth-pointing missions requiring high pointing accuracy, since no earth sensor will be provided with the IPS. Less accurate earth pointing can be achieved by programmed scanning under gyro control only.

POINTING PERFORMANCE

The performance requirements of the payloads intending to use the IPS are generally expressed in terms of pointing accuracy and pointing stability. These terms must be made more definitive, however, before a real hardware design can be arrived at, since the sources of these errors are quite different. This is particularly true when a manned vehicle is involved, as all crew movement generates pointing disturbances. A subdivision of the types of error affecting IPS performance is given in Table 1.

The required value of bias error (~ 1 arc sec), is approaching that of the optical sensor itself and cannot be achieved even by the most sophisticated mechanical mounting techniques. It is necessary therefore to perform an in-orbit measurement of the alignment error between the experiment line of sight and the bore sight of the IPS optical sensor. There exist basically two possible methods of doing this:

(i) The experiment optics itself can be used from time to time to observe the same star field as the IPS optical sensor, and any relative displacement of the fields of view can be measured and inserted into the IPS software in the CDMS.

or

(ii) The experiment can introduce an alignment beam into the field of view of bore-sighted star sensor, representing simulated star images. The IPS software then inserts the positional data of these images as an offset in the IPS software control equations.

The manner in which payload instruments will utilise these alignment methods depends upon their particular optical configuration.

The two major sources of disturbance stability error are man motion and Orbiter thruster firings. The nominal thrust impulse of the Orbiter attitude control system (2 X 25 lb thrust) has been found to cause a smaller error than a 'typical' wall push-off by the crew and therefore a standard man motion force originating in the Orbiter cabin has been used as the basis for the calculation of disturbance stability error. However, the resulting peak disturbance error varies considerably with:

- payload mass and inertia
- IPS location in Orbiter payload bay
- angles between disturbance direction, experiment line of sight and column of gimbal system.

Hence the performance to be expected for a given payload must take into account the characteristics of that payload and its viewing configuration on the Spacelab Pallet. Simulations of more typical configurations give values of the order of tenths of arc-seconds for disturbance stability error.

TABLE 1

Type of error	Characteristic	Cause of error
Bias Error	Long-term error between actual experiment line-of-sight and desired celestial direction	Star tracker accuracy, alignment, thermal/mechanical distortions
Quiescent Stability Error	Short-term jitter about mean attitude, without disturbance	Measurement noise, bearing friction/hysteresis
Disturbance Stability Error	Peak error occurring as result of disturbance of vehicle	Crew motion, Orbiter thruster firings

SCANNING AND TRACKING

In addition to inertial fine pointing, the IPS is also well suited to scanning, and even earth-pointing. The generation of the ramp scan (a symmetric saw-tooth scan) requires short bursts of very high torque, whereas for a parabola scan (series of parabolic sections) the torquers are required to produce a low torque continuously. Parabola scanning is therefore the optimal method of utilising the limited torque capability of IPS for large payloads requiring relatively swift scan motions, although the ramp scan may be generally preferred from a payload data viewpoint because of its linearity. A compromise to achieve scan linearity with limited torque capability would be a mixture of parabola sections joining ramp sections.

The IPS is also capable of tracking a fixed point on the earth's surface, in that the proper rate stabilisation and angular acceleration can be provided. This is valid even for the nominal design payload of 2000 kg at the lowest Shuttle orbital altitude of 180 km.

POTENTIAL FOR IMPROVED PERFORMANCE

Certain possibilities for further improving the performance of the IPS can already be conceived, although the technical means for implementing them may not be available for some years to come.

The optical sensors are essentially the only remaining source of bias error, and the error could be further reduced with more precise star or sun sensors. In certain cases it may be possible for the payload instrument itself to act as the star-tracker, providing attitude error data directly to the IPS software.

A major source of quiescent stability error is noise in the optical and gyro sensor signals, and better component performance would result in a corresponding improvement in IPS performance. The advent of laser gyroscopes will undoubtedly lead to improvements here, but ultimately the limitations imposed by the hardware of the drive assemblies will remain. A further improvement in stability would then require image-motion compensation within the payload instrument.

CONCLUSION

There are inherent dangers in attempting to design a facility for many different users. On the one hand, if every last detail of every user is provided for, the facility will be over-designed at the very least, and at the worst unrealisable within the required budgetary and schedule constraints. On the other hand, not satisfying a particular requirement may cause a significant degradation of the scientific output of the instrument, and a few such cases could lead to an IPS of little use to any user. Clearly, then, close co-ordination and co-operation between the IPS designers and its numerous potential users in Europe and the USA has been necessary from an early stage of definition. The result is an IPS design which satifies the vast majority of user requirements, which can be built and delivered for the second Spacelab flight in 1980, and which will be available for use on a co-operative basis during subsequent missions by all Spacelab users. □

Project Cost Control within the Agency

W. Brado, Contracts Department, ESA, Paris

H. Gehriger, Project Control Division, ESA, Paris

Space projects are both costly and complex; they commonly involve innovation and therefore uncertainty and risk. Within Europe, they are funded by public money and executed by networks of industrial contractors normally spread throughout the continent. In such a situation, if the customer wishes to make certain of value for his money he must operate a thorough, firm and systematic cost-control procedure to ensure that his requirements are carried out within the funds earmarked for them, and to permit detection of potential cost overruns early enough for his project manager still to have room for manoeuvre in re-assessing the overall position. This article merely outlines some of the major features of ESA's cost-control methods and techniques, a complete elaboration of which is beyond the scope of the Bulletin.

PHASED PROJECT PLANNING

When a project involves innovation and development, uncertainty and risk arise and these pose major threats to project completion within its financial ceiling. In the initial stages, the degree of uncertainty and risk is inevitably somewhat nebulous; it becomes more and more apparent as the project proceeds. A much stronger grip on the risks and their financial consequences can be gained if, instead of placing contracts for the complete project at the concept stage, the project is broken down into separate phases, each with its own distinct contractual commitments. In this way each phase can be planned, reoriented and costed in the light of the extra definition obtained during the previous phase. In the last resort, the customer retains the option of terminating his commitments at the end of any phase, should it become apparent that the eventual cost to completion cannot be kept within his available financial resources.

Major ESA projects are normally broken down into four phases:

Phase A – preliminary analysis, preparatory studies, feasibility assessment
Phase B – system definition
Phase C – design and development
Phase D – production of the operational system (hardware and software).

With satellite projects however, involving a great deal of development and only a limited number of flight models, it is not really practicable to make a strict separation of Phases C and D, because of their many overlapping and interdependent activities. Consequently, they are usually lumped together as Phase C/D, and the Agency's contracting and monitoring practices follow suit.

PHASE A

Phase A is exploratory and provides preliminary plans and cost estimates for the subsequent project phases. Its purpose is to enable the Agency to take a considered decision as to whether or not to pursue the project to completion. If that decision is positive, the project is formally taken into the Agency's development programme, is institutionalised within the Agency, and an Agency Project Manager is appointed.

Phase-A contracts are usually awarded on a firm fixed-price basis so that the cost control for this phase itself is elementary. Nevertheless, the Agency's cost-control effort is firmly associated with Phase A in order to ensure that it will lead to the development of effective control systems during Phase B. Cost control must start early in Phase A if the full benefit of its potential is to be achieved in the subsequent phases.

PHASE B

The system definition contract as such usually involves little uncertainty or risk and can normally be placed on a fixed-price basis. In this event the cost control is largely effected during the tendering and contract-negotiation stages.

The Invitation to Tender (ITT) requires the tenderer to provide sufficient information on his planning, scheduling, manpower use and cost data to allow the Agency to assess the viability and validity of the proposal. Cost control then relies on a careful scrutiny of the estimated services, materials and efforts in relation to the scope of the work. Rates, overheads and profits are examined and adjusted as necessary. These examinations enable the Agency to negotiate the final fixed price and to adjust the contractor's proposals accordingly.

If, exceptionally, a Phase-B contract involves a high degree of risk and uncertainty, it is placed on a cost-reimbursement basis and in addition to the negotiations already mentioned, cost monitoring and control during execution is carried out in the manner described below in relation to Phase C/D cost-reimbursement contracts.

PROJECT: XYZ		WORK PACKAGE MANPOWER AND COST PLAN										WP TITLE: PROTOTYPE PAYLOAD	
ITT/RFP/RFQ No.: AO/5727		CURRENCY: DM				DATE OF ISSUE: 75.07.01						WP NUMBER: 70150	
		NETWORK START EVENT:				NETWORK END EVENT:							
TYPE OF EFFORTS	LABOUR RATES	PERIODS FROM CONTRACT AWARD										TOTALS	
		1	2	3	4	5	6	7	8	9	10	HOURS	
LABOUR EFFORTS													
Management & Administration	50.00	400	450	500	600	600	650	500	400	200	100	4 400	
Engineering & Scientists	40.00	300	300	400	500	600	700	700	500	500	500	5000	
Drafting & Documentation	36.00	150	150	150	150	200	200	150	150	150	150	1600	
Manufacturing	40.00	100	100	200	200	200	200	200	200	100	100	1600	
Others (e.g. Technicians)	35.00	50	50	100	100	100	100	100	50	50	50	750	
TOTAL LABOUR EFFORTS (Manhours)		1000	1050	1350	1550	1750	1650	1650	1300	1000	900	13,350	
												LC	AU
LABOUR COST													
Management & Administration		20,000	22 500	25,000	30,000	30.000	32.500	25,000	20.000	10,000	5,000	220,000	72,173
Engineering & Scientists		12,000	12,000	16,000	20,000	24,000	28,000	28,000	20,000	20,000	20,000	200,000	65,612
Drafting & Documentation		5,400	5,400	5,400	5,400	7,200	7,200	5,400	5,400	5,400	5,400	57,600	18,896
Manufacturing		4,000	4,000	8,000	8,000	8,000	8,000	8,000	8,000	4,000	4,000	64,000	20,996
Others (e.g. Technicians)		1,750	1,750	3,500	3,500	3,500	3,500	3,500	1,750	1,750	1,750	26,250	8,612
TOTAL LABOUR COST		43,150	45,650	57,900	66,900	72,700	79,200	69,900	55,150	41,150	36,150	567,850	186,289
NON-LABOUR COST													
MATERIALS		1,000	1,500	10,000	20,000	50,000	50,000	50,000	40,000	40,000	10,000	272,500	89,396
Hi-Rel Electronic/Electromech. Parts													
Hi-Rel Mechanical Parts													
Materials Other Than Hi-Rel Parts													
INTERNAL SPECIAL FACILITIES		500	500	500	750	1,000	1,000	1,000	1,000	1,200	800	8,250	2,706
EXTERNAL MAJOR PRODUCTS		100	500	1000	1200	1,500	2,000	5,000	5,000	5,000	3,900	24,200	7,472
EXTERNAL SPECIAL EQUIPMENT		200	500	800	1000	2,000	5,000	2,000	4,500	3,080	1,600	22,000	7,217
EXTERNAL SERVICES				2800	2000	5,000	5,000	5,000	4,000	1,000	500	24,500	8,037
TRAVEL & SUBSISTENCE		2000	2000	2500	2500	3,000	2,500	2,500	2,000	1,000	500	20,500	6,725
PACKING & SHIPPING								1,000	2,000	2,000	2500	7,500	2,460
OTHERS (Specify)													
TOTAL NON-LABOUR COST		3,800	5,000	16,800	27,450	62,500	65,500	68,500	58,500	53,200	18,300	379,550	124,513
TOTAL COST (LC)		46,950	50,650	74,700	94,350	135,200	144,700	138,400	113,650	94,350	54,450	947,400	
TOTAL COST (AU)		15,402	16,616	24,506	30,952	44,353	47,470	45,404	37,284	30,952	17,863		310,802

NOTES: ESTIMATES ARE IN MANHOURS PER PERIOD
USE STANDARD LABOUR RATES (INCLUDING O/H, SOCIAL BENEFITS, R&D, G&A)
EXCLUDING PROFIT AND RISK

Prime Contractor : SPACEMEC
Sub-Contractor : NIELSA

Typical work-package manpower and cost plan.

PREPARATION OF THE PHASE C/D CONTRACT

The major cost of a satellite project arises from Phase C/D — the main development contract (some 20–40 million US Dollars for a scientific satellite). It is at this stage that cost-control procedures have to be applied in depth and detail. The Agency's Invitation to Tender therefore specifies in detail the information to be supplied in the tender and the project-control procedures to be followed during development and production of the operational system.

The secret of effective cost control in projects of this size and complexity is to break down the work into a series (usually several hundreds) of well-defined task- or product-oriented packages known as 'work packages' which together constitute the entirety of the contract work. This breakdown of the project into packages is known as the WBS (Work Breakdown Structure) and is vital to effective control. By applying such control to these much more manageable units, the whole contract is effectively controlled. For this purpose, the invitation to tender for Phase C/D requires, among other items,

- the development of a WBS in accordance with the Agency's guidelines
- a description sheet for each work package showing its scope, nature and quantity of manpower needed, and cost.

During negotiation of the final contract particular attention is devoted to incentive clauses. The incentive scheme practised by the Agency is regarded as a highly effective tool for motivating contractors to increased performance and cost-effectiveness by enabling them to obtain an above-average profit ratio from timely delivery, cost savings, and good technical performance. Conversely, contractors are penalised in the event of less than nominal performance in these areas. This conventional scheme allows reward to the contractor only at the conclusion of the work. In some contracts, however, an alternative 'award fee system' has been introduced, which allows a contractor to be rewarded periodically during the execution of the contract on the basis of his performance assessed against predetermined criteria, and this is expected to enhance even further the motivation for good performance and cost-effectiveness.

CONTROL OF THE PHASE C/D CONTRACT

The basic unit for specification, evaluation and control is the

DATE : 76.07.06

Project : XYZ

Contractor : SPACEMEC

Reporting Period : from : 76.06.01 to : 76.06.30

Responsible Officers : K. SCHMIDT

Labour Categories*
(as approved by ESA)

Work Package No.: 70150 Title : PROTOTYPE PAYLOAD

	Planned Hours	Actual Hours	Deviation Hours
Management and Administration	600	570	- 30
Engineering and Scientists	1350	1405	+ 55
Drafting and Documentation	250	260	+ 10
Manufacturing	725	700	- 25
Others, e.g. Technicians	300	280	- 20
TOTAL			

Work Package No.: Title :

*The Contractor shall use his normal internal labour categories if unable to conform to this breakdown.

Montly manpower status report.

PROJECT XYZ	PHASE C/D	W.P. REF.: 22218
W.P. TITLE STRUCTURAL TEST MODEL CONTRACTOR SPACEMEC SUBSYSTEM STRUCTURE START EVENT UL05 END EVENT UL32 W.P. MANAGER K.WEISS	 SCHEDULED DATE 75.04.01 SCHEDULED DATE 76.01.06	SHEET 1 OF 1 ISSUE REF. A ISSUE DATE 74.04.16

INPUTS REQUIRED FOR THE WORKPACKAGE

- Specification SS-A412BO-0221A (Module structure 5/5 Spec.)
- XYZ Statement of Work and System Requirements
- Manufacture and Assembly Plan
- Test Plan - PL-A6000-0187
- Test Spec. - SY-A30100-0313
- Phase C/D System/Subsystem Schedule - PL-A12000-0207

OUTPUTS FROM WORK PACKAGE

- Manufacture and Assembly Documentation
- Structure subsystem inputs to structural test procedure
- Structure equipment as listed in attached "Item List"

TASKS INCLUDED

Efforts and material required for manufacturing, assembling and testing the structural test model and acceptance by the Prime Contractor.
Testing activities shall include:

- dimensions, alignment, physical measurements
- static load tests
- model survey and vibration test
- ultimate load and mission life cycling
- acoustic noise test.

TASKS SPECIFICALLY EXCLUDED

Special facilities, test equipment and tooling covered by Work Package 46000. Tools for handling, transportation and storage. Manufacture of hatches, pallet pylons and integral floors.

RESTRAINING INTERFACES

Availability of test facility during August 1975.

Work package description

work package. The Agency endeavours to negotiate as many work packages as possible at fixed price, but usually a number have to be accepted on a cost-reimbursement basis. As industry gains more experience, it can be expected that a greater percentage of the work will be brought within the fixed-price bracket. It is the cost-reimbursement element of the contract that calls for elaborate and vigorous cost control. It is in this area, with its inherent uncertainty and risk, that potential cost overruns are likely, which is why the contractor is reluctant to specify a fixed price. Without an effective control system, the embarrassment of significant cost overrun, if it does occur, often comes only at or after the end of the contract. The objective of cost control is to reveal overrun tendencies early enough to be able to take corrective action.

MANPOWER AND COST MONITORING FOR COST-REIMBURSEMENT WORK PACKAGES

The great bulk of expenditure under a Phase C/D contract goes on manpower, and this is subject to special monitoring, which relies essentially on routine periodic (usually monthly) and speedy reporting by contractors on the use of their resources. At the end of each period the contractor must telex to the Agency details of all manhours (broken down into the agreed categories of labour and assigned to the various work packages) expended during the period. These data are checked against the approved baseline cost plans set out in the contract and any deviations, actual or potential, are identified. On this basis immediate steps can be taken with the contractor to clarify any manpower overruns and to initiate corrective action. Speed of contractor reporting is essential to allow the Agency to introduce remedial steps at a time when the ongoing work and resources involved can still be redirected.

Three to four weeks after the telex report, the contractor is required to supply a comprehensive cost/price report in the pattern of the cost breakdown set out in the contract, showing the incremental and cumulative planned and actual costs as well as the commitments. It is scrutinised by the Agency for:

- correctness of arithmetic
- relation to plan
- appropriateness of expenditure in relation to work performed
- correctness of labour categories, rates and cost structure.

Where appropriate, further details are requested by the Agency from the contractor and, if necessary, on-site examinations are carried out.

Trends are determined and predictions made about possible cost overruns or underruns which might occur at the end of the contract. Potential problem areas can then be identified at an early stage and corrective action initiated.

RE-EVALUATION OF COST TO COMPLETION

A key requirement in the control of cost-reimbursement work is regular re-evaluation in detail of the cost to completion. During this exercise, usually carried out six-monthly, the contractor re-examines the work and associated costs required to complete outstanding work packages. The results are added to the actual costs to date for comparison with the originally-agreed cost plan. It is usually at such a stage that potential cost overruns become evident. The details are reviewed jointly by the Agency and the contractor, and suitable corrective actions are arranged.

CHANGE CONTROL PROCEDURE

In development contracts, changes in both technical content and scope of the work during execution of the contract cannot be avoided. As such changes can have chain-reaction consequences and the financial implications can be serious, they must be carefully and systematically monitored and controlled.

The Agency has a well-established formal system for the processing of changes and this is defined within the contract documents. Contractors' proposals for changes have to be fully documented, including details of estimated financial impact, and must be formally approved by the Agency before implementation. Whether the financial consequence of a change has to be accepted by the Agency or by the contractor is decided by criteria already set out in the contract.

EARLY IDENTIFICATION OF PROBLEMS

To make a correct interpretation of a contractor's expenditure to date, it must be evaluated in relation to the technical and schedule progress to date and the effects of current or potential problems. This is achieved by:

- regular reporting of technical progress by the contractor usually on a monthly basis, highlighting special areas of interest or problems
- network/schedule reporting twice a month
- reviews, meetings and on-site inspections
- reporting of special situations within 48 hours
- continuous close contacts between Agency and contractor staff
- implementation of the relevant project-management and project-control procedures and requirements by the contractors.

ON-SITE INSPECTION

For even greater visibility of project progress and contract execution, the Agency carries out on-site inspections at the contractor's premises. These may be in the form of spot checks or long-period visits and in some cases the Agency places a resident representative on site. These means enable the Agency to:

- verify the accuracy of the contractor's reports and invoices
- check that the Agency's funds are used effectively
- ensure that the Agency's directives and requirements are observed
- obtain continuous information about the status of the project, with special emphasis on problem areas
- provide expertise and advice to the contractor, as needed.

WINDING UP OF DEVELOPMENT CONTRACT

Final Cost Verification

After termination of the contract, a final verification of the expenditure on elements not covered by a fixed price is carried out. Any necessary rectifications and adjustments are made.

The rates and overheads applied throughout the contract are verified and the application of the price variation formulae checked.

Final verifications also include checking of the direct costs charged to the Agency. Past final-cost verifications have, for example, revealed:
- costs already charged under the fixed price part of a contract again charged under the cost-reimbursement part
- costs already charged under overheads entered into the accounts as direct costs to be reimbursed by the Agency
- travel costs improperly charged to the Agency.

Calculation of Incentive
Based upon the assessed technical performance, conformity to schedule, and cost performance, the incentive fee is calculated and, if appropriate, credited to the contractor.

Final Invoicing and Payments
Finally, after the Agency has ensured that all appropriate claims for expenses for the contract have been processed and checked, the final invoicing and settlement are effected.

Statistical Data
To build up a solid basis for the further development of its own cost-estimating capability, the Agency collects and collates statistics on manpower and cost data. The development of a comprehensive data bank is under study and will be extended by taking into account comparable data from space projects of national agencies. This build-up of experience will continually improve the Agency's cost effectiveness during price negotiations.

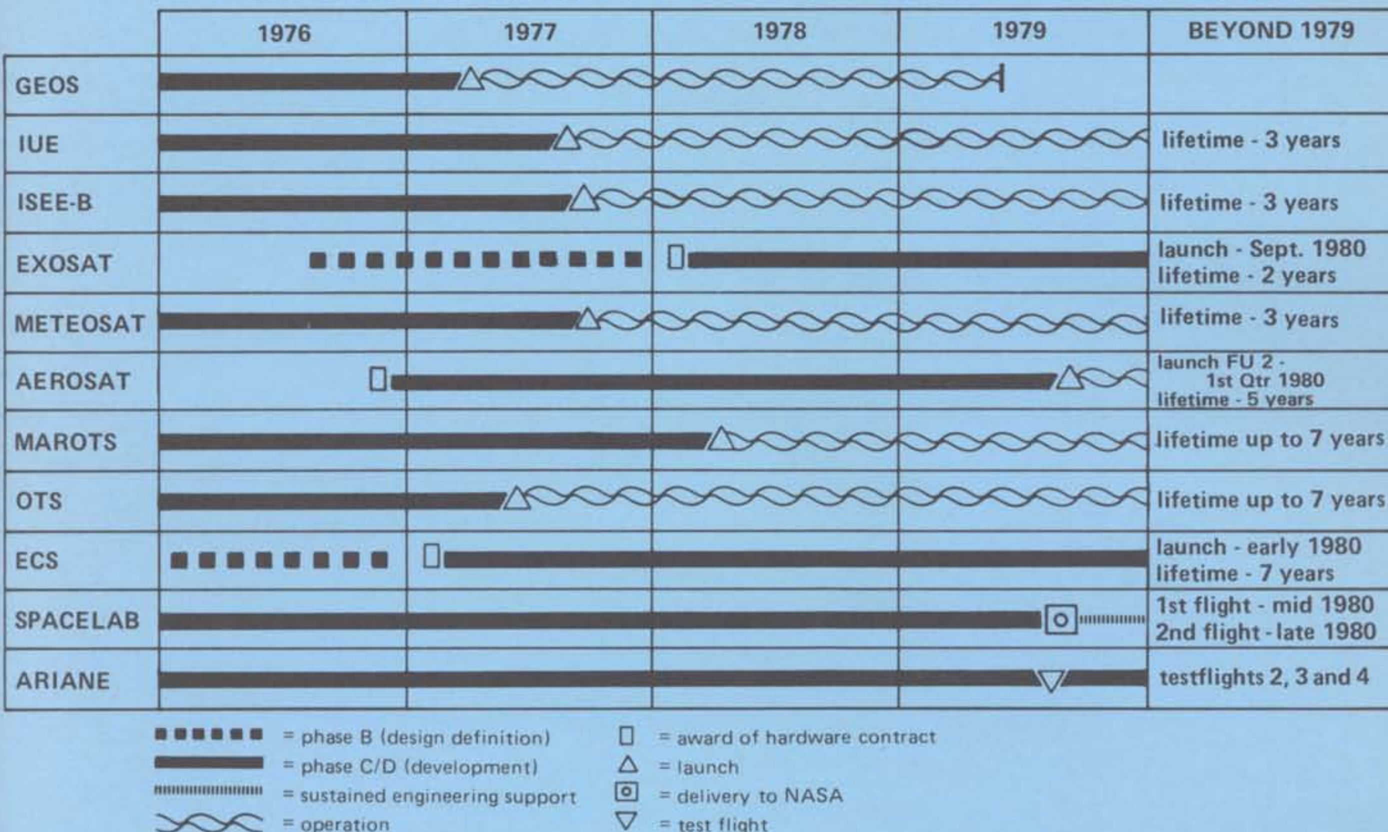
CONCLUSION

The cost-control and project-monitoring activities of the Agency encompass a broad spectrum of methods and techniques. Each procedure has been designed for a specific purpose and has its own benefits for the Agency. In addition, these individual procedures when integrated into a comprehensive project-control system lead to a synergetic effect which results in a greater effectiveness than if they were applied individually and in isolation.

The key feature of the ESA system lies in the enforced evolution of project visibility. The contractors are obliged systematically to carry out dynamic planning and budgeting, the precision and depth of which steadily increases with the proximity and complexity of the next project phase. After scrutiny and negotiations, these planning documents eventually form credible baselines which serve as the reference for monitoring the contractor's progress and costs as well as for the detection of deviations and trends. This allows Project Managers to alert higher ESA Management at an early stage of problem emergence and to take corrective action whilst there is still a reasonable chance of doing so with success. The system, properly and consistently applied, provides the foundation for achieving cost-effectiveness through project transparency, fairness and the proper conduct of business. □

Projects under Development
Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (as at July 1976)



GEOS

Qualification model
The spacecraft has completed electromagnetic-compatibility tests at BAC, Bristol (April), DC magnetic-cleanliness tests at IABG, Ottobrunn (May) and antenna-pattern measurements at MBB (June). A formal review of the EMC test results has shown that performance was better than specification, and the magnetic tests have shown a residue of 0.3 gamma (specification was 0.5 gamma maximum). The spacecraft is now at ESTEC for mechanical testing.

Flight model
After the functional tests on the integrated spacecraft, further success was achieved in the EMC chamber at Bristol, as cleanliness proved to be even better than that of the qualification model. The flight attitude-measurement system which had become available meantime was then substituted for the prototype unit, so bringing the hardware status to all-flight except for three power converters. This spacecraft too is now at ESTEC, for environmental testing.

Propulsion system
Two of the acceptance batch of apogee motors have been fired, with satisfactory results. This completed the major hardware activities for the programme; a formal review will take place in September.

Ground segment
The GEOS ground station at Michelstadt is nearing acceptance and the spacecraft suitcase model is being used to test out its subsystems. Development of the data-processing software for orbit/attitude determination and control is complete to a large extent and work is going on to complete basic software packages for spacecraft control and experiment data processing.

IUE

Solar array
The flight solar array has successfully completed its extensive series of acceptance tests at ESTEC. The arrays have subsequently been shipped to Goddard Space Flight Center, where mating and integration with the flight spacecraft will take place in July.

Ground system
The European Ground System Design Review was held in ESOC on 18–19 May 1976. ESA, NASA and SRC teams took part in the review, the timing of which was chosen to coincide with the finalisation of the design phase by the station integration contractor. A number of detailed recommendations were made and these are presently under active review.

In May, the Industrial Policy Committee authorised the placing of a contract with Bendix for the provision of two Experiment Display Systems identical to those procured by NASA for the US ground station. This commonality of hardware will ensure that the NASA-supplied software can be easily incorporated into the European stations.

Installation of the computer system began in May and is continuing satisfactorily.

ISEE

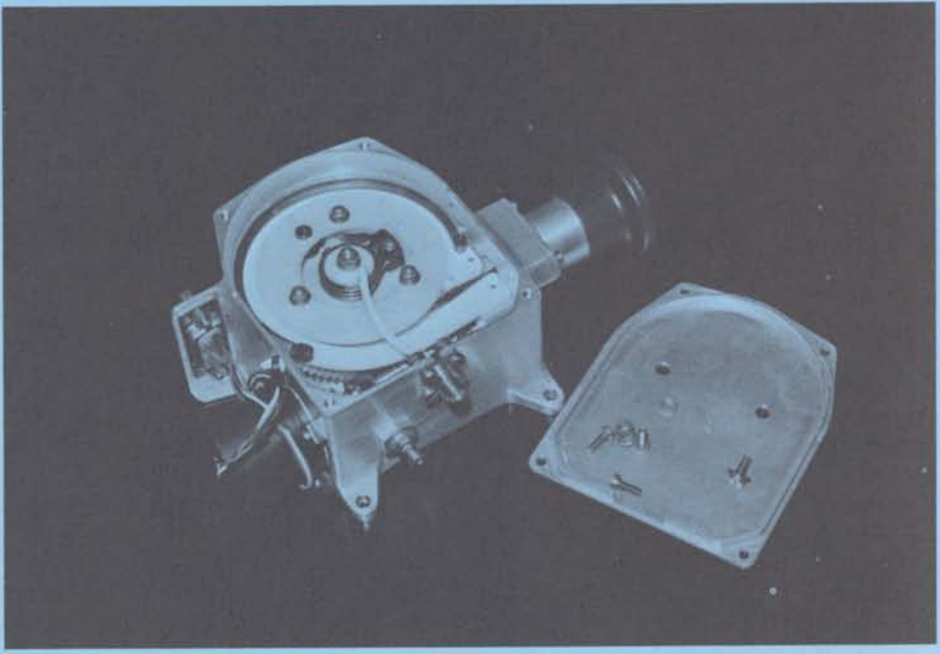
ISEE-B spacecraft

The work on the integration model of the spacecraft (which serves many of the roles of the prototype in a three-model programme) is continuing and the majority of the subsystems have now been incorporated and checked out.

Although there were further delays in the delivery of the power and telecommunications subsystems, it is anticipated that these will have been compensated for by the completion of experiment integration in late August. To achieve this, there has been an intensive effort by the integration team, involving both a longer working day and a six-day week. Careful scheduling has been necessary to accomplish this whilst respecting the labour laws of the countries involved.

In parallel with the technical work, managerial and contractual liaison continues. Detail points on the prime contract are being cleared preparatory to the final signature, envisaged for July.

ISEE-A spacecraft
The NASA ISEE-A Project Team, located at Goddard Space Flight Center, have commenced integration of the flight prototype spacecraft. The

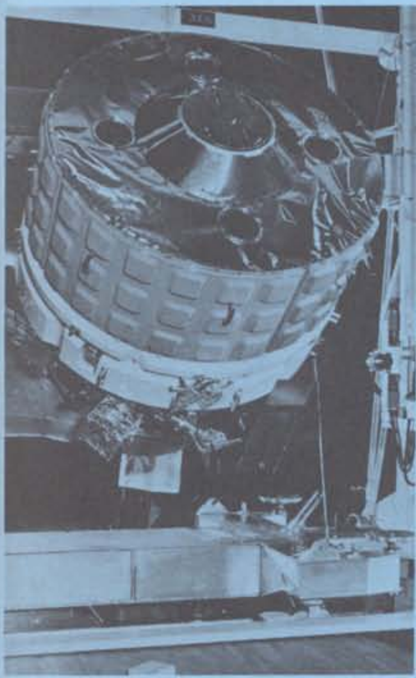


ISEE-B long-wire-boom deployment unit, designed and manufactured by Sener (Spain). It has just successfully completed qualification testing.

Un mécanisme de déploiement des bras filaires d'ISEE-B conçu et fabriqué par Sener (Espagne); il vient de subir avec succès ses derniers essais de qualification.

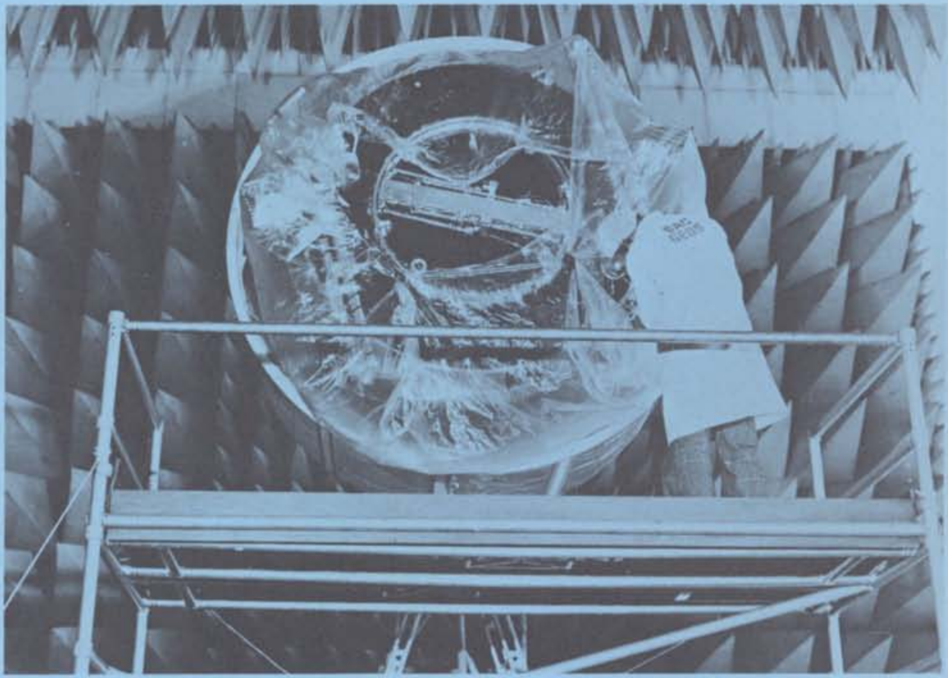
structure is now complete and the wiring is under way. The electrostatic-cleanliness problem encountered with the omnidirectional antenna system has now been overcome by means of a redesign. The work continues generally on schedule.

Scientific payload
Most of the integration model experiment packages are now complete and have successfully passed their qualification/acceptance tests. Only one experiment is slightly behind schedule and it is not anticipated that this will cause a delay in the overall spacecraft timetable.



Le modèle de qualification au cours des essais magnétiques à Ottobrunn.

Qualification model during magnetic tests at Ottobrunn.



Préparation des essais de diagramme d'antenne sur le modèle de qualification.

Preparation for antenna-pattern tests on qualification model.

GEOS

Modèle de qualification

Ce modèle du satellite a été soumis aux essais de compatibilité électromagnétique à Bristol au mois d'avril, aux essais de propreté magnétique CC (EMC) dans les installations de l'IABG à Ottobrunn en mai et les mesures de diagramme d'antenne ont été effectuées chez MBB au mois de juin. Les résultats des essais EMC ont fait apparaître une performance supérieure à celle spécifiée, les essais magnétiques révélant de leur côté en résidu de 0,3 gamma (la spécification était de 0,5 gamma au maximum). Le satellite se trouve actuellement à l'ESTEC pour y subir des essais mécaniques.

Modèle de vol

Après les essais fonctionnels effectués sur le satellite intégré, un nouveau succès a été enregistré dans la chambre EMC de Bristol, la propreté se révélant être supérieure même à celle du modèle de qualification. Le système de mesure d'attitude 'de vol', devenu entre temps disponible, a été substitué à l'unité prototype de sorte qu'à l'exception de trois convertisseurs de puissance, tous les équipements sont maintenant aux normes de vol. Ce modèle se trouve lui aussi actuellement à l'ESTEC pour y subir des essais d'ambiance.

Système de propulsion

Deux des moteurs d'apogée du lot soumis à recette ont été mis à feu avec succès. Ainsi ont pris fin les principales activités liées aux matériels pour ce programme qui fera l'objet d'un réexamen officiel en septembre.

Segment sol

La station sol GEOS de Michelstadt approche du stade de la recette et on utilise actuellement le modèle 'valise' du satellite pour en tester les sous-systèmes. Le développement du logiciel de traitement des données pour la détermination et le contrôle d'orbite et d'attitude est en grande partie achevé et les travaux se poursuivent en vue de la mise au point des lots de logiciel de base pour le contrôle du satellite et le traitement des données des expériences.

During a recent meeting of the Science Working Team, in Denver, Colorado, agreement was reached on the separation strategy for the first months in orbit. This strategy, which defines the separation distance and time between the ISEE-A and B spacecraft, has been designed to obtain the maximum spread of scientific output with minimum risk during the early mission. A sufficient propulsion gas margin has been built into ISEE-B to permit radical changes in strategy following scientific evaluation of these results.

Launch and mission operations
Work continues on the preparation of the launch phase and during a recent visit to Goddard Space Flight Center and Eastern Test Range, the launch date for the ISEE-A/B spacecraft was fixed at 14 October 1977 at approximately 15.45 GMT (10.45 local time). The various launch-preparation facilities to be utilised have been identified and administrative problems discussed.

Discussions are continuing between ESA and NASA on the operational planning after launch and in particular on the most flexible and economic way of manning the control centre based at Goddard. A liaison visit has been held at ESOC with NASA representatives of the network divisions and a visit by software specialists is expected in September.

All in all, the project is following the expected path and, although there have been delays, nothing has occurred which endangers the proposed launch date of 14 October 1977.

EXOSAT

Satellite
Responses from Industry to the Invitation to Tender have to be in ESTEC by 2 August 1976. Preparations for the evaluation process are nearing completion and the membership of the various panels has been established.

A number of alternative schemes for a possible structural configuration have been studied by the Project and ESTEC functional divisions. Their relative merits are being examined.

The feasibility of using the Ariane launcher for Exosat is currently being investigated by the Ariane group, supported by CNES and ESA (ESTEC & ESOC).

Implementation of the Exosat mission with the nominal Ariane launcher is not possible, and the addition of a perigee motor and associated auxiliary hardware (spin-up system, nutation damper, sequencer, etc.) is therefore being considered. The consequences of this adaptation and the impact on both the launcher and satellite programmes are being investigated and will be considered by the Executive before any recommendations are passed to delegate bodies.

Payload
The definition and development of the scientific payload is progressing satisfactorily and activities are continuing according to plan.

ESOC
The study of alternative star-tracker configurations has been completed. Results are currently being evaluated and the best configuration will be chosen by the end of July. In the meantime, the accuracy requirements associated with orbital adjustment are being studied.

In support of the Ariane feasibility study, some work on orbit definition has been carried out. A slightly different orbit has been specified for an Ariane launch, and this awaits approval by the scientists concerned.

METEOSAT

Space segment
The P1 model tests have progressed satisfactorily although somewhat perturbed by software problems. Nevertheless, all major test milestones will be completed by mid-July. After the summer closedown at SNIAS, Cannes, P2 integration, which started in May with the integration of mechanical items (structure, AOCS) and harness, will proceed with mounting and testing of electrical boxes. The second Check-out Station is ready, having been delivered by ESTEC at the beginning of June and accepted in mid-June. At subsystem level, qualification testing is in its final phases and except for two anomalies (one on the AOCS subsystem and one on the power subsystem), results are satisfactory. Both anomalies are under failure analysis and corrective action is expected in time for F1 deliveries. The Development Results Review has now been definitely scheduled for 11–15 October 1976.

Ground segment
Integration of the Data Acquisition Telecommand and Tracking Station (DATTS) is progressing and all equipment has been installed. The ground/space compatibility tests are now scheduled for November.

As foreseen in the last Bulletin, the Data Collection Platform (DCP) prototype will be available in November; the tenders for Primary and Secondary Data Users Stations (PDUS and SDUS) have been evaluated and the SDUS

IUE

Réseau solaire
Le réseau solaire de vol a subi avec succès la série complète des essais de recette à l'ESTEC. Les réseaux ont été ensuite expédiés au Centre spatial Goddard où l'adaptation et l'intégration avec le modèle de vol du véhicule spatial auront lieu en juillet.

Système sol
L'examen de conception du système sol européen a fait l'objet d'une réunion tenue à l'ESOC les 18 et 19 mai 1976. Les équipes de l'ASE, de la NASA et du SRC ont pris part à cette réunion dont la date avait été choisie de façon à coïncider avec la mise au point définitive de la phase de conception par le contractant chargé de l'intégration des stations. Un certain nombre de recommandations détaillées qui y ont été faites donnent actuellement lieu à une étude poussée.

Au mois de mai, le Comité de Politique industrielle a autorisé la passation d'un contrat avec Bendix pour la fourniture de deux systèmes d'affichage des expériences identiques à ceux que la NASA s'est procurés pour la station sol américaine. L'identité de matériel donnera l'assurance que le logiciel fourni par la NASA pourra être utilisé sans difficultés dans les stations européennes.

L'installation du système calcul a débuté en mai et se poursuit de façon satisfaisante.

ISEE

Véhicule spatial ISEE-B
Les travaux se poursuivent sur le modèle d'intégration du véhicule spatial (qui doit remplir un grand nombre des rôles d'un prototype dans ce programme à trois modèles) et la majorité des sous-systèmes ont déjà été mis en place et contrôlés. Bien que de nouveaux retards aient accompagné la livraison des sous-systèmes de puissance et de télécommunications, on prévoit qu'ils seront compensés par l'achèvement fin août de l'intégration des expériences. Pour obtenir ce résultat, l'équipe d'intégration a fourni un effort intense, allongé ses journées de travail et travaillé six jours par semaine. Il a fallu, pour ce faire, programmer soigneusement les horaires tout en respectant la législation du travail des pays en cause.

Parallèlement à ces activités techniques, la liaison continue d'être maintenue au niveau de la gestion et des contrats. Des points de détail du contrat principal sont en voie de règlement en préparation de la signature finale prévue pour juillet.

Véhicule spatial ISEE-A
L'équipe de projet ISEE-A de la NASA, installée au Centre spatial Goddard, a commencé l'intégration du prototype de vol du véhicule spatial. La structure est désormais terminée et le câblage en cours. Une refonte de la conception du système d'antenne omnidirectionnelle a permis de résoudre les problèmes de propreté électrostatique. Dans l'ensemble, le travail progresse selon le calendrier.

Charge utile scientifique
La plupart des blocs d'expériences du modèle d'intégration sont maintenant achevés et ont subi avec succès leurs essais de qualification et de recette. Une seule expérience est légèrement en retard sur le programme, mais l'on ne pense pas que cela entraîne un retard du calendrier général du véhicule spatial.

Au cours d'une récente réunion de l'équipe scientifique à Denver (Colorado), l'accord s'est fait sur la stratégie de séparation pour les premiers mois en orbite. Cette stratégie, qui définit les distances et le temps de séparation entre les véhicules spatiaux A et B, a été établie de façon à obtenir la meilleure répartition possible des données scientifiques avec un minimum de risques pendant le début de la mission. Une réserve suffisante de gaz de propulsion a été incorporée dans l'ISEE-B pour permettre des changements radicaux de stratégie en fonction de l'évaluation scientifique des résultats.

Lancement et opérations
Les préparatifs de la phase de lancement se poursuivent et, au cours d'une visite récente au Centre spatial Goddard et à l'Eastern Test Range, la date de lancement du véhicule spatial ISEE-A/B a été fixée au 14 octobre 1977 vers 15.45 h GMT (10.45 heure locale). Les différents moyens qui doivent être utilisés pour la préparation du lancement ont été recensés et des problèmes administratifs étudiés.

Les discussions se poursuivent entre l'ASE et la NASA au sujet du planning opérationnel après lancement et, en particulier, de la façon la plus souple et la plus économique de fournir le personnel du centre de contrôle basé au Centre spatial Goddard. Une réunion de liaison s'est tenue à l'ESOC avec des représentants de la NASA appartenant aux divisions 'Réseau' et une visite de spécialistes du logiciel est attendue en septembre.

Tout compte fait, le projet progresse sur le chemin tracé et, même s'il a connu quelques retards, aucun événement n'a remis en cause la date de lancement proposée: 14 octobre 1977.

contract has been awarded to CIR (Switzerland). The PDUS proposal is to be submitted to the Industrial Policy Committee on 2 July. Software development is progressing, but not as quickly as expected due to the prototype nature of the ICL 2980, the operating system of which is not yet fully reliable. The vital application software (mandatory for launch time) is expected to be ready by the end of 1976.

Operations
Recruitment of Meteosat Operations Division (MOD) staff is now starting.

The outcome of the Sixth Co-ordination Meeting on Geostationary Meteorological Satellites (Washington) was satisfactory, most of ESA's proposals being accepted.

MAROTS

Testing of Marots thermal and structural models is now in progress. Thermal testing of the satellite, in its transfer-orbit configuration and in the on-station configuration, will be taking place during July at the CNES SIMLES facility in Toulouse. Static testing of the structural model has recently been completed at the contractor's facility and dynamic testing of this model is foreseen for the latter part of this year at IABG, Munich.

OTS

Integration of the OTS qualification model is continuing and manufacture of the flight-unit equipment is also in progress, with work being directed towards a mid-1977 launch. As noted in a previous issue, it is anticipated that the Control and Test Station at Fucino will be ready during January 1977. Contracts have been placed recently with industry for a set of fluxmeters, and for a ranging station that employs antennas of relatively small dimensions and forms an integral part of the test programme. Planning of the test programme has continued in association with the competent authorities, and a meeting of these groups will take place during November 1976 to review the test schedule.

SPACELAB

The integration building at the prime contractor's site is functionally complete and integration of hardware for the Spacelab hard mock-up, scheduled for initial use as an engineering tool in February 1977, has been initiated.

NASA and ESA are currently preparing a 'Spacelab Users' Guide', the purpose of which is to introduce likely future users to the space laboratory and its potential in the fields of science, applications and technology.

The Director General of ESA and representatives of the German Government signed two Agreements and an additional Protocol in May 1976 concerning the conduct of Spacelab payload projects and the provision of resources by DFVLR for such projects. The Agreements cover, in particular, the arrangements for the setting up of ESA's SPICE (Spacelab Payload Integration and Co-ordination in Europe) management group at DFVLR's Porz-Wahn facility.

The third Annual Spacelab Review by the Director General of ESA and the NASA Administrator took place on 16 June in Washington. Major results include final agreement on the development of the Instrument Pointing System by European industry and agreement on certain programme cost savings. A possible European participation in the second Spacelab payload and ESA's role during the operational phase of Spacelab were also discussed.

March 1977 has been agreed as a tentative date for NASA to issue a request for proposal to ESA concerning Spacelab follow-on procurement.

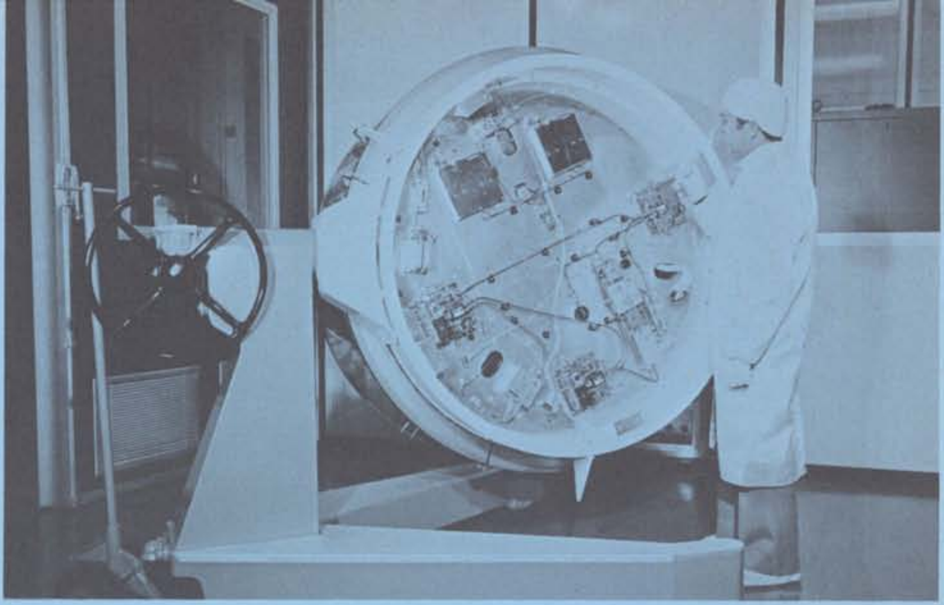
ARIANE

Improvement of launch-vehicle performance
A number of improvements to the Ariane launcher presently under development enable future users to be offered an increase in payload from 1500 kg to at least 1600 kg in transfer orbit. It can be assumed that in this way Atlas-Centaur-type performance will be reached, allowing satellites like Intelsat-V to be launched by Ariane. This can be achieved without compromising the overall programme schedule and the cost-to-completion ceiling.

The following measures have been taken or are under study:
- improvement of third-stage HM7 engine, resulting in higher specific impulse
- increase in propellant loading of second-stage L33
- increase in propellant loading of first stage L140
- optimisation of the first-stage engine nozzle shape, resulting in higher specific impulse and increased thrust at lift-off
- lightening of second and third-stage H8 equipment. □

Plate-forme d'équipements de télécommunications du modèle P1 de Météosat avant son montage sur le véhicule spatial.

Meteosat P1 telecommunications equipment platform before mounting on spacecraft



EXOSAT

Satellite

Les réponses de l'industrie à l'appel d'offres doivent parvenir à l'ESTEC pour le 2 août 1976. Les préparatifs en vue de l'évaluation sont presque terminés et la composition des divers groupes est fixée.

Un certain nombre de solutions de configuration structurelle ont été étudiées par les responsables du projet et les divisions de l'ESTEC assurant le soutien fonctionnel. Les mérites respectifs de ces solutions sont en cours d'examen.

La possibilité d'utiliser le lanceur Ariane pour Exosat est actuellement examinée par le Groupe Ariane avec le soutien du CNES et de l'ASE (ESTEC, ESOC).

Il n'est pas possible d'assurer la mission Exosat avec un lanceur Ariane type. On a donc envisagé l'adjonction d'un moteur de périgée et du matériel auxiliaire connexe (système d'accélération de la rotation, amortisseur de nutation, séquenceur etc.). Les conséquences de cette adaptation sur le programme du lanceur comme sur celui du satellite sont en cours d'examen et seront étudiées au niveau de l'Exécutif avant qu'une recommandation soit soumise aux instances délibérantes.

Charge utile

La situation actuelle de la définition et du développement de la charge utile scientifique est satisfaisante et les activités se poursuivent comme prévu.

ESOC

L'étude de plusieurs configurations possibles de suiveurs stellaires est achevée, ses résultats sont en cours d'évaluation et la meilleure configuration sera retenue à la fin juillet. Entretemps, on étudie les impératifs de précision liés à l'ajustement d'orbite.

Des travaux sur la définition de l'orbite ont été effectués en soutien de l'étude de faisabilité Ariane. Un lancement par Ariane imposerait une orbite légèrement différente qui doit être approuvée par les scientifiques intéressés.

METEOSAT

Secteur spatial

Les essais du modèle P1, bien que perturbés dans une certaine mesure par des problèmes de logiciel rencontrés pour l'équipement électrique de soutien au sol, ont progressé de façon satisfaisante. Les principales étapes des essais seront en tout état de cause terminées pour la mi-juillet; après la fermeture de la SNIAS à Cannes pour les vacances d'été, l'intégration du modèle P2, déjà commencée en mai en même temps que celle des éléments mécaniques (structure, système de pilotage et de correction d'orbite) et du câblage, se poursuivra jusqu'au montage et aux essais des boîtiers électriques. Livrée à l'ESTEC au début de juin et réceptionnée au milieu du mois, la deuxième station de vérification est prête. Au niveau des sous-systèmes, les essais de qualification sont dans leur phase définitive et, à part deux anomalies (constatées l'une sur le sous-système de pilotage et de correction d'orbite et l'autre sur le sous-système de puissance), les résultats sont satisfaisants. Ces deux anomalies font actuellement l'objet d'une analyse de défaillance et l'on compte y porter remède à temps pour les livraisons destinées à l'unité de vol F1. L'examen des résultats de développement (DRR) est maintenant définitivement fixé du 11 au 15 octobre 1976.

Secteur terrien

L'intégration de la Station de poursuite, de télécommande et d'acquisition des données (DATTS) avance et tous les équipements sont installés. Les essais de compatibilité sol/espace sont maintenant prévus pour novembre.

Comme indiqué dans le dernier Bulletin, le prototype de plate-forme de collecte de données (DCP) sera disponible en novembre; les soumissions relatives aux stations primaires et secondaires d'utilisation des données (PDUS et SDUS) ont été évaluées et le contrat pour la SDUS a été attribué à la CIR (Suisse). La proposition de passation de contrat pour la PDUS doit être soumise à l'IPC (2 juillet). Le développement du logiciel progresse, mais moins rapidement que prévu, du fait du caractère prototype de l'ICL 2980 dont le système d'exploitation n'est à l'heure actuelle pas complètement fiable. Le logiciel d'application, d'importance vitale (et indispensable au moment du lancement) doit, d'après les prévisions, être prêt pour la fin de 1976.

Opérations

Le recrutement du personnel de la Division 'Opérations de Météosat' (MOD) commence actuellement.

Les résultats de la Sixième Réunion de Coordination sur les satellites météorologiques géostationnaires (Washington) sont satisfaisants; la plupart des propositions de l'ASE y ont été acceptées.

MAROTS

Les essais du modèle thermique et du modèle de structure du satellite sont désormais en cours. Des essais thermiques dans la configuration prévue en orbite de transfert et après la mise à poste doivent se dérouler en juillet sur le simulateur du CNES à Toulouse. Les essais statiques du modèle de structure ont récemment pris fin chez le contractant; les essais dynamiques auront lieu en principe au second semestre dans les locaux de l'IABG, à Munich.

OTS

L'intégration du modèle de qualification du satellite se poursuit, de même que la fabrication des équipements destinés à l'unité de vol, en vue d'un lancement vers la mi-77. Comme il a déjà été annoncé dans un précédent Bulletin, la station de contrôle et d'essais de Fucino, en Italie, devrait être prête en janvier prochain. Des contrats ont récemment été passés dans l'industrie pour la fourniture d'une série d'installations de mesure de flux et d'une station de télémétrie pourvue d'antennes de dimension relativement faible, destinée au programme d'essais orbitaux. Les préparatifs du programme en question se sont poursuivis avec le concours des autorités compétentes; les différents groupes intéressés se réuniront en novembre prochain pour examiner le calendrier des opérations.

SPACELAB

Le bâtiment d'intégration chez le contractant principal a été achevé et peut maintenant être utilisé; l'intégration des équipements destinés à la maquette en dur du Spacelab, qui doit servir en premier lieu, en février 1977, pour aider à l'intégration technique, a commencé.

La NASA et l'ASE préparent actuellement un 'Guide des utilisateurs du Spacelab' destiné à présenter aux futurs utilisateurs éventuels le laboratoire spatial et les possibilités qu'il offre dans les domaines de la science, des applications et de la technologie.

Le Directeur général de l'ASE et des représentants du Gouvernement allemand ont signé, en mai 1976, deux Accords et un Protocole additionnel concernant la conduite des projets de charge utile du Spacelab et la fourniture de ressources pour ces projets par la DFVLR. Les Accords couvrent en particulier les arrangements relatifs à la mise sur pied du groupe de gestion SPICE (Intégration et coordination de la charge utile du Spacelab en Europe) implanté dans l'installation de la DFVLR à Porz-Wahn.

Le troisième examen annuel Spacelab, effectué en commun par le Directeur général de l'ASE et l'Administrateur de la NASA, s'est déroulé le 16 juin à Washington. Parmi les principaux résultats on peut citer l'accord définitif sur le développement par l'industrie européenne du système de pointage d'instruments (IPS) et un accord sur certaines économies à réaliser dans le programme. La possibilité d'une participation européenne à la deuxième charge utile du Spacelab et le rôle à jouer par l'ASE pendant la phase opérationnelle ont été également discutés.

La date de mars 1977 a été provisoirement acceptée pour l'envoi par la NASA à l'ASE d'une demande de proposition concernant la fourniture ultérieure d'équipements Spacelab.

ARIANE

Augmentation de la performance du lanceur

Un certain nombre d'améliorations du lanceur Ariane en cours de réalisation ont permis d'offrir aux utilisateurs futurs une augmentation de la masse sur orbite de transfert de 1500 kg à au moins 1600 kg. Il est même pratiquement certain qu'une performance équivalente à celle de l'Atlas Centaur peut être atteinte, ce qui permettra le lancement par Ariane de satellites comme Intelsat-V. Ce résultat peut être obtenu sans compromettre ni le calendrier général ni le coût à l'achèvement du programme.

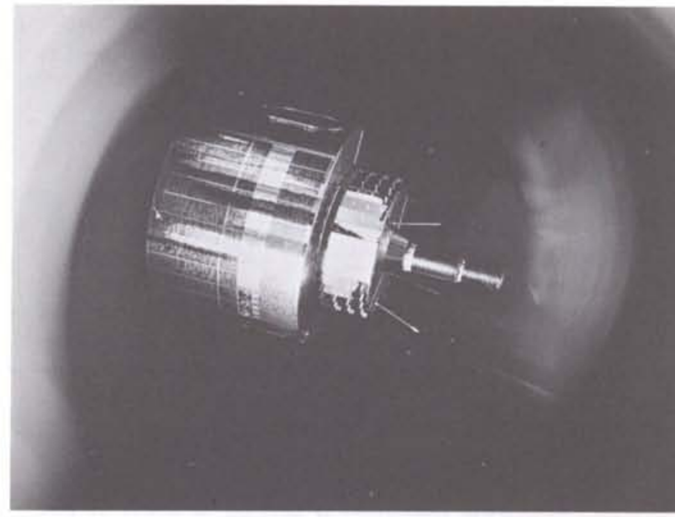
Les mesures prises ou à l'étude pour augmenter la performance portent sur:

- *l'amélioration du moteur du 3ème étage HM7, ce qui se traduit par une augmentation de l'impulsion spécifique*
- *l'augmentation de la charge d'ergols du 2ème étage L33*
- *l'augmentation de la charge d'ergols du 1er étage L140*
- *l'optimisation de la forme de la tuyère des moteurs du 1er étage, ce qui augmente l'impulsion spécifique ainsi que la poussée au décollage*
- *l'allègement de l'équipement des 2ème et 3ème étages H8.*

How Meteosat Images are Formulated and Disseminated

M.L. Reynolds and J.-P. Antikidis, ESA Meteorological Programme Office, Toulouse, France

The task of the operational meteorologist can be seen as one of collecting information on prevailing weather conditions and then analysing, extrapolating and summarising the data gathered to provide a continuous flow of information to the host of different users. Satellites can be of assistance in this activity by providing for interrogation of unmanned stations, data determination using remote-sensing techniques, and fast and efficient data-relay links. Here we will look specifically at the contribution of the imaging mission of ESA's Meteorological Programme, a remote-sensing mission which has application in operational and research meteorology and climatology. A previous article by Dr. B. Bizzarri has already treated the significance of Meteosat in a wider context ('The Scientific Aspects of Meteosat', ESA Bulletin No. 3, October 1975).



MISSION REQUIREMENTS

The technique employed by Meteosat for image generation, while unique in some respects, is similar in general concept to that used by the American GOES spacecraft, now in operation, and the Japanese GMS and Russian GOMS satellites presently under development.

The Meteosat images are intended to provide data on

- cloud cover
- surface temperatures
- wind velocity
- water-vapour distribution
- cloud attitude

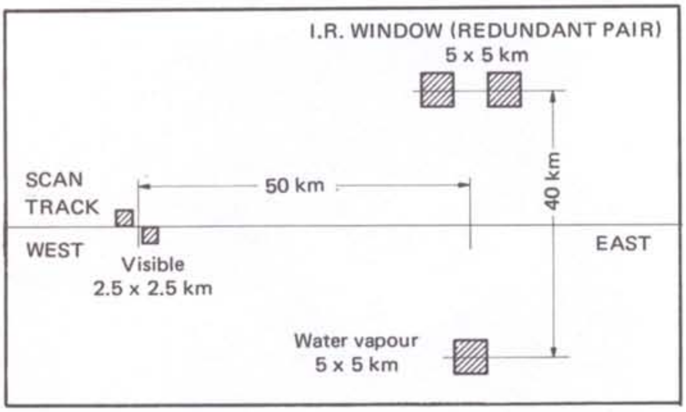
and it is expected that the information obtained will contribute to our understanding of the earth's radiation balance (energy budget) and atmospheric aerosol distribution.

The choice of a geostationary orbit for Meteosat provides for continuous and near-real-time coverage of a large proportion of the earth's surface. The image data is collected by a radiometric camera, designed to meet a performance specification based on spatial, temporal, radiometric and spectral resolution. In association with the satellite attitude and orbit performance, this specification serves to define the quality of the raw image transmitted to the ground. This image is then processed by ground-based computers to achieve the image quality necessary for extraction of the meteorological parameters. The definition of the raw image is necessarily a compromise between satellite cost and complexity and final requirements, and the approach adopted minimises space-segment complexity at the expense of a more sophisticated ground facility. This serves to emphasise that the final imaging performance required can only be achieved by the closest of co-operation between data users and those responsible for space- and ground-segment design.

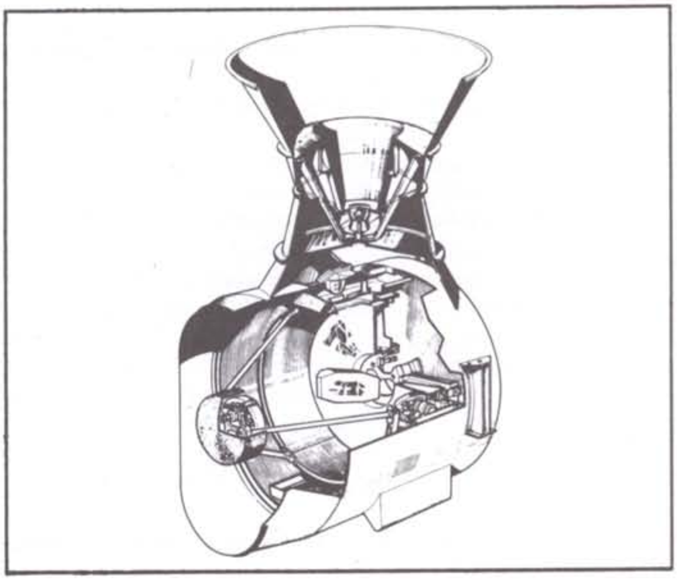
RAW-IMAGE GENERATION

The spatial resolution of the Meteosat imaging system is defined to be 2.5 km and 5 km at the satellite subpoint for visible and infrared images, respectively. This resolution is achieved by detectors viewing the earth through an optical system which includes a 400 mm aperture telescope. The angular sensitivity of the detector-optics combination to radiation arriving at the telescope is referred to as the instantaneous field-of-view (IFOV), which corresponds to the spatial resolution required with the radiometer in geostationary orbit. Each detector has a square sensitive area, giving a square IFOV. The images are generated by scanning the IFOVs over the earth's disc, by a combination of north-south tilting of the telescope assembly and east-west scanning derived from the satellite's rotation (100 rpm) normal to the orbital plane. During each rotation, one line of each infrared image and two visible image lines are generated. A complete image of 2500 lines (5000 for visible) can be generated in 25 min. A further 5 min are needed to reset the scanning mechanism and for various calibration functions, allowing complete images to be generated every half hour, which is the temporal resolution requirement.

Below: Schematic of Meteosat radiometer.
Right: Environmental qualification of radiometer.



Spatial resolution of Meteosat imaging system.



Infrared radiometric resolution is defined as 0.4 K at 290 K (1 K at 260 K for water-vapour measurements) and is achieved by using cadmium-mercury telluride detectors. Visible resolution is defined in terms of a minimum signal-to-noise ratio for a given earth albedo signal. This is calculated to provide good contrast between clouds and the terrestrial background. The energy available on board the satellite permits the use of silicon detectors operating at ambient temperature.

The complementary infrared and visible spectral intervals, or channels, are chosen as follows:

Visible channel	0.4 – 1.0 μm
Water-vapour channel	5.7 – 7.1 μm
Window channel	10.5 – 12.5 μm

The visible channel detects reflected and scattered solar radiation from the earth's surface and cloud cover and provides the best imagery of dense low clouds, while the window channel is sensitive to the earth's thermal emission and provides the best image contrast between the earth's surface and the tops of the higher, and hence colder, clouds. This window channel also allows sea-surface and cloud-top temperatures to be measured and the identification of approximate cloud altitude. The water-vapour channel is designed for maximum sensitivity to atmospheric water vapour in the high troposphere of the tropics, a region of important atmospheric movement with very few clouds. The primary aim of this channel is therefore to identify this movement by tracing water-vapour motions.

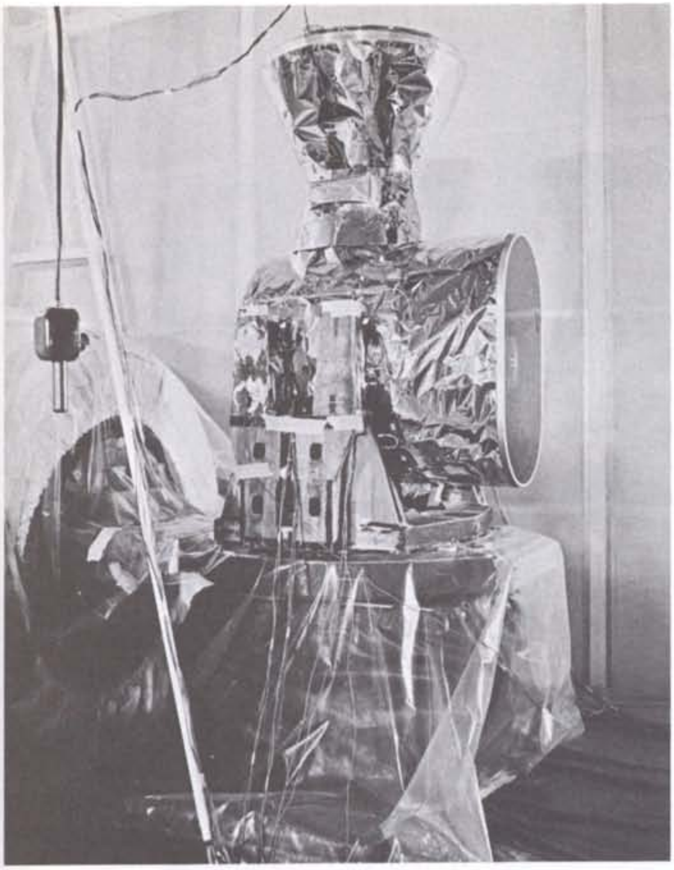
IMAGE PROCESSING AND DATA EXTRACTION

A distinction is made between the initial transmission to ground of the raw image, which contains the data uncorrected for calibration and the various inherent equipment distortions, and dissemination of the treated image to the various meteorological stations. Although the raw image is available to any suitably equipped centre within view of the spacecraft, we will concern ourselves here only with the provision of this data via the Data Acquisition, Telecommand and Tracking Station (DATTS) at Odenwald (Germany), the central station for the Meteosat programme.

As already indicated, the raw image is first processed to remove the various satellite-induced distortions, affecting both image amplitude and image geometry.

Amplitude processing is necessary because the image received by the Meteosat Ground Computer System may not be exactly representative of the landscape signal. The distortions stem from nonperfect optics, detectors, electronic transfer functions, sampling, and analog-to-digital conversion. Where distortions are small and linear (i.e. reversible), they can be compensated using an appropriate equipment parameter determined before flight or calibrated by special procedures from orbit. Only the sampling and A/D conversion errors are essentially nonlinear and thus remain as apparent supplementary noise in the system.

To achieve perfect image geometry, processing is necessary to correct for the various geometric errors arising from imperfections in the radiometer scanning mechanisms, line-to-line registration errors, and from spacecraft dynamics. Rectifica-



Data Acquisition, Telecommand and Tracking Station, Odenwald, Germany.

tion can be achieved by a combination of knowledge of these parameters and establishment of the relationship between image co-ordinates and geographical landmark co-ordinates (a task identified as 'earth location').

In practice, all the geometrical distortions present are not removed over the whole of the image, because of the extremely high processing load that this would entail. Instead, a 'law' describing the distortions is determined and transmitted with the images in the form of an overlaid grid.

The accuracy of this processing is derived directly from the wind-speed extraction accuracy requirement of 3 m/s. Wind speed is extracted – by observing cloud displacement between successive images – together with temperature and other radiation-amplitude-dependent data at the Meteorological Information Extraction Centre (MIEC).

Thereafter the image data, with the various additional image, geographical and meteorological data superimposed, are available for transmission to the numerous meteorological centres, and for archiving.

IMAGE DISSEMINATION

The operational meteorologist requires the image data to be available in near real-time, so that Meteosat's second task of image dissemination forms an important link in the chain between data acquisition and flow of meteorological information from the meteorological centres to the ultimate users. The image-dissemination mission provides for near real-time transmission of the processed image data back from the DATTS to suitably-equipped centres via the satellite. To cater for differing requirements, the dissemination is of two types:

- transmission at full resolution, using digital signals, to Primary Data User Stations (PDUS), which need relatively complex and expensive equipment;
- transmission of 30 partial pictures of visible images and 7 partial pictures of infrared images to Secondary Data User Stations (SDUS), using APT-format analog signals. Although relatively simple, these stations will be more sophisticated than current APT stations, the S-band frequency range being used for transmission.

CONCLUSION

It is anticipated that when the Meteosat system becomes semi-operational, at the end of 1977, the images that it provides will be widely used and published. It is to be hoped that this article has provided a preliminary indication of their origin and expected significance.

□

The European Space Tribology Laboratory

H.M. Briscoe, Structures and Thermal Division, ESTEC, Noordwijk, The Netherlands

E.J. Robbins, National Centre of Tribology, UKAEA, Risley, UK

Although ESA, in its former identity as ESRO, has always maintained a lively activity in space tribology, by 1970 it had become clear that the reliability of long-life applications satellites depended critically on the long-term reliability of such tribological components as bearings, slip-rings and gears. To provide itself with the capability of achieving solutions to the many problems of long-life lubrication of spaceborne machines and to provide facilities for testing them under closely controlled simulated space conditions, the Agency decided to establish a laboratory to specialise in space tribology. As a result of a tender action in 1971, the European Space Tribology Laboratory was established in February 1972 at the United Kingdom Atomic Energy Authority (UKAEA) Establishment in Risley, England, to be operated by the National Centre of Tribology (NCT), itself part of UKAEA, under contract from the Agency. The first contract, for a period of four years, was completed in February 1976 and a new contract to maintain the Laboratory in operation for a further four years, until December 1979, has now been awarded and will enable the current long-term programme to be continued to within two years of completion.

Before going any further, we should define the word 'tribology'. It was coined in the UK in 1966 as a portmanteau word to cover the field that had loosely been referred to as 'lubrication and wear'. It comes from the Greek word tribos, meaning rubbing, and is nowadays used throughout the world to refer to all matters concerning bearings, lubricants and lubrication, wear and the interactions of moving surfaces. It is thus a truly interdisciplinary subject of great complexity.

Space tribology has its own special problems which arise from the high vacuum of space (10^{-9}–10^{-14} torr), the extreme temperature ranges experienced by some satellites, and the absence of gravitational forces. The absence of oxygen is all important since protective oxide films cannot be renewed in vacuum and without some other form of lubrication welding of metal surfaces can rapidly occur. For short-life applications and one-shot devices, such as solar-panel or boom hinges, there are a number of readily available solutions but for critical mechanisms which must operate throughout the seven- to ten-year life of a communications satellite, the problems of wear and lubricant retention become all important. Examples of such mechanisms are solar-panel drives, antenna-pointing mechanisms, gimbals for momentum wheels, and momentum wheels themselves. Although these wheels are protected from the vacuum of space by sealed covers, their bearing systems must continue to operate at speeds of 3000–4000 rpm for the full life of the satellite and at the same time consume minimum power. The bearings therefore run with minimum lubrication, which must nevertheless sustain them throughout their lives.

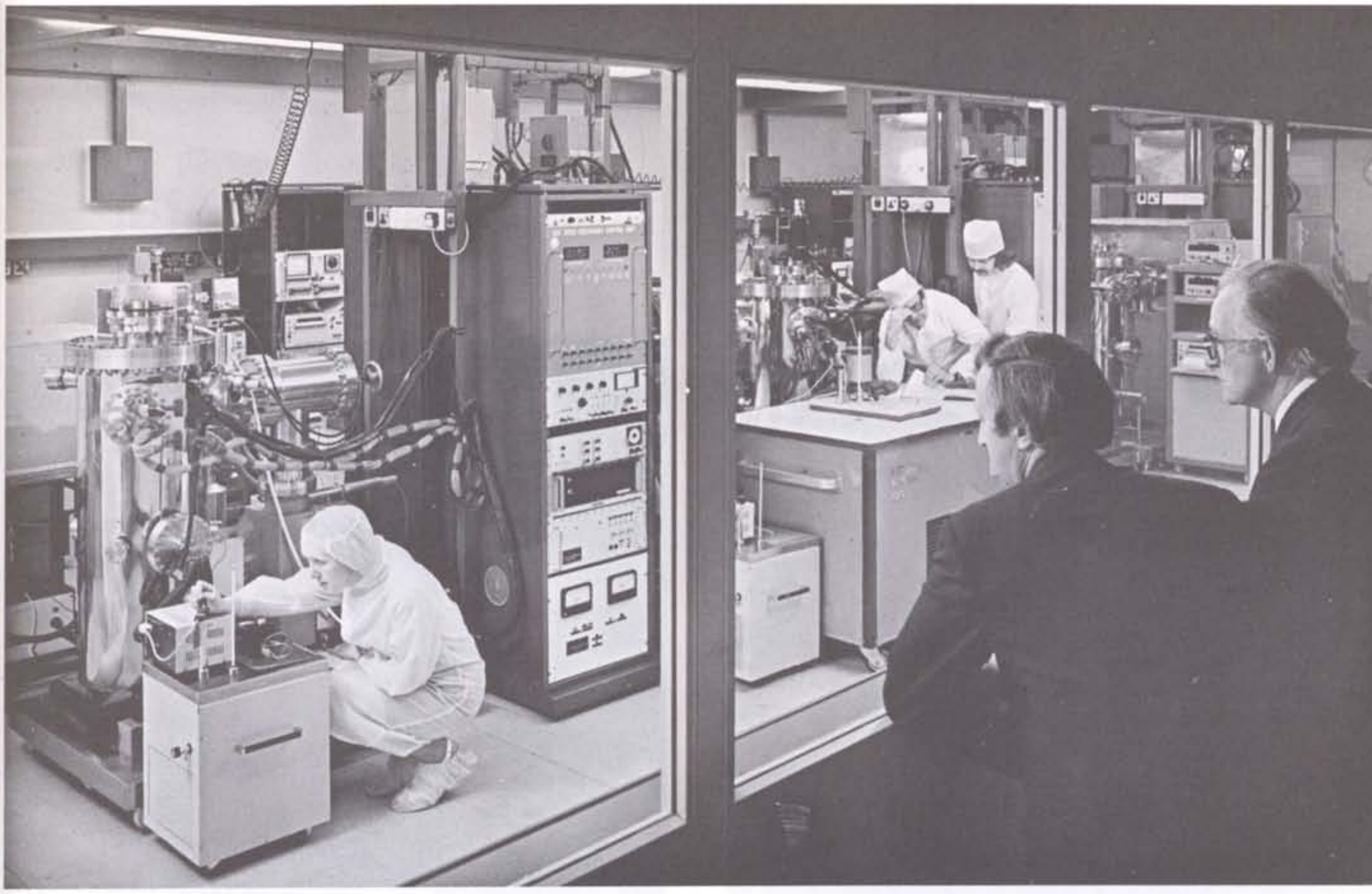
THE LABORATORY AND ITS EQUIPMENT

The Laboratory is a selfcontained clean room, which is essential if flight hardware is to be tested therein. A section of it is maintained at Federal Standard Class 100 cleanliness, which means less than 100 particles of 0.5 μm or larger per cubic foot (3.5 particles per litre). This allows bearings to be assembled without risk of particle contamination, a condition which is known to promote torque fluctuations and even bearing failure.

The equipment in the laboratory is too extensive to be listed here, but the heart of the facility consists of six 40 cm-diameter vacuum chambers and two 60 cm-diameter chambers, all fitted with thermal shrouds and radiating pancakes to enable large temperature gradients to be generated in any mechanism under test. To simulate eclipse conditions in orbit it is also necessary to be able to vary these thermal gradients very rapidly and this capability has also been included.

The chambers are designed for long-life operation and even allow for a change of vacuum pump without breaking the vacuum, should the need arise, since real-time life tests of more than seven years duration are now in progress. All pumps are ion pumps with absorption roughing pumps to avoid any possibility of pumping fluids contaminating the system. Even monomolecular layers of oil can markedly alter the performance of a tribological system.

To achieve the ultimate goal of extremely reliable long-life satellites, the testing of a mechanism and observation of a failure is not enough; the cause of failure must be identified and understood, and then a solution to prevent its recurrence must be found, tested and proved. It was with this objective in mind that the Laboratory was equipped with eight small vacuum stations capable of running custom-made vacuum envelopes for the many and varied tribology tests required. Bearing-torque tests, slip-ring material development and behaviour in vacuum, heat transfer through bearings, and control of the creep of liquid lubricants on surfaces are just a few of the investigations now in progress.



General view of part of the Laboratory from the observation corridor.

ESTL has recently acquired a facility for the deposition of thin metallic or ceramic films by ion plating, a technique that enables very adherent films of controlled thickness to be deposited on metallic surfaces. The first application of this technique at ESTL is to the preparation of ball bearings coated with thin films of lead, which is now the preferred ESA dry lubricant for the solar-array drives of OTS, Marots and ECS, but the technique is capable of far wider application.

In summary then, ESTL must perform three distinct, if related, functions:

- it must be a test house of the highest possible calibre for testing mechanisms for ESA and European space companies
- it must maintain a programme of development in space tribology in support of all ESA programmes
- it must provide a readily accessible consultancy service in space tribology to all who are in need of it.

The Laboratory is now too small to house all of its equipment and at the same time to allow all the work to proceed, so plans for its extension have been approved and it will be operational at its new size before the end of 1976.

Let us now see how the laboratory performs these important tasks.

ESTL AS A TEST HOUSE

In general, the tests conducted at ESTL fall into one of two categories

- formal tests for flight-associated hardware
- less formal tests in support of a development programme.

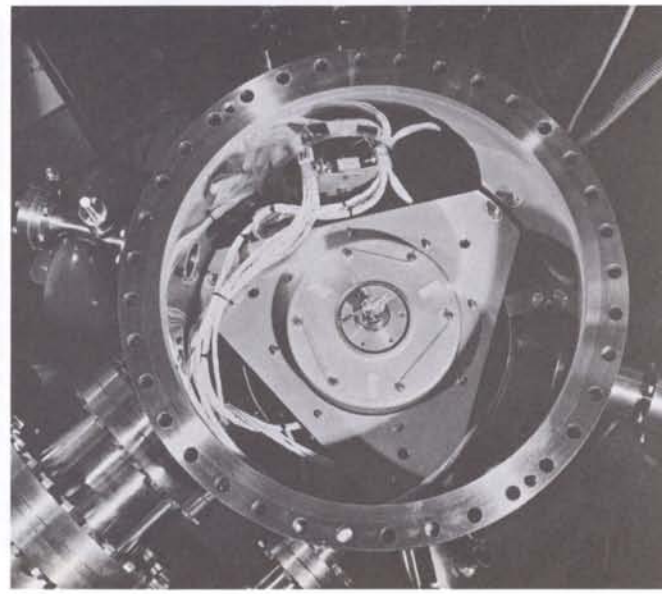
The formal tests are of three types.

Qualification Tests are a series of short-term tests, each lasting perhaps eight hours, in which the mechanism is subjected to a range of temperatures considerably greater than those expected on the satellite and, of course, in the vacuum environment. This type of test is applied to the Qualification Unit of a class of mechanism destined for flight and is proof of the suitability and integrity of the design.

Acceptance Tests are similar short-term tests in which the temperature limits are less severe and represent the limits that the mechanism is expected to encounter in space. Flight Units are given only Acceptance Tests to avoid possible damage from the more extreme conditions of the Qualification Test and, very importantly, to establish the integrity of the build of an individual unit.

Life Tests which aim to determine whether there is any deterioration in the performance of the mechanism during its expected lifetime of perhaps seven to ten years. In some cases, depending very much upon whether the lubrication system is dry or wet, it is possible to accelerate life tests by increasing the speed and/or the load. However, this must be done with the greatest care if the results are to be meaningful.

All of the above tests must be carried out with great formality and absolute control of all activities, both to satisfy contractual obligations and to ensure the absolute integrity of the tests. To achieve this, a system of Quality Assurance Procedures must be established, formalised and applied. During 1975 ESTL, with assistance from ESA (ESTEC), applied a very large effort to establishing such a system. A Quality Assurance Procedures Manual was written which can now stand as a model for all space test facilities and which fully satisfies the requirements of both ESA and its contractors in this important activity. A flight-standard mechanism arriving at ESTL for test is continuously under the surveillance of the Quality Assurance organisation from the moment it is delivered until it is despatched back to the contractor.



Solar-Array Drive installed in the chamber.

The first application of the system has been to the testing of the Solar-Array Drive units for the OTS and Marots projects. At the time of writing the first drive unit for OTS has successfully completed its test, to the entire satisfaction of both ESA and Hawker Siddeley Dynamics (HSD), the OTS prime contractor. The remaining three mechanisms in this programme will be tested during the summer of 1976 and will be followed by those for Marots before the end of the year.

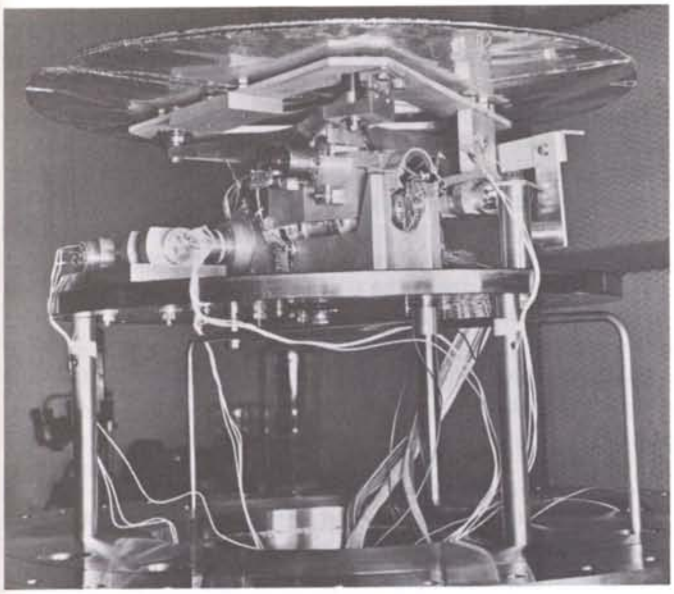
It is both fair and true to say that ESTL is the first fully certified test house devoted wholly to spacecraft mechanisms, and available to all, to be established anywhere in the world.

Informal tests, the second category of test we mentioned, are much more varied of course in both character and objective. They are almost always development tests which can at any moment be diverted to investigate a failure mode.

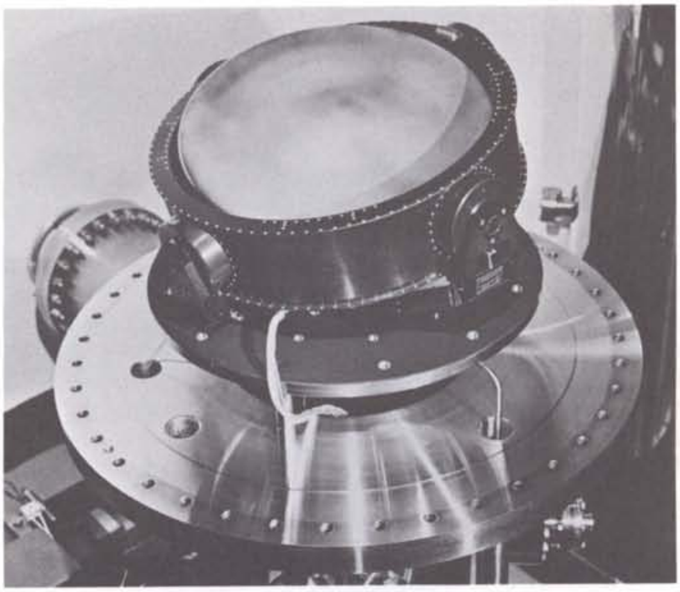
During the years 1972–75, four major mechanisms of the ESA programme underwent extensive development testing at ESTL. As part of the Supporting Technology Programme for the European Communications Satellite programme, two solar-array drive units were developed, one designed by HSD and the other by Marconi Space and Defence Systems (MSDS). Two HSD units and three MSDS units were tested and the first of each type exhibited an unsuspected failure mode which could only be revealed by testing under fully simulated space conditions. In each case a minor modification enabled both mechanisms to pass qualification test and one of each type is now undergoing real-time life testing at ESTL for a projected period of at least seven years.

The two other mechanisms tested as part of the Supporting Technology Programme are an Antenna Pointing Mechanism (APM) and a Double Gimbal Momentum Wheel (DGMW). The former required the establishment of an optical system inside the vacuum chamber to enable its performance to be verified under representative conditions, where it was necessary to measure angular movements to a precision better than 3 arc sec. The DGMW is being tested to examine the performance of different lubrication systems for the gimbal bearings. The use of lead for this purpose is very attractive from the point of view of life and lack of contamination, but its performance in bearings operating in an oscillating movement has not so far been established. Further tests on the APM are planned, and a second model of the DGMW will arrive for test later in the year.

Another mechanism now running on life test is a 100 rpm de-spin unit, designed and manufactured by Dornier System under ESA contract, and originally intended for a de-spun communications satellite. The unit uses bearings lubricated with one of the new lubricants developed by BP Ltd. specially for space machinery, and to date is behaving very well.



Antenna Pointing Mechanism ready for test.



Teldix Double Gimbal Momentum Wheel mounted on base plate in test chamber.

THE DEVELOPMENT PROGRAMME AT ESTL

A full report on all the work at ESTL which falls into this category would be beyond the purpose of this article, so we must content ourselves with a review of the most important activities. It should be understood that the facilities at ESTL enable small investigations to be carried out very quickly, and each year an increasing number of projects is making use of this ability of the Laboratory to respond immediately to the need for a solution to an urgent problem.

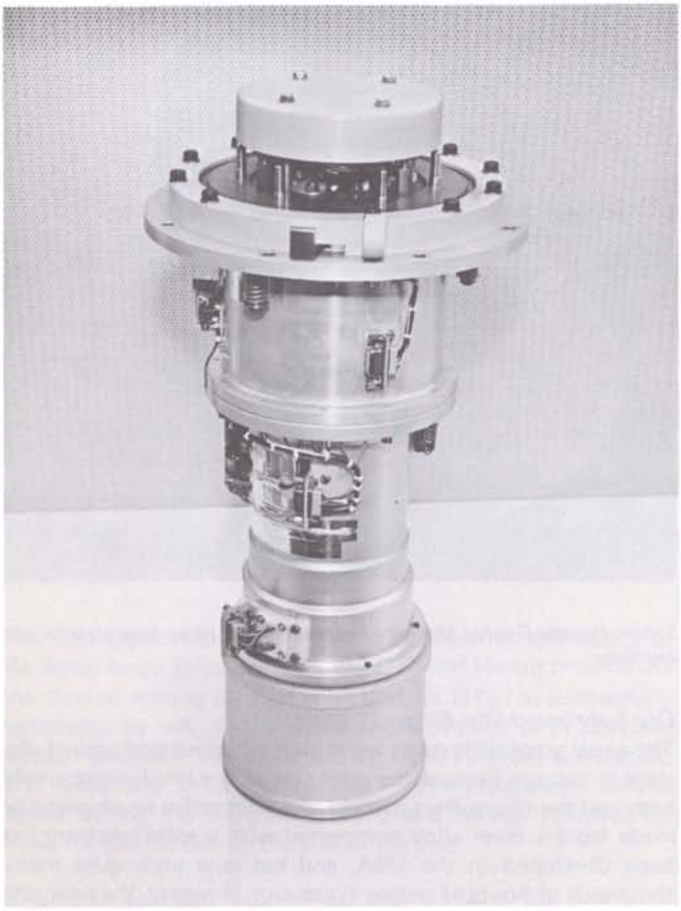
Because tribology relies as much for its progress on empirical results as on theoretical expertise, any programme of development must extend over periods ranging from a few months to seven to ten years. The programme at ESTL has so far concentrated on dry lubrication systems, since these are of major interest to ESA projects, but work on some aspects of liquid-lubricated systems is now also in progress. Some of the more important activities cover:
- dry-lubricated slip rings
- oil creep and its control
- rod-end bearings
- lead lubrication (basic understanding)
- heat transfer in bearings
- torque noise of rolling bearings
- ion-plating techniques for lubrication.

Dry-Lubricated Slip Rings

The usual graphite brushes are useless when rubbed against slip rings in vacuum because the wear rate of the brush is extremely high and the ring suffers damage. An alternative brush material made from a silver alloy compacted with a solid lubricant has been developed in the USA, and has now undergone many thousands of hours of testing in vacuum. However, the wear rate is barely acceptable for medium and high-speed mechanisms on long-life space missions. ESTL has concentrated on two aspects of the operation of slip rings using this material:

- the effect of contamination on the performance of the slip-ring pair
- the effect of manufacturing variations on the performance of the brush material.

To examine the first of these effects, a test rig had to be built eliminating all polymer-type materials. All insulating materials in the rig are glass or ceramic, which can be cleaned and baked in vacuum. Controlled quantities of polymeric materials can then be introduced to examine their effect on slip-ring performance. Results to date show that slip rings can readily become contaminated by certain polymers, and thus it is recommended to use only glass or ceramic insulation materials in dry-lubricated spacecraft slip-ring systems. The MSDS solar-array drive mentioned above incorporates this feature.



100 rpm satellite De-Spin Mechanism.

The effect of manufacturing inconsistencies in any material is significant, but for selflubricating brushes uniform and repeatable performance is essential. The material used is a sintered compact of silver, copper and molybdenum disulphide which is very sensitive to small changes in manufacturing technique. Accordingly, ESTEC has initiated complementary programmes at ESTL and the Atomic Energy Research Establishment to develop a production process which can be fully documented and homologated to reproduce always a uniform product, and to evaluate the resulting material in a series of strictly controlled tests. In 1976 this goal should be reached.

It should also be said here that an excellent pin and disc machine in an ultra-high-vacuum chamber at the Laboratoire Suisse de Recherches Horlogeres is being used in this programme. This is consistent with ESA policy of not duplicating at ESTL test facilities already available in Europe, but rather utilising their unique features to support the European space-tribology programme.

An interesting aspect of the use of dry-lubricated slip rings is control of the movement of the wear debris in a weightless environment. On Earth gravity takes charge and the debris collects harmlessly at the bottom of the casing, but in a weightless environment the particles float, reacting to minute disturbing forces, and may cause short-circuits or find their way into bearings. To examine this phenomenon and develop methods of controlling it, an experiment is being planned to be flown on Spacelab.

Oil Creep

The movement of a liquid lubricant on a surface is a complex function of the composition and surface tension of the fluid and the material of the surface. It is of extreme importance in liquid-lubricated space systems, since it can be the predominant force controlling the movement of the lubricant in the mechanism. It can also be the prime cause of loss of lubricant to space and must therefore be controlled.

Work at ESTL has been concentrated on the evaluation of the performance of commercially available anti-creep barriers in vacuum in conjunction with space lubricants. It is proving very difficult to achieve reproducible results, which amply demonstrates the subtleties of the problem and the need for further understanding of the phenomena controlling the action. This investigation, which is now becoming fundamental in character, is continuing.

Spherical Rod-End Bearings

The use of commercially available dry-lubricated spherical bearings is very attractive for a number of spacecraft applications, such as boom or solar panel hinges. This programme is an evaluation of a number of competing types of bearing to enable a choice to be made on the basis of low wear, low torque and insensitivity to changes in temperature, and is another example of the varied programme pursued at ESTL, this time of a completely empirical nature.

Limits of Lead Lubrication

The use of lead as a vacuum lubricant for bearings has been more than amply demonstrated by a test programme run over ten years by the Royal Aircraft Establishment and MSDS in the UK and later extended by ESA. The complete test programme has now resulted in more than one million hours of operation with remarkably few failures. Some small bearings have now been running at 3000 rpm for more than eleven years and are not showing any signs of failure.

However, when operated in air, rapid failure can occur due to oxidation of the lead. A programme run at ESTL has shown that speed is the principal factor involved and that, when run at less than 5—10 rpm, bearings can also be operated in air. It was the confirmation of this behaviour that enabled ESA to adopt lead lubrication for the bearings of the OTS and Marots solar-array drives, which rotate at only one revolution per day.

Complementary to this work was a programme carried out at DERTS, Toulouse, on their pendulum machine wherein a ball is rolled on a track in an oscillating mode and both the viscous and Coulomb friction measured. Yet another example of utilising equipment available elsewhere in Europe.

Heat Transfer in Bearings

Several years ago ESA attempted to obtain published data on heat transfer through a rolling bearing and discovered that so little was available that calculations of heat flow through mechanisms were little better than estimates, or worse still, guesses.

The Agency therefore contracted the design and building of a suitable rig to NLR, Netherlands. This rig is now installed at ESTL and giving some very interesting results. Liquid-lubricated bearings appear to have a speed at which the heat transfer coefficient is minimum, a phenomenon that awaits explanation.

A body of results on both liquid- and dry-lubricated bearings under conditions of varying speed and load will be accumulated during 1976 and will be published in 1977.

Torque Noise of Rolling Bearings

The Instrument Pointing Subsystem to be mounted on Spacelab (see pp. 12-17) is required as an articulated mounting for telescopes and similar instruments and must have a performance allowing a pointing accuracy of one second of arc. To achieve this aim, frictional disturbances in the bearing system must be reduced to a minimum or totally eliminated. The latter solution, involving some form of flexible suspension inside a rolling bearing system, has proved to have well nigh insuperable difficulties.

The present proposal is to use rolling bearings only for the suspension and this has led at once to a programme at ESTL to determine the torque noise from bearings fitted with various cages and lubrication systems. Theoretically, rolling bearings can be employed for the IPS and the purpose of the test programme is to demonstrate the validity of the proposal. This work is just now starting and will have significance for many other applications where low-torque-noise bearing systems are essential.

Ion-Plating Techniques for Lubrication

The success of lead as a space lubricant for ball bearings is now manifest, but the method of applying it to achieve the best results has yet to be established. So far, all long-life test results have been achieved with vacuum-deposited lead, a technique much used commercially for silvering mirrors and applying very thin coatings of many metals. The relatively new process of ion-plating employs an electric field to accelerate ionised particles of lead onto the surface and theory predicted that this would result in much improved adhesion. With the collaboration of the Department of Mechanical Engineering at Salford University, ESTL has built and commissioned an ion-plating facility to demonstrate the expected improvement. Results obtained during recent months on a number of test bearings have clearly shown good control of the thickness of the coating allied to superior adhesion. The next step is to determine whether this results in a reduction in bearing-torque fluctuations, and whether it assists in increasing the life of the larger ball bearings required for medium- or high-speed space mechanisms.

The process is currently being used to plate a number of ball screws to actuate an experiment of the Rutherford Laboratory which will be flown on the American Nimbus satellite.

Ion plating can of course be used to apply almost any metal to a conducting surface, which opens up a virtually limitless field of experiment in space tribology. Gold, silver and indium are excellent soft metal lubricants in certain circumstances, and all can easily be deposited by this method.

ESTL AS CONSULTANT

One very important objective in creating ESTL was the provision of a consultancy service in space tribology to serve the Member States of ESA, and indeed anyone anywhere who wished to use it. The need for such a service was demonstrated by the wide variety of not always correct solutions offered for space-tribology problems by engineers in Europe. Indeed, the variety of solutions often equalled the number of engineers proposing them, interpreting the large quantity of test results coming across the Atlantic.

To provide an expert consultancy appeared to ESA to be the only way to resolve the situation, and although an adequate level of expertise was available at ESTEC the task was clearly much larger than could be managed by the limited resources available.

Since ESTL is operated by the National Centre of Tribology, it was very clear that it was admirably equipped, in both knowledge and ability to provide the needed service. NCT has a total staff of some 35 people who are devoted exclusively to tribology, with particular emphasis on tribology in hostile environments, such as helium, liquid sodium, intense radiation and vacuum.

To make the service readily and quickly available to firms and organisations in the ESA Member States, the first 10 h of consultancy is provided free of charge and is available at the end of a telephone line. If the consultancy is to extend beyond this time, or involves experimental work, a more formal agreement is required. This service can also be extended to non-Member States if requested.

Naturally, a service of this character cannot be created or utilised overnight and it is only during the last two years of the first four-year contract that ESTL has been able to establish itself as the major centre of space tribology expertise in Western Europe. It is now true to say that no European space firm need lack for expert guidance and advice on matters of space tribology.

There is, however, another objective for ESTL which we have not so far mentioned, and that is co-ordination of space-tribology activities in Europe. Many investigations of great value are carried out by space firms or national organisations, mostly for their own purposes, and it is inevitable that some duplication occurs. ESA is able to act as a clearing house for information, to put workers in touch with one another, and to encourage or discourage certain areas of investigation, thus influencing, if not directing, the co-ordination of work in Europe. It should be said that some degree of duplication is not only desirable but essential, but it should be deliberate and guided rather than haphazard. As part of this activity ESA organised in Frascati, Italy, in April 1975 the First European Space Tribology Symposium which attracted papers from 35 authors, including some from the USA and an attendance of 90 delegates. The proceedings were issued some months later as ESA Special Publication No. 111, and a repetition of the event is planned for 1978.

CONCLUSION

This brief resumé of the creation of ESTL and of its work during the first four years of its existence, presents a picture of a laboratory fulfilling the dual function of high-grade test house and expert development organisation rolled into one, which is just what it was created to be. The workload through 1976 is at a constant high level and the programme planned for 1977 will fully occupy the resources of the laboratory.

Space tribology has now reached the stage where numerous solutions are available and a number have proved themselves by operating in space for extended periods, but all have limits to the operational conditions under which they may be used. For many systems these limits have not yet been established and the element of risk in using them is large enough to raise doubts about their reliability. Consequently, the work to be done in space tribology becomes the establishment of limits for accepted tribological systems, the development of new systems for long and reliable lives and for special applications and, finally, the search for a further understanding of why some systems operate at all.

This work should lead to a handbook of space tribology in which designers will be able to find solutions and the limits of the circumstances in which they should be applied. The creation of such a handbook is itself a major undertaking, but a start will be made in 1977 for publication in 1978 or 1979.

Looking to the future, we do not expect the laboratory to grow in size, but we do expect to improve the methods and means of test and to refine the development techniques.

The cost of testing spacecraft mechanisms is a significant fraction of their overall cost, but the cost of not testing them at all, or inadequately, can be infinitely higher. ESTL have now achieved a routine standard test procedure which enables the tests to be carried out within the quoted price and schedule and with full Quality Assurance supervision.

ESTL will continue to provide a service to all, to be always ready and able to undertake either test or development work at short notice, and to be the focal point of space tribology for ESA in Europe.

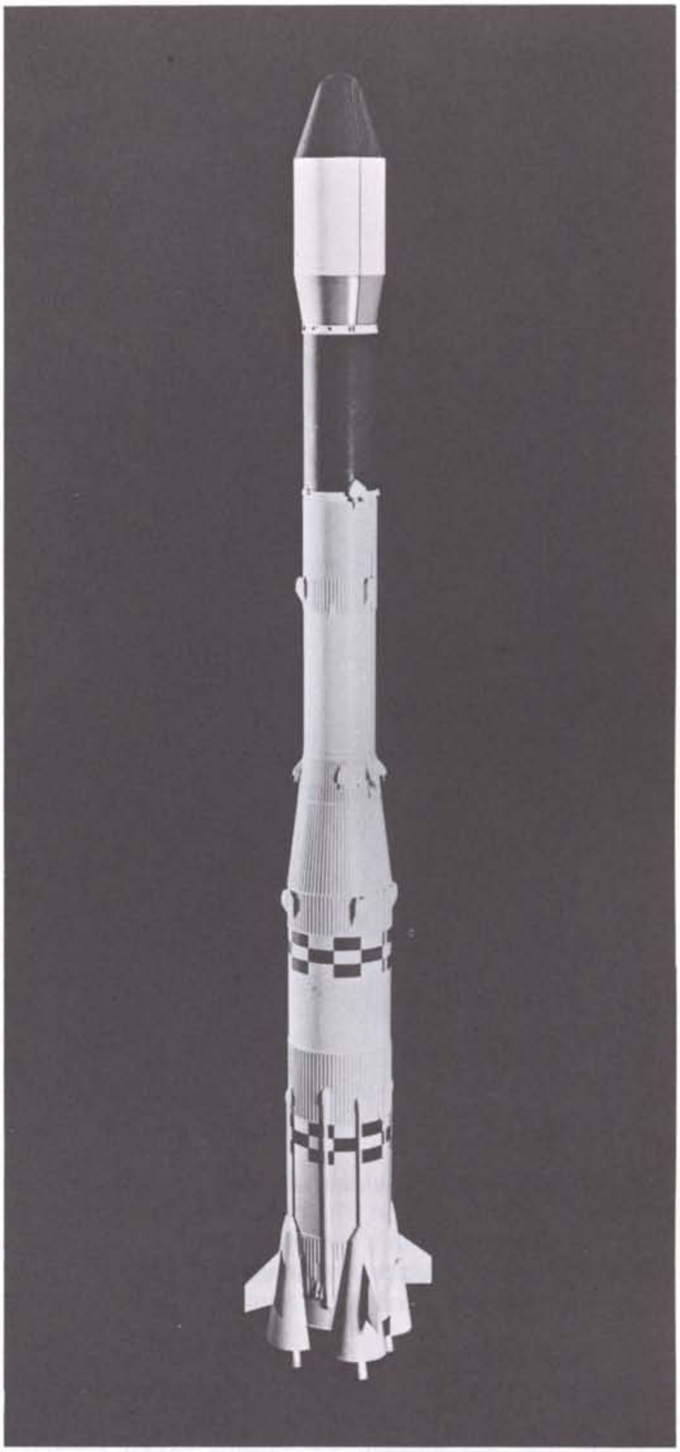
□

The Apex Programme

B.R.K. Pfeiffer, Space Transport Systems Department, ESA, Paris

Within the framework of the development of the European Ariane launch vehicle, managed by the French national space organisation CNES, four development flight tests are foreseen in the years 1979 and 1980. The primary objective of these flights will be to qualify the launch vehicle. In addition, the Ariane Programme Board of ESA has authorised the flight of passenger experiments on board the second, third and fourth development flights (coded L02, L03 and L04). This offer of free flight opportunity has been transmitted to the Agency's Member States, and to organisations in non-Member States with whom ESA has close links. Each experimenter is, however, responsible for all passenger-related costs.

In response to the offer, 93 experiments were proposed, most of which were non-autonomous in the sense that a spacecraft structure, attitude-control system, power supply, etc. still had to be provided. This approach of providing non-autonomous experiments turned out to be fairly costly for the experimenter and if maintained would have led to considerable underemployment of the capacity available on the development flights. A more acceptable approach of selecting autonomous passengers from already-assembled spacecraft remaining in hand from earlier space programmes has now been substituted.



ARIANE LAUNCH VEHICLE

The recently improved nominal payload capability for Ariane is the injection of 1600 kg into a geostationary transfer orbit, with perigee 200 km, apogee 36 000 km, and inclination 10.5°.

As the launch vehicle carries additional measurement equipment on these development flights, in each stage as well as in the payload area, the volume and mass budgets available for the passenger are slightly reduced and the orbital parameters are somewhat different, in particular the inclination which is 17.7° for L02 because of the longer visibility range required for extended launch-vehicle telemetry reception during qualification flights.

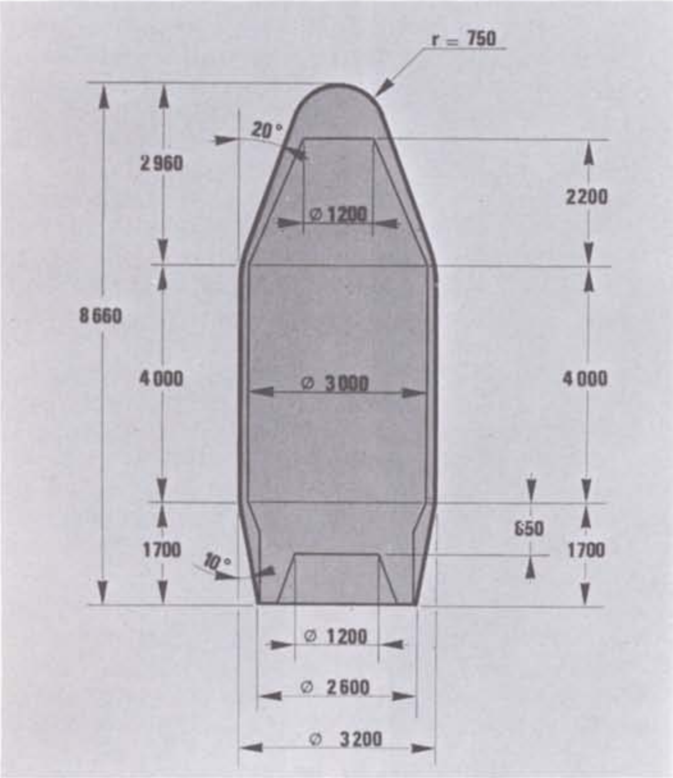
POSSIBLE PASSENGER MISSIONS

As the number of proposed passenger experiments exceeds the number of development flight opportunities, a selection has to be made taking into account the interest that exists in a particular mission in the ESA Member States, as well as the feasibility of the mission itself and any funding constraints.

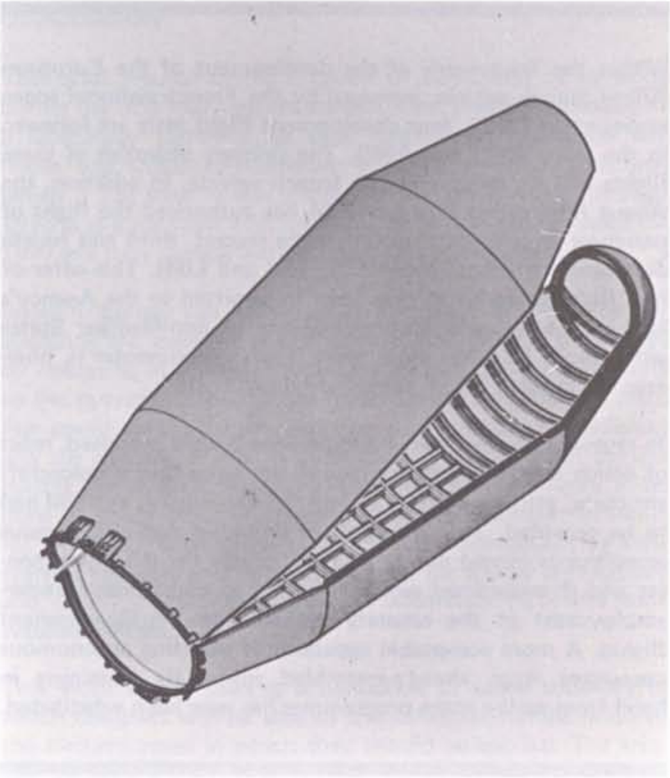
FLIGHT OPPORTUNITY L02

The L02 launch has been assigned essentially to scientific passenger payloads, to be chosen from the following:

COS-B Second Flight Model with an additional boost motor to



The maximum possible Ariane payload volume (dimensions in millimetres).



The two parts of the Ariane fairing.

raise the apogee provided by Ariane, the scientific experiments being the same as on the first COS-B mission.

GEOS Second Flight Model, with the same scientific experiments as will be carried on the first flight model next year.

COSARI: For this mission, the existing COS-B spacecraft would be modified to carry scientific experiments to investigate the magnetosphere and the plasma, as well as experiments on relativity (gravitational red shift), extreme ultraviolet emission and the measurement of the diffuse infrared sky background.

APPLE: This passenger, proposed by the Indian Space Research Organisation (ISRO), comprises a small experimental geostationary telecommunications satellite with a C-band communication transponder (4–6 GHz). An Effective Isotropic Radiated Power sufficient to cover the Indian subcontinent is foreseen (at least 30.2 dBW).

AMSAT: The International Amateur Radio Satellite Organisation has proposed, through its German affiliate, an amateur radio satellite of the so-called 'Oscar-type', weighing 68 kg and carrying two redundant transponders receiving in the VHF and transmitting in the UHF band, allocated to the use of amateurs.

COS-B, COSARI and GEOS are considered the principal candidates, with APPLE and AMSAT as additional passengers that could be accommodated in a lateral position within the payload fairing.

The Indian telecommunications satellite is also being considered as a possible additional passenger for the L03 flight.

FLIGHT OPPORTUNITY L03

The proposed passengers for this flight are:

OTS: An OTS platform procured on a marginal cost basis, additional to the platforms for the main OTS-Marots programme, could carry a modified telecommunications payload operating in the 4/6 and 2.5 GHz frequency bands.

Meteosat: This mission could provide (i) a complementary series of experiments to the basic Meteosat system, by having the two satellites in orbit simultaneously (giving increased image rate and stereoscopy), or (ii) in-orbit redundancy to increase operational reliability, if necessary, after 1981, or (iii) experiments with new spacecraft- or observation-instrument -related technologies.

Symphonie: The Franco-German Symphonie programme has proposed the Symphonie protoflight model as an APEX passenger. This model, built with flight-proven hardware, was originally to be launched on the last pre-operational flight of the now superseded ELDO Europa-II launch vehicle. Its launch on L03 would allow the Symphonie programme to be extended beyond 1980/81, when the two flight models then in orbit will be approaching the end of their expected lifetime.

The investment made in the ground segment could also then provide a return for an extended period.

Canadian Satellite derived from CTS: The Canadian authorities have informed ESA of their interest in taking advantage of APEX flight opportunity to extend the CTS programme, the basic assumption being that the CTS Engineering Model can be refurbished to serve as a telecommunications payload platform. One payload option might be a UHF transponder designed to test telecommunication systems required for the far north of Canada after 1980.

None of the four satellites proposed as principal passengers for the L03 flight will occupy the full capacity of the launch vehicle, and flight of a combination of any two might have been a theoretical solution. However, in the light of the major modifications that would be needed structurally and in the launch procedures, the Agency does not intend to examine this possibility further. Nevertheless, accommodation of the Indian APPLE satellite as an additional passenger on the L03 flight is still being seriously investigated; as this satellite's configuration has not yet been frozen, its design could take into account the constraints of a combined launch.

FLIGHT OPPORTUNITY L04

The L04 vehicle, the last of the qualification launches, might be of help in preparing for the Agency's second generation of applications satellites. Both ESA and its Member States are studying how to make the best use of this launch.

Several satellite configurations offering high power and long lifetime are under investigation and could be flight tested and qualified on L04. A technical payload, such as a direct television or an advanced telecommunications mission, could be accommodated, and discussions are still in progress between ESA and its Member States.

CONCLUSION

At the moment, the Agency is performing an accommodation study to investigate the feasibility of pairing two satellites – one of the proposed principal passengers and one of the proposed additional passengers – for the L02 and L03 launchers.

Final selection of the L02 and L03 passengers should take place in Autumn 1976, with the results of the above studies and an assessment of the Agency's scientific and/or technical interests in the principal programmes serving as a basis for decision.

A detailed mission analysis will subsequently be conducted prior to final project-like implementation of the passengers chosen.

Use of Ariane development flights to launch low-cost autonomous flight hardware in the way described will be to the benefit of the overall space activities of all organisations participating in the APEX programme.

□

La base de lancement Ariane

R. Orye, Département Ariane, ESA, Paris

Les lancements de qualification et les lancements opérationnels du lanceur Ariane seront effectués à partir de la Base de Lancement de l'Agence située à Kourou en Guyane française en réutilisant au maximum les installations du CECLES réalisées pour le programme Europa 2.

La Base de Lancement comprend d'une part l'Ensemble de Lancement Ariane qui regroupe les installations spécifiques nécessaires pour la préparation, l'assemblage final, les contrôles et les opérations de lancement et d'autre part les moyens techniques complémentaires nécessaires pour assurer le suivi du lanceur depuis l'aire de lancement jusqu'à l'insertion en orbite de transfert (il s'agit essentiellement des stations aval).

Le coût total des travaux nécessaires pour mettre à la configuration Ariane la Base de Lancement de l'Agence a été estimé à 120 MFF (aux conditions économiques du 1er janvier 1973).

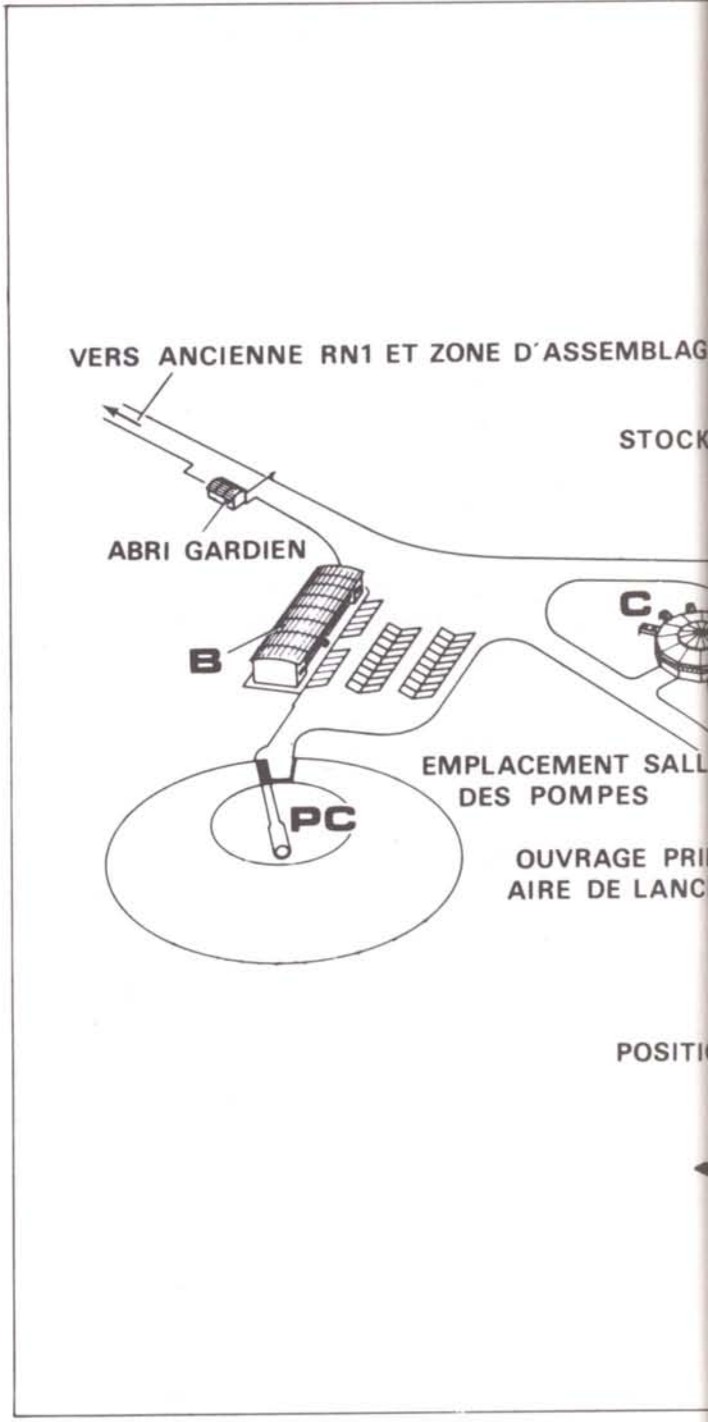
Ces travaux réalisés sous la responsabilité du CNES, assisté par un bureau d'étude Sodeteg, ont commencé en Guyane au début du 2ème semestre 1975 et se poursuivront par les opérations de recette technique provisoire des installations et moyens entre le 1er juillet 1977 et le 1er février 1978. La validation électrique, mécanique et les opérations de remplissage de l'Ensemble de Lancement sont envisagées pendant l'année 1978, la première campagne de lancement Ariane devant débuter en mai 1979 pour l'exécution du premier tir prévu en juillet de la même année.

Le plan ci-contre montre l'organisation générale de la nouvelle Aire de Lancement et du Centre de Lancement à Kourou.

A l'extrême gauche, la route d'accès, protégée par un poste de garde, débouche d'abord sur les bâtiments de bureaux (B) et le parking, puis sur la centrale de climatisation installée dans un bâtiment en rotonde (C) et sur le Centre de Lancement (PC), local blindé enterré d'où sont contrôlées et commandées toutes les opérations finales de mise en oeuvre du lanceur.

L'Aire de Lancement Ariane conserve une grande partie des installations Europa 2, telles que la rampe d'accès (R) et la plate-forme de lancement. Cette plate-forme en béton, d'une part, protège les locaux terminaux qui contiennent les équipements nécessaires aux alimentations, aux contrôles et à la sécurité du lanceur et, d'autre part, supporte le nouveau mât ombilical (M) et la tour de montage mobile (T).

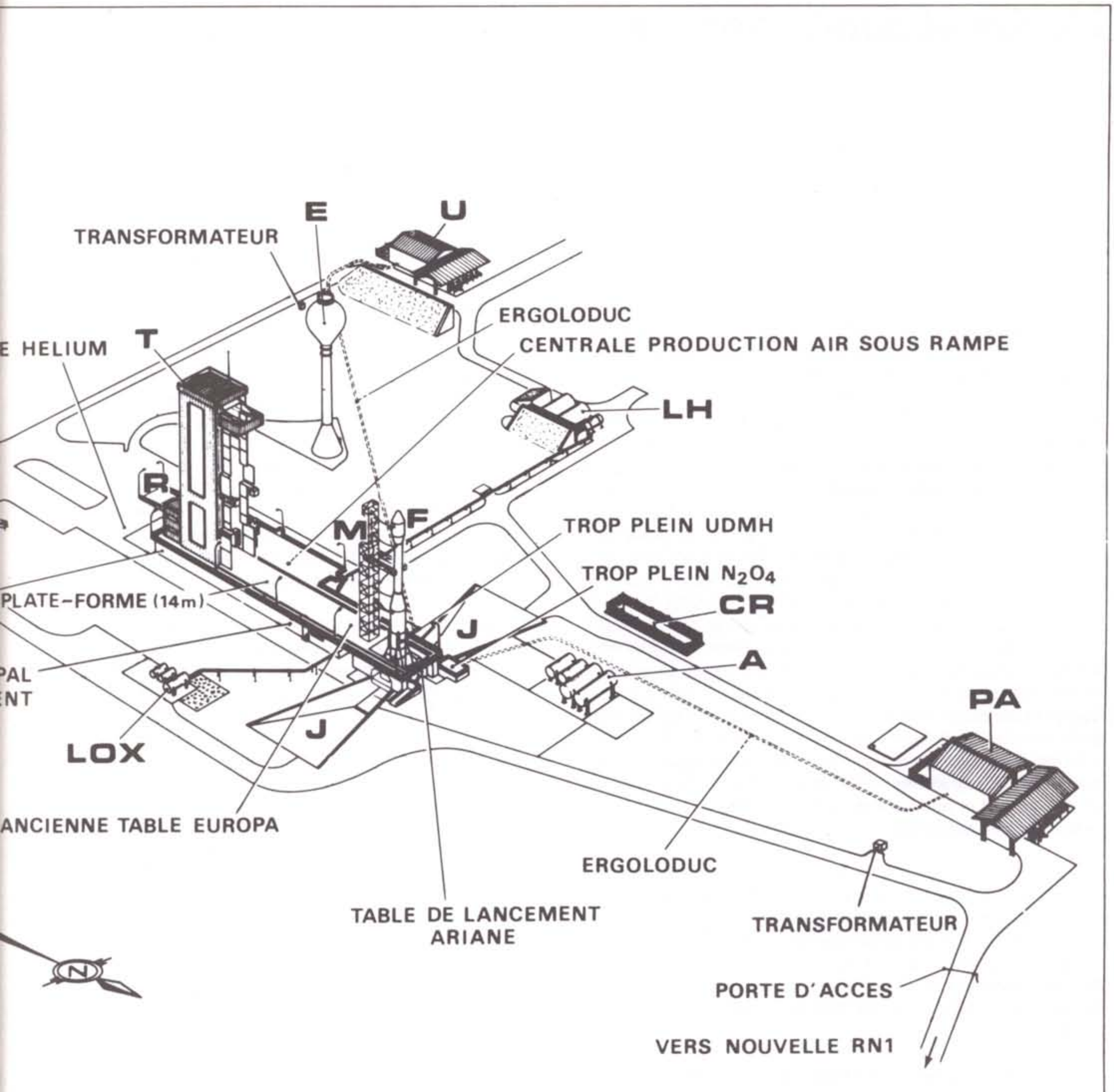
La tour de montage dans laquelle le lanceur (F) est érigé et raccordé à ses équipements permet l'accès aux différents



niveaux de travail sur les étages et assure la protection climatique du lanceur et des exploitants.

La tour de montage Europa 2 (environ 720 t) est intégralement réemployée mais, compte tenu de la hauteur plus importante d'Ariane, a été surélevée de 6,5 m. Pour la même raison le plan de pose de la table de lancement sur laquelle est posé le lanceur sera surbaissée de 6 m environ pour permettre de rentrer le lanceur à l'intérieur de la tour.

Deux grands carnaux semi-enterrés (J) débouchent latérale-



ment sur la table de lancement pour permettre l'évacuation des jets des moteurs du premier étage.

Le système d'avitaillement d'Ariane sera entièrement nouveau et complètement automatisé.

Les deux premiers étages du lanceur utilisent les mêmes ergols UDMH comme carburant et peroxyde d'azote (N_2O_4) comme comburant, tandis que le troisième étage brûle de l'hydrogène liquide et de l'oxygène liquide, l'azote étant utilisé comme gaz de pressurisation.

Les nouvelles aires de stockage sont disposées à proximité de l'aire de lancement: le parc UDMH (U), protégé par un remblai, est situé derrière le château d'eau (E). Le parc hydrogène liquide (LH), lui aussi protégé par un remblai, abrite les réservoirs de stockage et une remorque avitailleur. Plus loin, le parc de stockage du peroxyde d'azote (PA); les réservoirs d'azote liquide et de production d'azote gazeux (A) à côté de la cuve de rétention d'ergols (CR) et, enfin, les trois cuves de stockage d'oxygène liquide (LOX). □

Etudes et applications des matériaux spatiaux

J. Dauphin, Division Assurance Produit, ESTEC, Noordwijk, Pays-Bas

OBJECTIFS

La Section Matériaux de l'ESTEC est née lors de la réorganisation, en 1968, de la Division Assurance Produits qui a abouti à la scission de l'ancienne Section Matériaux et Composants en deux branches. La définition de ses fonctions s'est cristallisée au cours des années et a maintenant atteint une certaine stabilité. Il s'agit essentiellement d'une activité de service: la Section Matériaux opère à 95% en soutien fonctionnel direct ou indirect au profit des différents projets de l'ASE (Fig. 1).

La Section s'occupe uniquement des problèmes technologiques concrets liés aux matériaux — incluant les procédés d'application associés — et à leur utilisation dans l'ambiance spatiale. Elle n'est donc pas engagée, par exemple, dans les études de 'sciences des matériaux' prévues dans la charge utile Spacelab et qui relèvent de la physico-chimie expérimentale. Elle évite aussi de gaspiller ses moyens, forcément limités, en cherchant à résoudre les problèmes de technologie classique, qui pullulent lors de la conception et la fabrication d'un engin spatial, mais pour la solution desquels les contractants de l'ASE sont en principe bien armés et expérimentés grâce à une longue pratique des programmes aéronautiques et électroniques civils ou militaires. Les fonctions de la Section Matériaux peuvent se classer en deux catégories:

(a) *Expertise* (y compris la formulation d'avis et de recommandations sur l'utilisation de matériaux définis dans des circonstances déterminées, ou sur le choix d'un matériau ou procédé susceptible de résoudre un problème particulier). La fonction d'expertise couvre aussi la rédaction de spécifications applicables aux matériaux et procédés spatiaux et la révision des listes de matériaux établies par les maîtres d'oeuvre des projets de l'ASE.

(b) *Essais* (qualification, contrôle de qualité et analyses de défaillances). Ces tâches, qui sont indispensables à la réalisation des projets, s'effectuent au sein des laboratoires de la Section Matériaux.

(c) Il faut aussi mentionner une fonction mineure par le volume d'activité, mais importante par ses implications futures: il s'agit du développement de *technologies nouvelles* dans le domaine des matériaux: produits ou procédés nouveaux, méthodes d'essais, etc.

MOYENS

La réalisation des tâches de la section Matériaux a nécessité la mise en place de moyens matériels et humains compatibles avec sa mission:

(a) Documentation
On a rapidement ressenti le besoin de disposer d'un système de documentation pratique et adapté aux problèmes de matériaux posés constamment par les projets (Fig. 2). Ce système a été mis au point depuis quelques années (voir note technique ESRO TN-120 ESTEC). Sa principale caractéristique est de fournir une réponse rapide aux questions concernant les matériaux, l'accès se faisant à l'aide 'd'identificateurs' simples: nom commercial, fabricant, nature chimique, résultats d'essai de dégazage, propriétés optiques etc. Le programme APL + utilisé est d'une grande flexibilité d'emploi.

Ce système est limité aux documents détenus dans la Section Matériaux, qu'il s'agisse de rapports ou mémoranda internes ou de résultats publiés, car il est destiné à des utilisations immédiates. Il n'y a donc aucune concurrence avec le système 'Recon' — qui est toujours largement utilisé pour établir des bibliographies sur des problèmes nouveaux — mais plutôt complémentarité.

(b) Laboratoires
Les laboratoires de la Section sont implantés à l'ESTEC (voir document ESA TN-128 ESTEC). Ils permettent de réaliser les essais de matériaux en vue de la sélection, de la qualification, du contrôle de qualité ou de l'analyse de défaillance. Ils travaillent presque exclusivement au profit direct des projets de véhicules spatiaux de l'ASE et se limitent aux essais 'typiquement spatiaux' et en particulier à ceux qui ont été mis au point, au cours des dernières années, par la Section Matériaux elle-même.

Les laboratoires réalisent en particulier les essais suivants:

- essais Micro-VCM de sélection au vide thermique (Spécification ESRO PSS-09/QRM-02-T)
- essais d'irradiation UV/protons avec mesures optiques in situ (Fig. 3)
- essais de cyclage thermique (Spécification ESRO PSS-11/QRM-04-T)
- mesures des propriétés thermo-optiques (Spécification ESRO PSS-16/QRM-09-T)
- mesures de contamination de surfaces (Spécification ESRO PSS-15/QRM-05-T)
- mesures d'adhérence de revêtements (Spécification ESRO PSS-18/QRM-13-T)
- mesures d'inflammabilité (ESA QRM-21-T & NASA NHB 8060.1)
- analyse des produits toxiques (NASA NHB 8060.1)

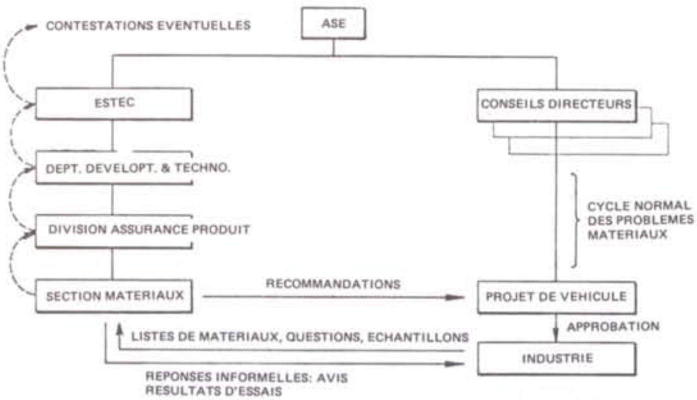


Figure 1 — Schéma des responsabilitès

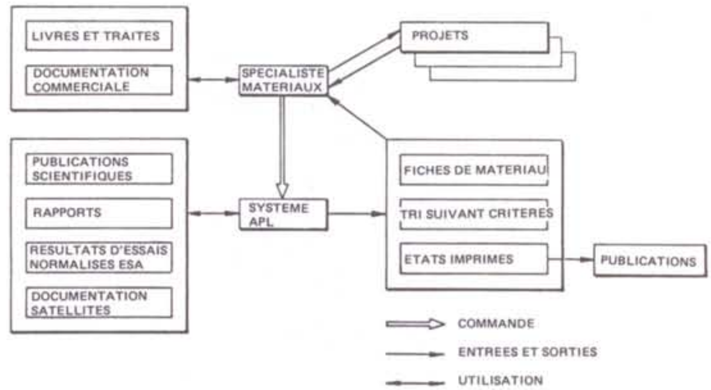


Figure 2 — Circulation de l'information

La Section matériaux intervient en soutien aux projets dans les cas suivants:

- les industriels concernés ne sont pas équipés pour les types d'essais demandés;
- les délais fixés pour l'obtention des résultats sont trop courts pour qu'il soit possible de recourir à un contractant extérieur;
- il est nécessaire de vérifier ou de corroborer les résultats obtenus par d'autres laboratoires;
- des essais préliminaires sont nécessaires pour cerner le problème avant de négocier un contrat;
- des essais sont réalisés au profit des expérimentateurs (satellites scientifiques).

(c) Personnel
Le Personnel de la Section Matériaux, qui se monte actuellement à 16 ingénieurs et techniciens, se répartit en quatre sous-sections: Vide et Contamination, Surfaces et Radiations, Métallurgie et Mécanique, Véhicules habités.

RESULTATS

Quelques chiffres relatifs à l'année 1975 montrent le volume des activités de la Section Matériaux au service des projets de l'ASE:

– Essais Micro-VCM:	315	matériaux à l'INTA
	434	matériaux à l'ESTEC
– Mesures de contamination de surfaces:	979	
– Mesures optiques – absolues:	210	
– par appareils portables:	400	
– Inflammabilité (opérationnel seulement vers la fin de l'année):	100	
– Rapports d'analyses métallurgiques:	108	

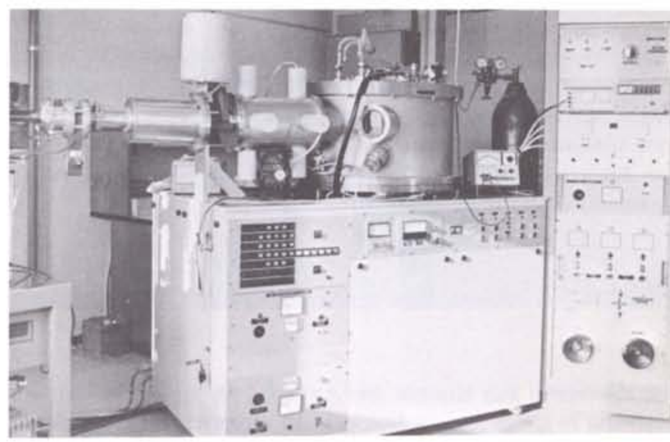


Figure 3. Dispositif d'essais d'irradiation UV/protons.

Les activités ont maintenant atteint un 'rythme de croisière' qui ne devrait pas varier beaucoup si le programme de l'ASE ne change pas notablement de volume au cours des années à venir.

COORDINATION EUROPEENNE

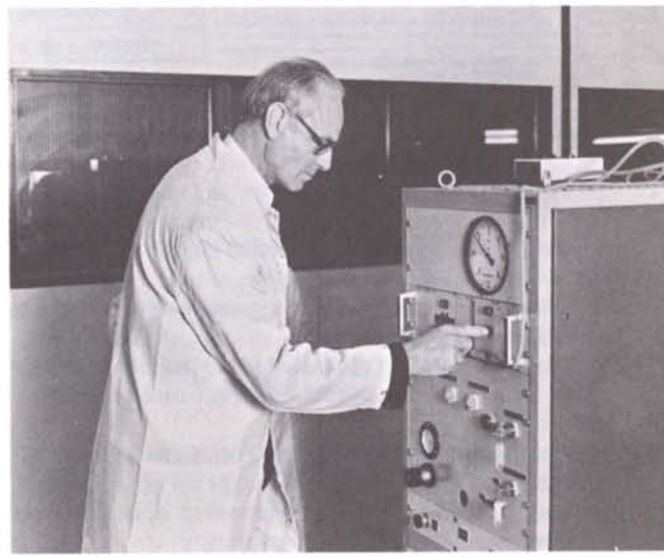
Vers la fin de 1975, il est apparu qu'un effort vers une plus grande coordination des activités concernant les matériaux spatiaux était souhaitable en Europe. Plusieurs réunions, d'abord non officielles puis officielles, ont permis de définir une philosophie d'action au niveau européen. Cette philosophie se caractérise par une coopération *'sous une forme non officielle et sur une base volontaire de participation des Organismes concernés'.*

L'activité s'est orientée d'abord vers un échange de résultats d'essais: un bulletin trimestriel contenant une compilation de ces données (dégazage, mesures optiques, inflammabilité etc.) a été mis en circulation par l'ESTEC entre les firmes participantes. La participation à ce bulletin n'a pas encore atteint le niveau souhaitable et jusqu'à présent y figurent surtout les résultats obtenus à l'ESTEC.

Un inventaire des installations d'essais a été réalisé en commun et distribué aux participants.

Deux séries d'expériences comparatives ont été menées à bien, l'une concernant les propriétés thermo-optiques mesurées dans six laboratoires, l'autre concernant la mesure du dégazage effectuée dans sept laboratoires.

Ces résultats sont encourageants mais il est évident que, avec l'avènement de l'Agence spatiale européenne, des efforts plus importants doivent être accomplis par tous les organismes concernés en vue d'une coopération plus étroite. Les organismes spatiaux nationaux qui ont une activité dans le domaine des matériaux spatiaux peuvent jouer un rôle important et soutenir l'ASE dans ce domaine. □



Mr. A.L. Goedhart commissioning the new DTC facility at ESTEC.

Inauguration of ESTEC's Large Dynamic Test Chamber

Mr. A.L. Goedhart, Chairman of the Administrative and Finance Committee and Netherlands Delegate to the ESA Council visited ESTEC on 22 June 1976 to inaugurate the new Dynamic Test Chamber. The ceremony, witnessed by some 80 invited guests, marked the end of a major effort, begun in December 1972, to provide the Agency with a vacuum chamber suitable for testing Europe's second – and larger – generation of scientific and applications satellites.

In opening this impressive addition to ESTEC's facilities, the result of a co-operative effort by the Centre's Engineering, Test Engineering and Technical Facilities Sections, Mr. Goedhart spoke at some length about the cordial relations between the Agency's staff at ESTEC and the Government of the Host Country, drawing particular attention to the importance of ESTEC's role as a *European centre* for co-ordinated space research and technology: quote

"The signature of ESA's Convention in 1975 and the execution of ESA's current programmes strengthen Europe's position in the space field. This fact inspires confidence and interest both in Europe and outside and attracts possible customers one might not have expected. This development underlines the importance of ESTEC as the up to date European centre for space research and technology. A centre that was created and is maintained by joint effort of the Member States. Here one might perhaps quote the following sentence from ESA's Annual Report 1975: 'Member States which have no national space programme would not wish to see part of their contributions being used as a form of subvention to other Member States' space organisations'. One single glance at the geographic map of Western Europe and its economic situation would suffice to see that Governments, employers and employees should join hands. The heraldic device of Belgium 'l'Union fait la Force' is as relevant as it was in the past. Indeed, Member States are convinced that the magnitude of the human, technical and financial resources required for activities in the space field is such that these resources lie beyond the means of any single European country. They therefore desire to pursue and to strengthen European co-operation, for exclusively peaceful purposes, 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. In this joint venture not only Governments are involved but European society as a whole". □

IN BRIEF / EN BREF

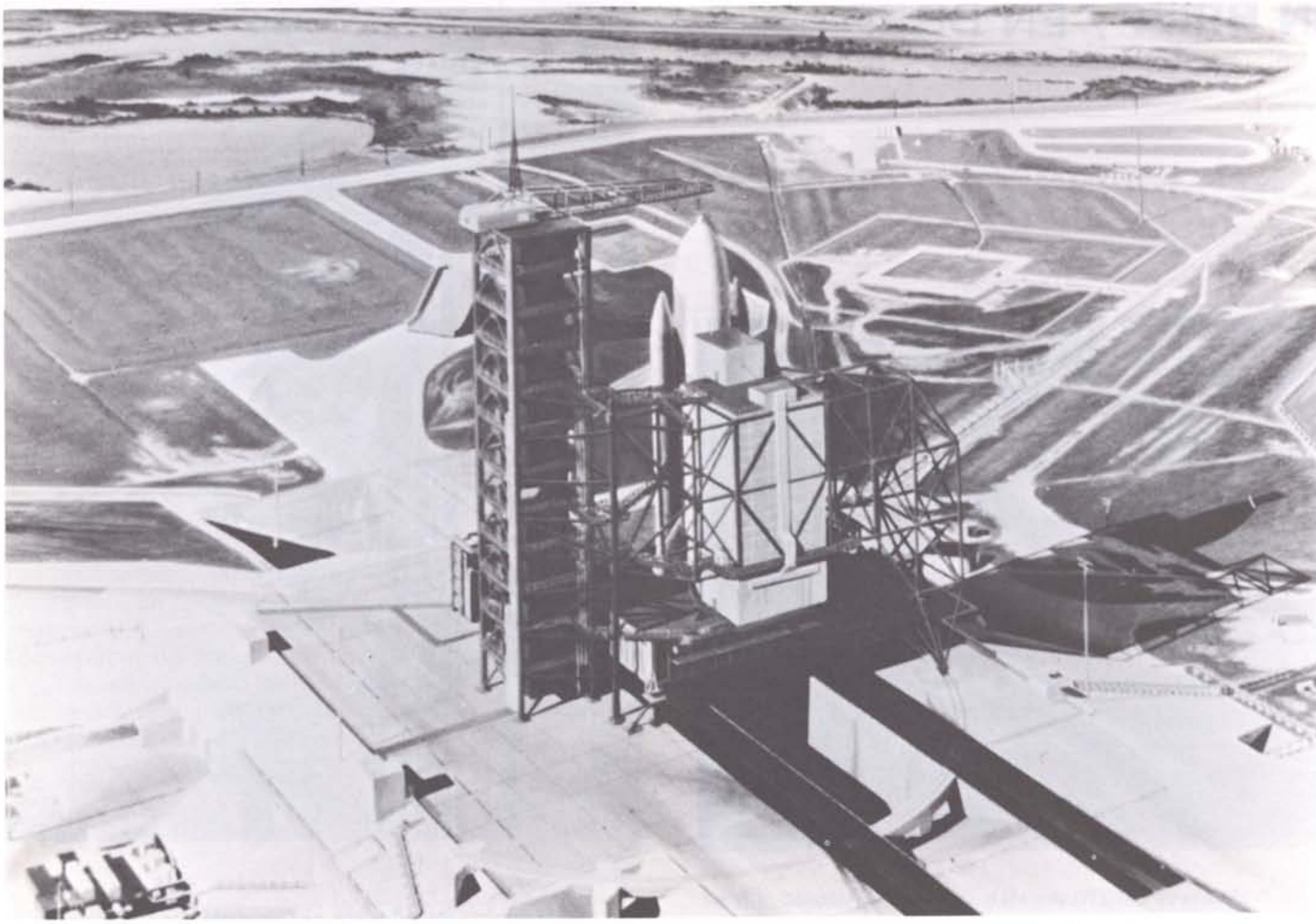
L'ASE au Salon de Hanovre

En participant aux grandes manifestations de l'aéronautique et de l'espace, le service des Relations publiques de l'ASE vise essentiellement à informer le public et à le sensibiliser aux programmes et activités de l'Agence. Au Salon allemand de l'Aéronautique et de l'Espace de Hanovre, du 1er au 9 mai 1976, le stand de l'ASE a attiré une foule importante de visiteurs.

Le stand se trouvait dans le hall B qui regroupait principalement la DFVLR, Dornier, Fokker-ERNO, MBB, MTU. Les éléments les plus marquants du stand étaient les moteurs des divers étages d'Ariane rassemblés autour d'une maquette au 1/10 du lanceur, des modèles grandeur nature d'OTS et de Météosat. Un programme audio-visuel sur trois écrans, dans une salle tapissée de miroirs évoquant l'infini de l'espace, illustrait les multiples applications et utilisations du Spacelab.

Il est difficile de dénombrer la foule qui a visité le stand ASE sur les 200 000 entrées enregistrées par les organisateurs. On a distribué 6000 affiches, 20 000 autocollantes, 25 000 dépliants, sans compter les Bulletins ESA et la documentation plus spécialisée sur les programmes: OTS, Marots, Météosat, Ariane, Spacelab, ainsi que deux brochures nouvellement éditées en allemand, l'une intitulée 'Weltraum in Europa' (l'Europe spatiale), l'autre sur l'ESOC.

Les représentants de l'Agence ont accordé des interviews aux nombreux représentants de la presse parlée, écrite et télévisée. Le 3 mai, 'Journée de l'Espace', le Ministère allemand de la Recherche et de la Technologie (BMFT) a organisé une conférence de presse au cours de laquelle le Dr Strub — représentant le Ministre (M. Matthöfer) indisponible — et M. Gibson — Directeur général de l'Agence — ont pris la parole. A l'issue de la Conférence, l'accord SPICE entre la DFVLR et l'ASE a été signé par le Professeur Jordan et M. Gibson (voir ci-dessous).



The Space Transportation System of the Eighties

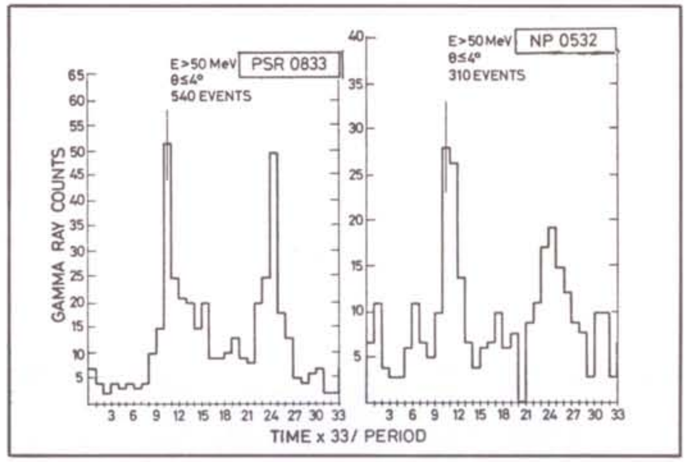
The Space Transportation System being developed for the 1980's comprises three elements: the US Space Shuttle, the European Spacelab and the IUS propulsion system. The re-usable Shuttle will be used to carry Spacelab into a low earth orbit for several days and/or to carry automatic satellites for discharge from the Shuttle in earth orbit and placing into transfer orbit by means of the IUS.

ESA organised a presentation (Paris, 12–14 May 1976) by NASA of the current status and future plans for this Space Transportation System, with ESA staff dealing with the Spacelab portion of the programme. It attracted over 150 senior representatives from governments and industry in ESA Member States anxious to listen to NASA's views on the operation of the Space Transportation System and in particular their charging policy for its use.

Although NASA's considerations are still preliminary, it became clear that they hoped to establish firm fixed prices for use of the System during its first three years from 1980–1983. The basic Shuttle launch cost (excluding the costs of Spacelab and payload operations) was stated to be in the order of 18–21 million US dollars, which fee would include a guaranteed reflight in the case of launch failure. During the transition period from the current expendable launchers to the new reusable Space Transportation System, NASA would ensure the launch using either method, at the price applicable for a Shuttle launch.

Also discussed were the various Shuttle/Spacelab mission activities and the integration of payloads into the Shuttle. An important objective of the Shuttle/Spacelab system is to accommodate all classes of users and to minimise payload costs.

In the ESA Director General's address to the meeting he called particular attention to the several thousands of people in Europe now engaged in the development of Spacelab and the preparation for its utilisation. This alone spoke for the enthusiasm within Europe for further co-operation with the United States in the exploitation of the Space Transportation System.



Outstanding First Year for COS-B

The COS-B γ-ray astronomy mission celebrated its first year of operations on 9 August. Data so far analysed indicate that it has been a highly successful year, contributing much to the investigation of the origin of extraterrestrial gamma radiation and the structure of the Galaxy.

The experimental payload consists of a single instrument provided by the Caravane Collaboration which measures the arrival direction and energy of cosmic γ-rays of energy greater than about 30 MeV. So weak are the source intensities that the γ-ray telescope must spend periods of about one month orientated towards one region of the sky in order to detect the presence of a source. During the first year of operations, COS-B has completed eleven observation periods and has thereby obtained coverage of about 75% of the galactic plane in a latitude range of about +20° to −20°. Two observation periods were dedicated to the study of objects outside our own Galaxy, namely Centaurus A, a radio galaxy, and the Virgo cluster of galaxies – the field of view of the instrument is about ±15°.

During the year extensive use has been made of the experimenters' 'Fast Routine Facility' at ESOC, by means of which the performance of the payload has been monitored and preliminary analysis of the scientific data has been carried out. The value of the FRF was appreciated soon after the launch when, during the Crab nebula observation period, measurements of the pulsed X-ray emission of the Crab pulsar (NP 0532), as detected by the pulsar-synchroniser instrument, were made. By the end of the first period, from the 20% of data made available to the FRF, maps of the arrival directions of the observed γ-rays already indicated the γ-ray emission from the Crab nebula itself and, the first exciting result of COS-B, the existence of a new γ-ray source about 15° away from the Crab (earlier tentatively reported by the SAS II satellite). This new object has not been identified with a source observed by other means, e.g. optical, radio or X-ray astronomy, and for this reason during the second year of operation COS-B will return to scrutinise the region of the new source in greater detail.

The second period was devoted to the study of the γ-ray emission from the galactic centre, a well-known but poorly understood phenomenon. Analysis of the arrival directions indicates that the flux is composed of two components, one of γ-rays produced relatively close to us in the Galaxy (less than 3000 light years away), and a second which is produced more than 10 000 light years away.

At the end of the third observation period, dedicated to the study of the Vela supernova remnant, sufficient information had been accumulated in the FRF to warrant the publication of the first COS-B paper. The γ-emission from a point-like source located at the position of the radio pulsar (PSR 0833-45) was observed to extend to energies in excess of 1 GeV. The pulsed emission from Vela has only been observed at radio wavelengths so it was not possible to use the pulsar synchroniser to correlate the X-ray and γ-ray arrival times, as was done for the Crab pulsar. However, in the analysis of the full data it was possible to transpose the time of detection of the event to the time at the barycentre of the solar system. By this means the doppler effects due to the satellite's motion around the earth and the earth's motion around the sun were eliminated. When examined in this time frame, the events emanating from the vicinity of the Vela pulsar were observed to be pulsed with an 89 ms period, i.e. the same period observed in the radio observations. The 'light curve' of the pulsed emission is shown in the accompanying figure for events exceeding 50 and 200 MeV, with a similar plot for the Crab (33 ms period).

It is remarkable that, like the Crab, there are two pulses; only one is seen in the radio data, and it is noteworthy that the pulses for both sources are separated by 0.40 of the period. Considering that the Crab and Vela pulsars behave so differently at other wavelengths but so similarly at γ-ray wavelengths, it has been suggested that the primary pulsar mechanism may manifest itself in the γ-ray emission and at other wavelengths the observed emission arises from more complex secondary processes.

The intensity of the emission from the Vela source measured by COS-B is about 1.2×10^{-5} cm^{2}s^{-1} for γ-rays above 100 MeV of which at least 85% are pulsed. This value is about twice that reported earlier, although the measured intensities for the Crab and galactic centre are consistent with previous observations. To check the hypothesis that the Vela emission varies with time, a second observation, the first of the second year, was devoted to further study of this source.

The Collaboration have now received the final data for the remaining observation periods of the first year. The detailed analysis is underway and there are already strong indications of exciting new discoveries.

From left to right: D. Lennertz (ESA), A. Maenhout (Belgium), G. Simmen (Switzerland), B.J. Mason (UK), P. Creola (Switzerland), L. Porpqra (Italy), E.A. Trendelenburg (ESA) and M. Bourély (ESA).

Switzerland and United Kingdom sign Protocol authorising ESA to exploit Meteosat

A Protocol authorising the European Space Agency to undertake the exploitation phase of its meteorological satellite Meteosat was signed in Paris on 22 June by Switzerland and the United Kingdom, the first two participating States to sign. The Protocol will remain open for signature by the other participants (Belgium, Denmark, France, Germany, Italy and Sweden) until 30 September 1976, and also provides for other countries to participate.

The Meteosat programme covers the design, development, construction, placing in orbit, management and control of a pre-operational meteorological satellite. ESA's responsibility for checking out Meteosat in orbit during the first six months after launch (scheduled for the third quarter of 1977) will be extended by the Protocol to include the subsequent two-and-a-half year exploitation phase of the satellite. This will be undertaken in close liaison with meteorological authorities in the participating ESA Member States.

Meteosat is being developed for ESA by the COSMOS consortium, with Aérospatiale (France) as prime contractor. It is one of four current ESA applications programmes, the others being OTS (telecommunications), Marots (maritime communications) and Aerosat (air traffic control). □

From left to right: Mr. Chapman (Canadian Assistant Deputy Minister), Mr. André Lebeau (Director of Planning and Future Programmes, ESA), Lady Minister Jeanne Sauvé, Mr. Pelletier (Canadian Ambassador to France), Mr. Roy Gibson (Director General, ESA), Mr. Yalden (Canadian Deputy Minister), Mr. Walter Luksch (Director of Communication Satellite Programmes, ESA).

Visit of Canadian Minister of Communications to ESA

In the course of a three-day visit to the Agency in May (24–26th), Mrs. J. Sauvé, Canadian Minister of Communications, visited the Space Documentation Service at Frascati, the Space Research and Technology Centre at Noordwijk, and ESA Headquarters in Paris. The Lady Minister was accompanied during her tour by her Deputy Minister, Assistant Deputy, and Executive Assistant. □

ESA Scientific and Technical Review

Revue scientifique et technique ESA

Copies of the Review are available free of charge. Requests to be placed on the distribution list should be addressed to ESA Scientific and Technical Publications Branch, c/o ESTEC, Domeinweg, Noordwijk, Netherlands.

The following papers were published in Vol. 2, No. 2.

Improvements in the characterisation of high-power amplifiers in multicarrier operation, *by G. Berretta, R. Gough & J.T.B. Musson*

ABSTRACT

The use of Frequency Division Multiple Access (FDMA) techniques for satellite communications systems is increasing for a number of reasons. The main ones are the flexibility of such systems and the possibility of operating from a large number of small earth terminals. Typical applications are the Marots and Aerosat systems, and possibly North-Sea oil platform communications.

One of the difficulties involved in optimising the communications system is to establish the multicarrier performance of the nonlinear high-power amplifiers on the satellite. This paper describes how this multicarrier performance can be determined accurately without recourse to complex laboratory measurements and expensive computer simulations. The technique described relies upon a knowledge of the statistical properties of the FDMA signal and the monocarrier characteristics of the power amplifier.

RESUME

L'utilisation des techniques d'accès multiple par répartition en fréquences (AMRF) pour les systèmes de télécommunications par satellite se développe pour plusieurs raisons, les principales étant la souplesse d'utilisation qui en résulte et la possibilité de communiquer à partir de plusieurs petites stations au sol. Les systèmes Marots, Aérosat et éventuellement le réseau de communications pour les plates-formes pétrolières de la Mer du Nord en sont des applications typiques.

L'un des problèmes de l'optimisation du système est de déterminer les performances des amplificateurs de puissance non linéaires de bord, lorsqu'ils fonctionnent en multiporteuse. Cet article décrit une méthode précise de détermination de ces performances qui ne fait appel ni aux mesures complexes ni aux simulations coûteuses sur ordinateur. La méthode repose sur la connaissance de propriétés statistiques du signal global et sur les caractéristiques opérationnelles des amplificateurs en mono-porteuse.

Etablissement de modèles mathématiques pour régulateurs de puissance à modulation de largeur d'impulsion (PWM): 2. Modèles continus, *par R. Prajoux, J.C. Marpinard & J. Jalade*

RESUME

Les modèles discrets qui ont fait l'objet de la précédente publication permettent l'étude à petit signal des régulateurs PWM en tenant compte de la nature discrète du phénomène analysé. Toutefois leur mise en oeuvre impose l'utilisation du calcul numérique dès que l'on s'écarte d'un exemple simple; la synthèse des réseaux, souvent malaisée, est conduite suivant des méthodes avec lesquelles les ingénieurs de conception ne sont pas familiers. En effet tout changement dans la partie dynamique de la boucle de commande exige soit de remettre en équation le système global soit de recourir à une approximation. Aussi, afin de disposer d'une méthode permettant de faciliter la simulation ainsi que d'une approche de synthèse de réseaux correcteurs de la boucle de commande par les procédés puissants de la théorie des systèmes linéaires, a-t-on été amené à étudier un modèle continu non linéaire à fort signal et linéaire à petit signal.

ABSTRACT

The discrete models described in the first part of this article led to a study of small-signal PWM power regulators, taking into account the discrete nature of the phenomenon analysed. Their implementation, however, requires digital calculation as soon as complicated examples are involved. Furthermore, the network synthesis is not easy and is carried out using methods with which design engineers are not familiar, any change in the dynamic part of the control loop requiring either a reformulation of the overall system equation or recourse to an approximation. Therefore, in order to derive a method facilitating the simulation as well as an approach to the correcting network synthesis of the control loop by means of rigorous system theory, we have been induced to study a nonlinear continuous model for large signal and a linear model for small signal.

Analyse assistée par ordinateur et simulation du système de puissance de Météosat, *par J.G. Ferrante & A. Capel*

RESUME

Les trois régulateurs (shunt, chargeur, déchargeur) composant le système de distribution d'énergie à barre régulée de Météosat sont séparément analysés du point de vue de leurs perfor-

mances dynamiques (stabilité, bande passante, impédance de sortie).

Les moyens informatiques utilisés sont le programme IMAG III de conception assistée par ordinateur (CAO) et/ou le programme d'analyse de fonction de transfert développé à l'ESTEC. Le choix dépend de la nature de la boucle de régulation (analogique ou à commande PWM) et des conditions de simulation (réponses temporelle et harmonique).

ABSTRACT

The three regulators (shunt, charger and boost) composing the Meteosat regulated bus power-distribution system are analysed separately from the viewpoint of their dynamic performances (stability, band width, output impedance).

The software programs used were the CAD (computer-aided design) IMAG III and/or transfer function analysis carried out at ESTEC. The choice depends on the control-loop characteristics (analog or PWM control) as well as on simulation conditions (time and frequency responses).

Definition of various geodetic datums and transformations between them, *by J.M. Dow*

ABSTRACT

The concepts involved in the definition of regional and global geodetic datums are discussed. Methods of satellite geodesy are classified and the development of the associated datums is described. It is shown how to transform station co-ordinates from one geodetic system to another, the co-ordinates of four ESA tracking stations being taken as an example. Finally, the accuracy achievable in determining the position of a ground station is considered.

RESUME

On examine les concepts relatifs à la définition des systèmes de référence géodésiques régionaux et globaux. Les méthodes de géodésie par satellite sont classifiées et les développements des systèmes de référence associés sont décrits. On expose la transformation de coordonnées d'un système géodésique dans un autre, en prenant comme exemple les coordonnées de quatre stations de poursuite de l'ASE. On examine enfin la précision qu'il est possible d'atteindre dans la détermination de la position d'une station terrestre.

Outgassing from sounding rockets and its significance for aeronomic measurements, *by R.H. Moore & L.J.C. Woolliscroft*

ABSTRACT

Measurements of outgassing from Durestos DTD5511A, a material used on the exterior of sounding-rocket motors, are described. At elevated temperatures, considerable outgassing occurs and mass spectra show that these contaminants would seriously perturb in-situ aeronomic measurements. Surfaces exposed to aerodynamic heating should be clean stainless steel or aluminium alloys.

RESUME

On décrit les mesures de dégazage du Durestos DTD5511A utilisé comme matériau de revêtement des moteurs de fusées-sondes. A haute température, on observe un fort dégagement de gaz polluants, ce qui, d'après les spectres de masse, risque de compromettre gravement les mesures aéronomiques directes. On en conclut que les revêtements exposés à un échauffement par suite du frottement de l'air devraient être en acier inoxydable ou en alliage d'aluminium parfaitement propres.

Note on remote magnetic-field observations with real-time data transmission via telephone lines, *by B. Theile & H. Luehr*

ABSTRACT

The installation and use of two magnetometer stations about 100 km north and south of Esrange, Sweden, is reported. Data collected by these stations were transmitted in real time via telephone lines to, and recorded at, Esrange.

RESUME

On décrit deux installations de magnétomètres implantées à environ 100 km au nord et au sud de l'Esrange (Suède). Les données recueillies par ces stations sont transmises en temps réel par téléphone à l'Esrange où elles sont enregistrées.

Publications

In order to simplify the ordering of ESA and NASA scientific and technical publications, as from 1 September 1976 a single address will be introduced for the receipt of requests for all documents, except that there will initially be two exceptions – those in the ESA PSS series (which are working documents) and public relations material such as brochures, posters etc.

Requests for publications should be addressed as follows:

1 All publications other than those at 2 and 3 below
ESA Space Documentation Service,
114 avenue Charles de Gaulle,
92522 Neuilly-sur-Seine, France.

2 Documents in the ESRO/ESA-PSS series
The ESA Division or Department responsible.

3 Public relations material
ESA Public Relations Service, 114 avenue Charles de Gaulle,
92522 Neuilly-sur-Seine, France.

Unless otherwise requested, and as long as printed hard copy stocks last, orders will be supplied in hard copy form except the following series which are NOT available in hard copy:

- the ESA CR(P) series
- the ESA TT series
- all NASA series.

Future editions of the ESA Bulletin and the ESA Scientific and Technical Review will contain order forms. In the meantime requests should be made by letter or telex (telex ESA Paris 620389).

Publications

Afin de simplifier les modalités de commande des publications scientifiques et techniques de l'ASE et de la NASA, toutes les demandes de documents, hormis ceux de la série ESA PSS (qui sont des documents de travail) et les fournitures ressortissant au domaine des relations publiques telles que brochures, affiches ou autres, seront centralisées à une seule et même adresse à compter du 1er septembre 1976.

En conséquence, les demandes de publications sont à envoyer aux adresses suivantes:

1 Tous les documents autres que ceux des catégories 2 et 3 ci-dessous
Service de Documentation Spatiale de l'ASE, 114 avenue Charles-de-Gaulle, 92522 Neuilly-sur-Seine (France)

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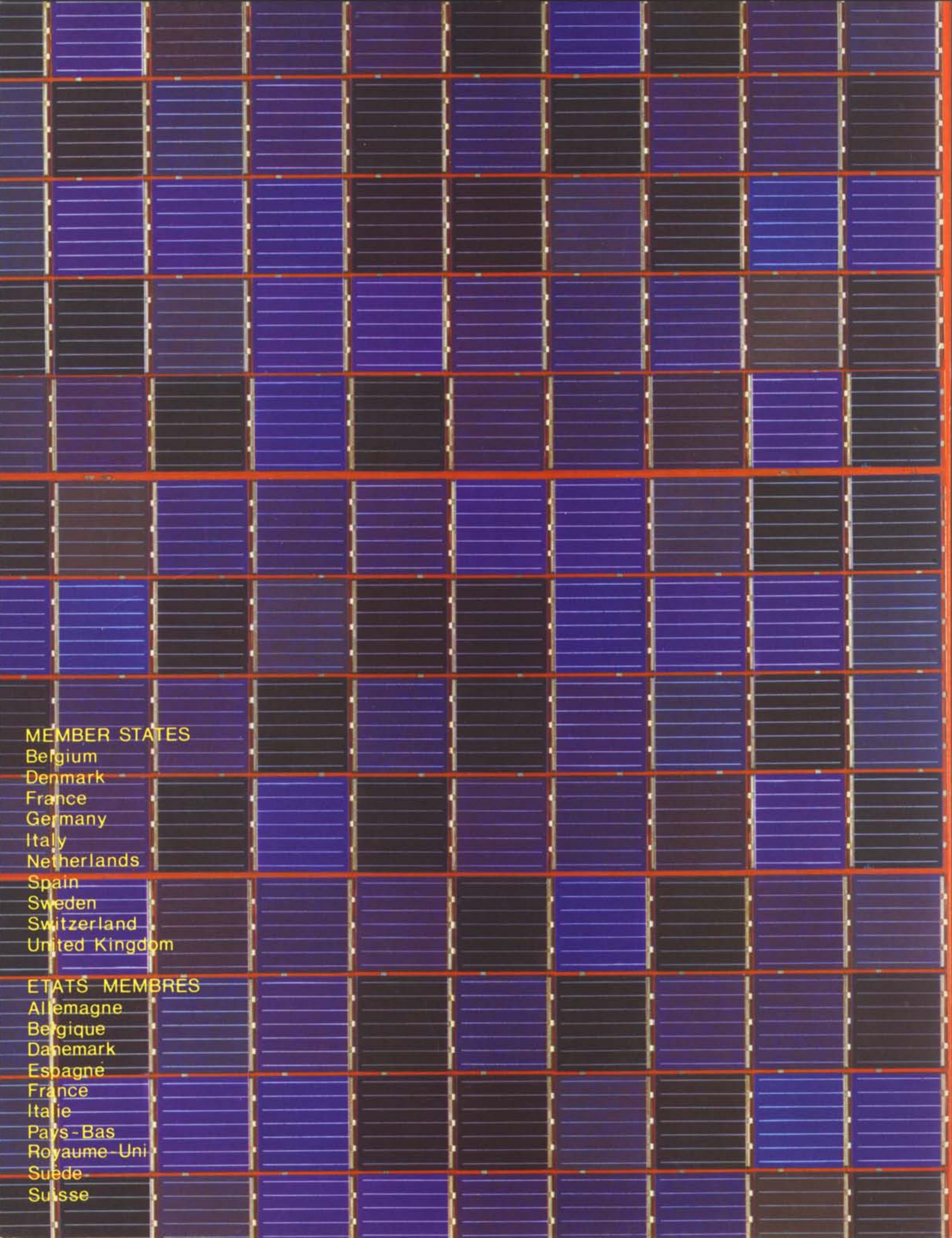

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