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european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Dr. H.H. Atkinson.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

Président du Conseil: Dr. H.H. Atkinson.

Directeur général: Prof. R. Lüst.

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Editorial/Circulation Office
ESA Scientific and Technical Publications Branch
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Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Editorial Assistants
Erica Rolfe, Jim Hunt

Layout
Carel Haakman

Advertising Agent
La Presse Technique SA
3 rue du Vieux-Billard
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A Way Ahead

Prof. R. Lüst, Director General,
European Space Agency, Paris

I would like to share some personal thoughts following the ESA Council Meeting at Ministerial Level in Rome, on 30 and 31 January 1985.

As the Ministers nodded their agreement to the wording of the final Communiqué, no-one in Villa Madama could have doubted that a decision that may prove to be of historical importance had been reached. The way ahead for European cooperation in space had been plotted for the next decade.

For one-and-a-half days, discussion and debate had been lively and forthright, and there were moments when one wondered whether a suitable formula, acceptable to all Member States, could be found. But there was always a feeling of hope, for this was a Meeting noteworthy for the positive approach taken by all the Ministers. The knowledgeable and confident way in which they presented their arguments spoke volumes for the hard background work undertaken by the Ministers and their advisers in the capitals of the Member States and by the ESA Executive. As a result there was a professional and well-informed atmosphere throughout, which enabled Ministers to take and accept decisions on the spot.

On reflection, I see two underlying themes to the Meeting which are most heartening. Firstly, there is a genuine and strong political will within the Member States at the highest level to achieve a European Space Programme. Of course national aspirations cannot be completely subordinated, but there is a better appreciation of what Europe can accomplish as a whole, and particularly the advantages to be gained from having a strong programme when negotiating with other major space powers.

Secondly, cooperation has reached a level of maturity where Member States can talk confidently of autonomy in space research and technology. I take this to mean not that we should attempt to conquer all aspects of space on our own, but that when cooperation with other major space powers is undertaken we have the sureness to seek equitable partnerships.

These two factors will give me a firm base from which to approach forthcoming negotiations with other space powers.

That the Ministers want the World to be fully aware of the outcome of their deliberations was evidenced by their insistence that the Resolution they had agreed should be publicised as widely as possible. The full texts of both the Resolution and the final Communiqué are given after this article.

Of course all sections of the Resolution are important and have significance, but I would like to comment on one or two subjects of more general interest.

The decision that the mandatory science budget should increase by yearly increments of 5% until it reaches 162 million accounting units (US$ 132 million at 1984 economic conditions) was not reached without much heart searching and, on the part of some Delegations, plain hard arithmetic. Some Member States were pressed uncomfortably close to the limits of their financial mandates when, in the spirit of cooperation, and with an acceptance of the central role science plays within the Agency, they agreed to this figure. The hard work of the science community in putting together an imaginative but feasible and viable programme (published as ESA SP-1070: 'European Space Science – Horizon 2000') had therefore been rewarded. The knock-on effect of this decision should not be underestimated: Universities and Institutes will now be able to attract recruits with stimulating programmes.

At the same time Ministers underlined their understanding of the key role of scientific research by requesting us to study possible ways to extend the scope of the mandatory scientific activities to other scientific disciplines. This I welcome and, without prejudice to the traditional space sciences, we shall find ways of accommodating the new sciences, and for them to build on the experiences of our past endeavours.

Of particular public interest must be the decisions to undertake the Columbus venture and the Ariane-5 launcher as optional programmes.


PRESIDENT

The Columbus programme, a major element of our in-orbit infrastructure programme, is offered as a significant part of an international Space Station programme, which the United States of America has proposed. Very shortly I shall be negotiating with interested US Government agencies Europe's response to the USA's offer to participate in the Space Station. It would be discourteous to the USA to reveal the nature of the European proposals in advance of their being sent to the US Government by Minister van Aardenne on behalf of the Member States. As I said earlier, however, our position during the detailed negotiations will be greatly enhanced by the knowledge that we have very strong support for our stance from all the Member States. I hope to return to these negotiations in future articles. This does not represent the end of the Member States' thinking on this subject, for the Resolution expressly tells us to bring forward in due time elements which add up to a fully independent Columbus complex, including polar orbiting platforms. This is far-reaching in its implications.

The decision to endorse the development of the Ariane-5 launcher, equipped with the Large Cryogenic Engine HM60, is a definite step in pursuit of one of the objectives that the Ministers set for us, namely:

'... to strengthen the European space-transportation capacity, meeting foreseeable future user requirements within as well as outside Europe, and remaining competitive with space transportation systems that exist or are planned elsewhere ...'. There can be no questioning that, with Ariane, Europe has a powerful voice in the forum of space-transportation systems. The agreement on Ariane-5 reinforces the policy of Europe reaching and maintaining an independent posture in space. The Resolution also looks further into the future to give due notice of our intention not to rest on our laurels, for there is the invitation to France to keep the Agency informed of progress on the HERMES manned space-plane programme, with a view to its incorporation, as soon as feasible, into the optional programmes of the Agency. Beyond that, note has been taken of the UK studies of the future-generation HOTOL (Horizontal Take-off and Landing Vehicle) project, and significantly other Member States were invited to keep the Agency aware of studies in this area. All this suggests a very vigorous, healthy, and confident look beyond the year 2000; and a commitment to pool ideas for the common benefit of Europe.

All our other programmes have received boosts which are clearly spelt out in the Resolution. One should not overlook the language used '... pursue vigorously ...', 'an enhanced utilisation programme ...', 'advanced payload systems ...', '... second generation'. The Ministers wanted to show that the thrust of European effort was towards well-defined objectives.

Moreover, the need to back all these ambitious programmes by in-depth studies of new technologies and the means of testing them was recognised in the increases to the General Budget, to which the proviso has been added that priority be given to the Technology Research Programme and investments.

Of course there is much to do to turn these good intentions to practical ends, and Ministers understood the problems that surround attempts to reach fair returns to the industries of Member States.

The Resolution therefore lays squarely on my shoulders the need to redress the imbalance in the geographical distribution of contracts, as the central theme in a wide-ranging look at the whole of our industrial policy. We must not forget either that in addition to wanting value for money, Member States expect European space industry to be competitive on the World markets.

In summary, the Member States have given ESA a comprehensive, balanced programme full of interest and challenge. They have done so enthusiastically and with the essential political backing that will ensure Europe's place among the World's major space powers in the decades to come.

Prof. R. Lüst


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Resolution on the Long-Term European Space Plan

(adopted on 31 January 1985)

The Council, meeting at Ministerial Level,

CONSIDERING that the Agency's activities and programmes have proved to be valuable to its Members and associated States and have contributed to satisfy the objectives assigned to the Agency by its Convention,

CONSIDERING the evolution in space activities and their fast expansion both in scope and volume throughout the World,

RECOGNISING that the present scope of the Agency's overall programmes has to be enlarged within a coherent, complete and balanced long-term European space plan to cope with the challenges of the next decade and beyond,

CONSIDERING the offer made to Europe by the President of the United States to participate in the Space Station programme,

HAVING REGARD to the Director General's proposal on the Long-Term European Space Plan,

HAVING REGARD to the proposed level of resources to be made available to the Agency for the coming five-year period 1985–1989,

I. Objectives

REAFFIRMS its commitment to maintain and develop European independent capabilities in space.

AGREES to orient the European Space Programme:

- towards a coherent whole, in which the spending on the tools needed for space activities, and on the activities themselves, such as science and applications, are appropriately balanced; and
- in a direction so that all sectors utilising space techniques are adequately covered, ensuring that they are developed in such a way that advances in one field can be taken advantage of by others.

APPROVES the objectives set out below as guidelines for the Agency's activities during the next decade; these objectives are based on the need for Europe to maintain and build on the achievements of the first two decades of European space cooperation, and to expand Europe's autonomous capability and Europe's competitiveness in all sectors of space activity.

These objectives are in particular:

- to enable the European scientific community, via an expansion of the scientific programme, to remain in the vanguard of space research;
- to develop further the potential of space in the areas of the telecommunications and meteorology;
- to prepare a substantial contribution of space and ground techniques to earth observation science and applications and prepare for the setting-up of operational systems, and of user-oriented organisations to operate them as required;
- to improve the competitiveness of European industry in applications areas by means of advanced developments of space systems and technology;
- to pave the way, via a substantial research programme (materials and life sciences), for practical application of microgravity in space;
- to strengthen European space transportation capacity, meeting foreseeable future user requirements within as well as outside Europe, and remaining competitive with space-transportation systems that exist or are planned elsewhere;
- to prepare autonomous European facilities for the support of man in space, for the transport of equipment and crews and for making use of low earth orbits;
- to enhance international cooperation and in particular aim at a partnership with the United States through a significant participation in an international Space Station.

II. Programmes

Taking into account the above-mentioned objectives,

II.1 AGREES to a balanced long-term European Space Plan for the next decade along the lines proposed by the Director General, leading to a comprehensive autonomous European capability in space and containing the following major elements: in-orbit infrastructure programme, space transportation systems programme and programmes for earth observation, telecommunications, microgravity, space science and technology.

II.2 WELCOMES and ENDORSES the proposal to undertake, as an optional programme in the field of in-orbit infrastructure, the Columbus programme, as a significant part of an international Space Station programme, as proposed by the United States of America; the Columbus programme, whose detailed content will be defined in the course of its preparatory phase and will also depend on the terms and conditions of the partnership agreement to be concluded with the United States, is at present estimated to cost 2600 MAU* until 1995, including a three-year period of operation and initial utilisation,

and ENDORSES the agreement to undertake the Columbus Preparatory Programme.

II.3 WELCOMES and ENDORSES the proposal to undertake, as an optional programme in the field of space transportation systems, the development of the Ariane-5 launcher, equipped with the large cryogenic engine HM60, with a view to completing it by 1995 and at a cost currently estimated at 2600 MAU; and ENDORSES the

* All figures expressed in terms of 1984 economic conditions.

agreement to undertake the Large Cryogenic Engine Preparatory Programme.

II.4 TAKES NOTE with interest of the French decision to undertake the HERMES manned space-plane programme and the proposal by France to associate her European partners, interested in this programme, in the detailed studies and INVITES France and associated partners to keep the Agency informed of progress in these studies with a view to including this programme, as soon as feasible, in the optional programmes of the Agency.

II.5 WELCOMES the proposal to bring forward and incorporate in the Agency's optional programmes, in due time, additional elements of a European autonomous capability in automatic and manned orbital operations, comprising in particular a manned space-transportation capability, a fully independent Columbus complex including polar orbiting platforms, an operational data-relay system, and the development of the necessary technology along with its in-orbit demonstration; to prepare for these future activities, a funding of some 50 MAU per year is envisaged. TAKES NOTE of the studies underway in the United Kingdom of the future generation HOTOL project and, following Annex IV of the Convention invites the United Kingdom to keep the Agency informed. A similar invitation is also extended to other Member States undertaking studies in this area.

II.6 WELCOMES and ENDORSES the proposal to pursue vigorously the Agency's activities in the fields of earth observation, space telecommunications and microgravity, to maintain its activities in space transportation through an Ariane-3 and -4 support programme, and to complement its activities in space technology by an in-orbit technology demonstration programme, and REQUESTS the Director General to proceed with the execution of already agreed optional programmes and the preparation of new ones for:

(i) earth observation, centred around the ERS-1 project already agreed and around future elements, i.e. the ERS-1 follow-on missions on oceanographic and meteorological applications, a land-applications project, participation in the development of the second-generation meteorological satellite, and studies aiming at solid earth, atmospheric and climatology missions. The funding level for the earth-observation activities would rise from 150 MAU in 1985 to a level corresponding to a yearly average of 190 MAU over the period 1985 – 95.

(ii) space telecommunications, building on the achievements reached and centred around the development and the in-orbit testing of advanced payload systems. The funding level for the telecommunications activities would move from 180 MAU in 1985 to around 150 MAU over 1988–95, corresponding to a yearly average of 170 MAU.

(iii) microgravity, centred around an enhanced utilisation programme for Spacelab and Eureca leading to the utilisation of Columbus and the international Space Station for microgravity R&D. The funding level for microgravity activities would increase from about 30 MAU in 1985 to 80 MAU per year over the period 1988 – 92, the funding for the following years being included in the Columbus programme.

II.7 AGREES, in order to reinforce in the next decade space-science activities in Europe, progressively to increase the level of funding of the mandatory scientific programme to reach 162 MAU by 1989;

and REQUESTS the Director General to submit to Council the Level of Resources for the period 1985 – 89 accordingly.

INVITES the Director General to study a possible extension of the scope of the mandatory scientific activities to other scientific disciplines without reducing the effort on the scientific disciplines presently covered, as well as the possible inclusion into the mandatory scientific programme of financial support to groups of experimenters.

II.8 TAKES NOTE that the execution of this long-term European space plan will require a substantial increase in the Agency's resources and that in particular the overall funding level will progressively increase to reach about 1650 MAU per year by 1990.

AGREES that the rise in the General Budget included in the above amount and expected to accompany this expansion in the volume of the Agency's activities, will lead to a level of contributions of 90 MAU per year by 1989; this increase is to be assigned, by priority, to the technology research programme and investments and REQUESTS the Director General to submit to Council the Level of Resources 1985–89 accordingly, to be followed by proposals for the possible improvement of the financial system of the Agency not later than mid-1985, so that Council may decide on them in parallel with the approval of the 1986 Budget.

III. Industrial Policy

III.1 REQUESTS the Director General actively to pursue an industrial policy in line with the objectives defined in the Convention and its Annex V, and in particular:

- to study how the present imbalances in the geographical distribution of contracts have developed and to propose to Council before mid-1985 remedies for the future
- to study what is the degree of specialisation desirable in industry and the methods of achieving it, as well as the industrial structures capable of meeting European needs, of improving the cost-effectiveness of ESA programmes, and of being competitive on the World markets, while striving for a sufficient complementarity between the space firms of the major contributors and the others; and to make proposals to the Council in the near future.

III.2 REAFFIRMS that the objective in the distribution of contracts is to reach an overall return coefficient as near as possible to the ideal value of 1 for all countries and

REQUESTS the Director General to take the necessary measures to achieve a substantial reduction by the end of the next three-year period (1985–1987) in the current imbalances of the geographical distribution of contracts, with the aim of bringing, by the end of 1987, the cumulative return coefficients of all States above 0.95, on the understanding that the appropriate additional measures will be taken from 1988 onwards if this objective is not achieved by the end of 1987.

REQUESTS that correction measures be aimed in the first place at increasing the industrial participation, in particular in the mandatory programmes, of the countries whose overall return coefficient is below the ideal target of 1.

III.3 DECIDES that for the following three-year period (1988–1990) the lower limit for the cumulative return coefficient below which special measures are to be taken to redress the situation and referred to in Article IV, paragraph 6, of the Annex V to the Convention, is fixed at 0.90.

DECIDES that for the next three-year period (1985–1987) the preference clause for the States participating in optional programmes (Article II of Annex V to the Convention) will be waived in favour of the non-participating States whose overall return is below 0.90.

III.4 ACCEPTS, in order to enable the Director General to redress the current situation and thereafter to maintain a balanced geographical distribution of contracts, and when all possibilities for re-allocation of work in the optional as well as in the mandatory programmes have been exhausted, the principle of applying to optional programmes financial compensation measures, such as decreasing for a limited time period the contributions of States whose cumulative return is below 0.90.

III.5 NOTES that, to this end, States, when participants in optional programmes, will include appropriate provisions in relevant Declarations for such measures to be applied for limited time-periods, according to a procedure to be defined.

Communiqué

The Council of the European Space Agency met at Ministerial Level in Rome on 30 and 31 January 1985, under the Chairmanship of Mr. G.M.V. Van Aardenne, Vice Prime Minister and Minister for Economic Affairs of The Netherlands. It reviewed the development of Europe's space activities within the framework of a Long-Term Space Plan and set new directions, building on the achievements of the first two decades of European space cooperation, and expanding Europe's autonomous capability and Europe's competitiveness in all sectors of space activity.

The Ministers, representing thirteen European States and Canada, noted the impressive achievements made by Europe in the space field during the last 20 years, and in particular after the impetus given in 1973 by the European Ministers at the European Space Conference in Brussels. Besides carrying out successfully a large number of scientific and applications satellite programmes, Europe has acquired, through the Ariane programme, an independent and competitive launch capability, and now has access to manned-flight technology through the construction and flight of Spacelab.

They also noted that, during the same period, the exploration and utilisation of space had taken on a substantial economic dimension and that, by the end of the century, space activities as a whole would constitute an important factor in the political, economic and social life of all countries.

Considering also that the large programmes decided in 1973 have now come to a successful completion, that a new Long-Term Plan for space activities in Europe has been proposed, and that the President of the United States has invited Europe to participate in the Space Station programme, the Ministers recognised that the present scope of the Agency's programmes had to be enlarged within a coherent, complete and balanced Long-Term European Space Plan to cope with the challenges of the next decade and beyond.

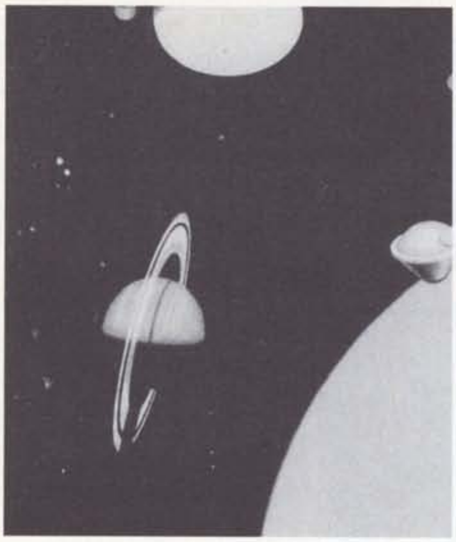
On this basis, the Ministers agreed:

- to a balanced Long-Term European Space Plan for the next decade, along the lines proposed by the Director General, leading to a comprehensive autonomous European capability in space
- to welcome and accept the offer by the President of the United States of America to participate in the Space Station, with a view to continuing and strengthening a genuine partnership in the space field, subject to the achievement of satisfactory agreement
- to reinforce and expand the scientific programme
- to build on existing achievements by pursuing vigorously the Agency's activities in the fields of earth observation, space telecommunications, microgravity and technology
- to initiate the Columbus programme as a significant part of an international Space Station
- to initiate the development of a new-generation advanced launcher system (Ariane-5) equipped with the large cryogenic engine HM 60
- to take note with interest of the French decision to undertake the Hermes manned space-plane programme and the proposal by France to associate in the detailed studies her European partners within ESA interested in this programme
- to welcome the proposal to bring forward and incorporate in the Agency's optional programmes, in due time, the additional elements of a European autonomous capability in automatic and manned orbital operations.

The Ministers also noted that the above decisions would require a substantial increase, between 1985 and 1990, in the Agency's financial resources.

The Ministers recorded their determination to achieve an early and effective implementation of the measures they approved to strengthen the industrial policy and practices of the Agency.

In summary, the Council of the Agency, meeting at Ministerial Level, has shown that the European States share a common vision of Europe's future in space and that the political will exists which will enable Europe to improve its already strong position among the World space powers.



Cassini – A Concept for a Titan Probe

G.E.N. Scoon et al., Future Science Programme Studies Office, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

In April 1984, the Joint Science Working Group (JSWG) on Cooperation for Planetary Exploration* recommended three candidate projects as possible joint missions, of which the Saturn Orbiter Titan Probe (SOTP) was one (Fig. 1). Subsequently, on the recommendation of ESA's scientific advisory bodies, a nine-month joint ESA/NASA Assessment Study was initiated last September of the so-called 'Cassini Mission', the European element of which is a potential candidate for Phase-A (design study) selection in the Autumn of 1985. This article outlines the novel features of this interesting mission and presents a preliminary design concept for the 'Titan Probe' which might represent ESA's contribution.**

Introduction

Titan was discovered in the spring of 1655 by the Dutch astronomer Christiaan Huygens. The first hint that it might have an atmosphere stemmed from observations of the body by the Catalan astronomer José Comas Solà in 1908. Before 1980, Titan was known to be the only moon in the solar system having a substantial atmosphere. Its reddish colour, unique among Saturn's moons, suggested that the chemistry of its atmosphere might be producing 'coloured compounds'. On 12 November 1980, the Voyager-1 spacecraft passed within 7000 km of Titan, its instruments showing that the body's atmosphere (Fig. 2) is denser than that of Earth and that Titan's surface may be at least partially covered by liquid (methane or ethane). This denser atmosphere on Titan, which is composed of methane, nitrogen, and hydrocarbons, but lacks molecular oxygen, has retained conditions much like those that probably existed on all of the planets soon after they formed. The chemical reactions evolving in Titan's atmosphere today may therefore well be giving rise to some of the organic molecules that are thought to have been the precursors to life on Earth.

Scientific payload

Although this article will address itself primarily to the design concepts for the Titan Probe, it is useful to mention the Orbiter's instrument complement, which includes:
- Imaging
- Microwave altimetry/mapping
- Ultraviolet and infrared spectroscopy
- Plasma and dust analysis

* Created in 1982, under the auspices of the European Science Foundation and the US National Academy of Sciences, to study possible cooperation between ESA and NASA in planetary science.

** Named in honour of Giovanni Domenico Cassini (1625–1712), a French-Italian astronomer, first director of the Paris Observatory, discoverer of the Saturnian moons Tethys, Dione, Rhea, Iapetus and the wide separation between the planet's bright B ring and outer A ring ('Cassini Division').

Main Phases of the Cassini Mission

- Launch of the spacecraft in 1993–94
- Earth swingby some three years after launch
- Possible asteroid flybys
- Saturn arrival six to seven years after launch
- Saturn orbit insertion
- Orbital tour of Saturn and its satellites using Titan for gravity-assist manoeuvres
- Titan Probe release and descent to Titan's surface

Figure 1 – Artist's impression of the Saturn Orbiter Titan Probe Mission (courtesy of NASA/JPL)

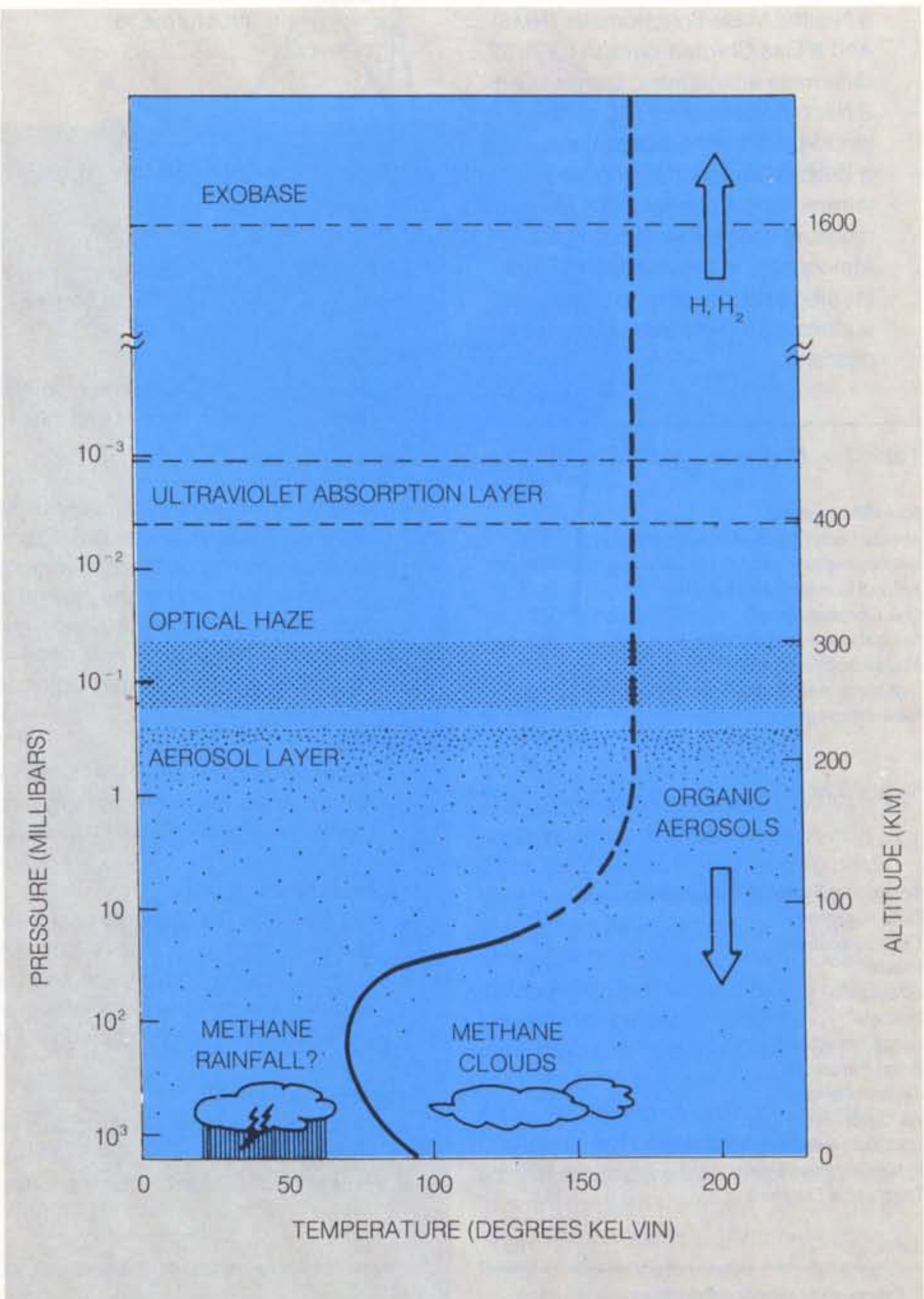


Figure 2 – Schematic of Titan's atmosphere derived from Voyager-1 operations (courtesy of D. Gautier & W.-H. Ip)

- Ion mass-spectroscopy
- Magnetometer
- Low-energy plasma instruments.

The presently defined instrument complement for the Titan Probe (Table 1) includes:
- Atmospheric-Structure Instrumentation (ASI), with accelerometers and temperature and pressure sensors
- a Neutral Mass-Spectrometer (NMS) and a Gas Chromatograph (GC), to determine atmospheric composition
- a Nephelometer (NEP), to measure cloud-particle size distributions
- a Descent Imager (DI) and Near-Infrared Spectrometer (NIS), to measure spectral radiance of the atmosphere in the visible and near infrared and, possibly, to image the surface during the last phase of the descent
- an Aerosol Collector and Pyroliser (ACP), to perform an analysis of the chemical constitution of the aerosols in Titan's atmosphere
- a Lightning- and Radio-emission Detector (LRD), to detect and verify the presence of lightning, determine the scale of cloud turbulence and, by observation of lightning-generated radio waves, yield information on atmospheric properties such as composition, structure and dynamics.

Table 1 – Preliminary Mass Budget

Scientific Payload	
Atmospheric-Structure Instrumentation	3.8
Nephelometer	4.4
Aerosol Collector and Pyroliser	4.15
Gas Chromatograph	3.0
Neutral Mass-spectrometer	12.0
IR Spectrophotometer (IRS)	4.0
Lightning- and Radio-Emission Detector	2.5
Descent Imager	3.0
	36.85
Surface Science	4.15
Total	41.0 kg
Spacecraft Systems/Subsystems	
Data Handling	17.0
Communications	5.0
Power	17.5
Structure*	15.0
Harness*	9.0
Large Parachute*	9.5
Small Parachute*	6.0
Jettison Devices*	8.0
Aft Cover* (incl. Spin Release Mechanism)	4.0
Nose-Cap Heat Shield	5.0
Deployable Decelerator*	14.0
Total	151.0 kg

* Estimated or extrapolated values

Mission scenario

The Probe mission scenario can be divided into four phases:
- launch and cruise
- coast
- entry
- descent.

During the launch and cruise phase, the Probe is mounted on one of the Orbiter's lateral axes [decelerator folded on the Mariner Mk-2 Orbiter spacecraft (Fig. 3)]. It is released from the Orbiter by a spin-

Scientific Objectives of the Cassini Mission*

Saturn
- Thermal structure, cloud properties, and composition of the atmosphere
- Atmospheric dynamics and general circulation of the atmosphere

Rings
- Configuration and composition of the ring system, dynamical processes in the rings, interrelation of rings and satellites

Titan
- Thermal structure and composition of the atmosphere, with special emphasis on physiochemical processes driving prebiotic chemistry. Nature and location of aerosols and clouds, search for lightning
- Atmospheric dynamics and general circulation of the atmosphere
- Investigation of topography, state, history, and composition of the surface, and the nature of the atmosphere – surface interaction
- Interaction of Titan with the solar wind.

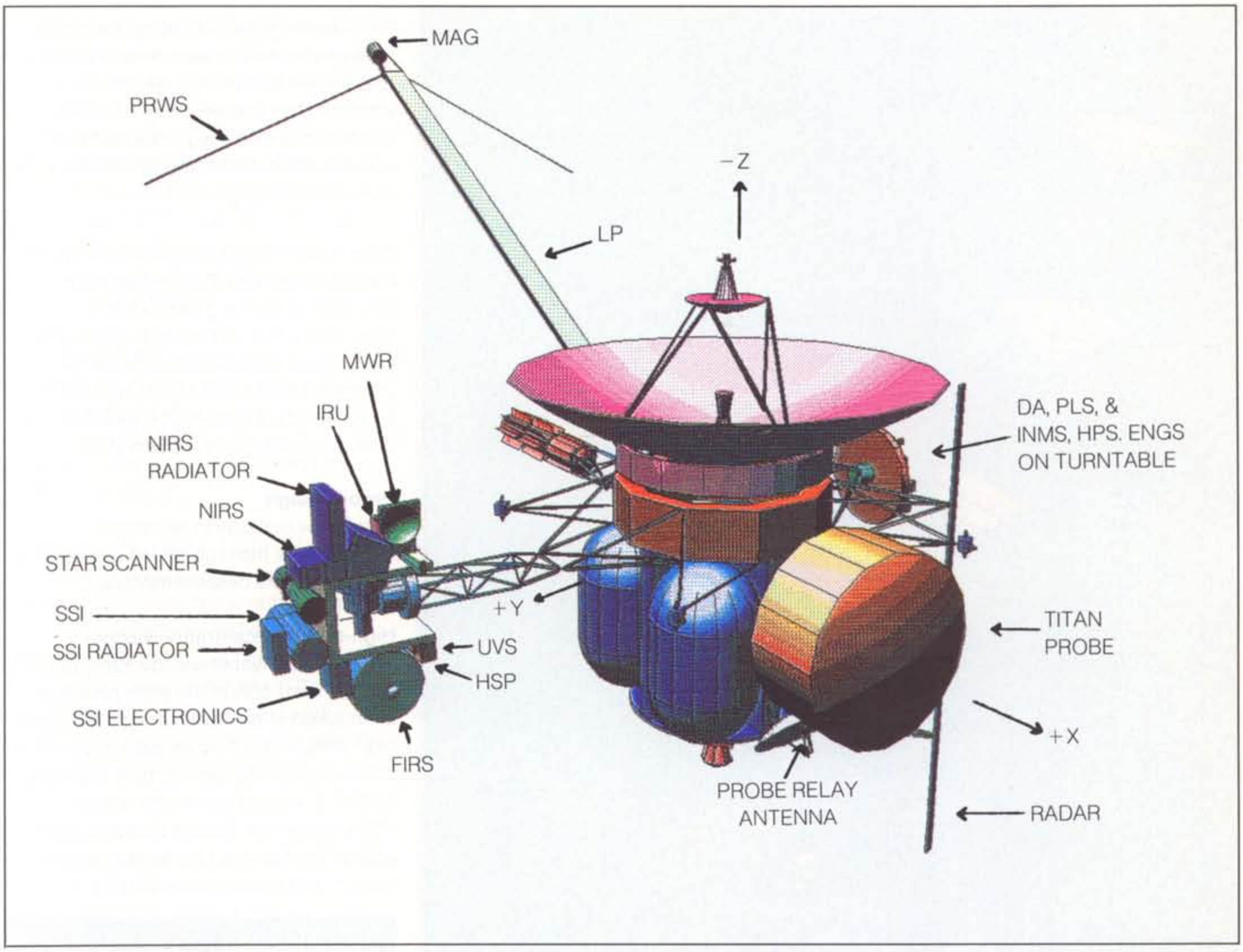
Satellites
- Surface properties and bulk composition of satellites to determine origins, sources of internal activity, and processes responsible for surface modification. Comparative studies within the satellite system

Magnetosphere
- Configuration and generation of the nearly axially symmetric magnetic field and its relation to the modulation of Saturn Kilometric Radiation (SKR)
- Current systems; composition, sources and sinks of thermal and energetic charged particles, and dynamics of the magnetosphere of Saturn and its interactions with the solar wind, the satellites, and the rings

Targets of Opportunity
- Definition of asteroid and/or comet properties from flyby with existing payload *en route* to Saturn
- Post-impact studies of Titan's surface and atmosphere by the Probe

* Draft scientific objectives per September 1984, at the start of the joint ESA/NASA Assessment Study.

Figure 3 – Orbiter and Probe in cruise-phase configuration (courtesy of NASA/JPL)



eject device and an umbrella-like deceleration system is deployed prior to the Probe's entry into the Titan atmosphere. In this phase, the descent module within the Probe is isolated from aerodynamic heating by a fore body, consisting of a nose cap and heat shield, and an aft cover on its rear face. Probe stability is provided by the aerodynamically stable entry configuration and its spinning mode.

The large deployed drag area will reduce the Probe's entry velocity of 7.1 km/s to subsonic levels at an altitude of about 200 km above Titan's surface. The deceleration system will be jettisoned at this point, the descent module passing through the decelerator as it is retarded due to its larger drag surface (Fig. 4).

The subsequent parachute-deployment sequence is initiated by firing a pyrotechnic device and deploying the drogue chute through a hole near the centre of the Probe's aft cover. The aft cover is pulled away after firing separation bolts and, once it has separated far enough from the Probe, the main chute is deployed. The Probe's spinning motion is assured by a swivel mechanism between the parachute harness and the descent module, and possibly also spin vanes on the Probe.

The covers of the inlets and viewing ports are opened by pyrotechnic devices to allow the scientific instruments to begin their measurements and sampling during the Probe's descent through Titan's atmosphere. In parallel, scientific data transmission is initiated over the radio link between Probe and Orbiter, for retransmission from the Orbiter to Earth.

After one hour of sampling, the large parachute will be released and a second, smaller chute deployed to speed up the descent through the lower, denser parts of Titan's atmosphere. [Another option being considered is to use only one large parachute with adaptive control during

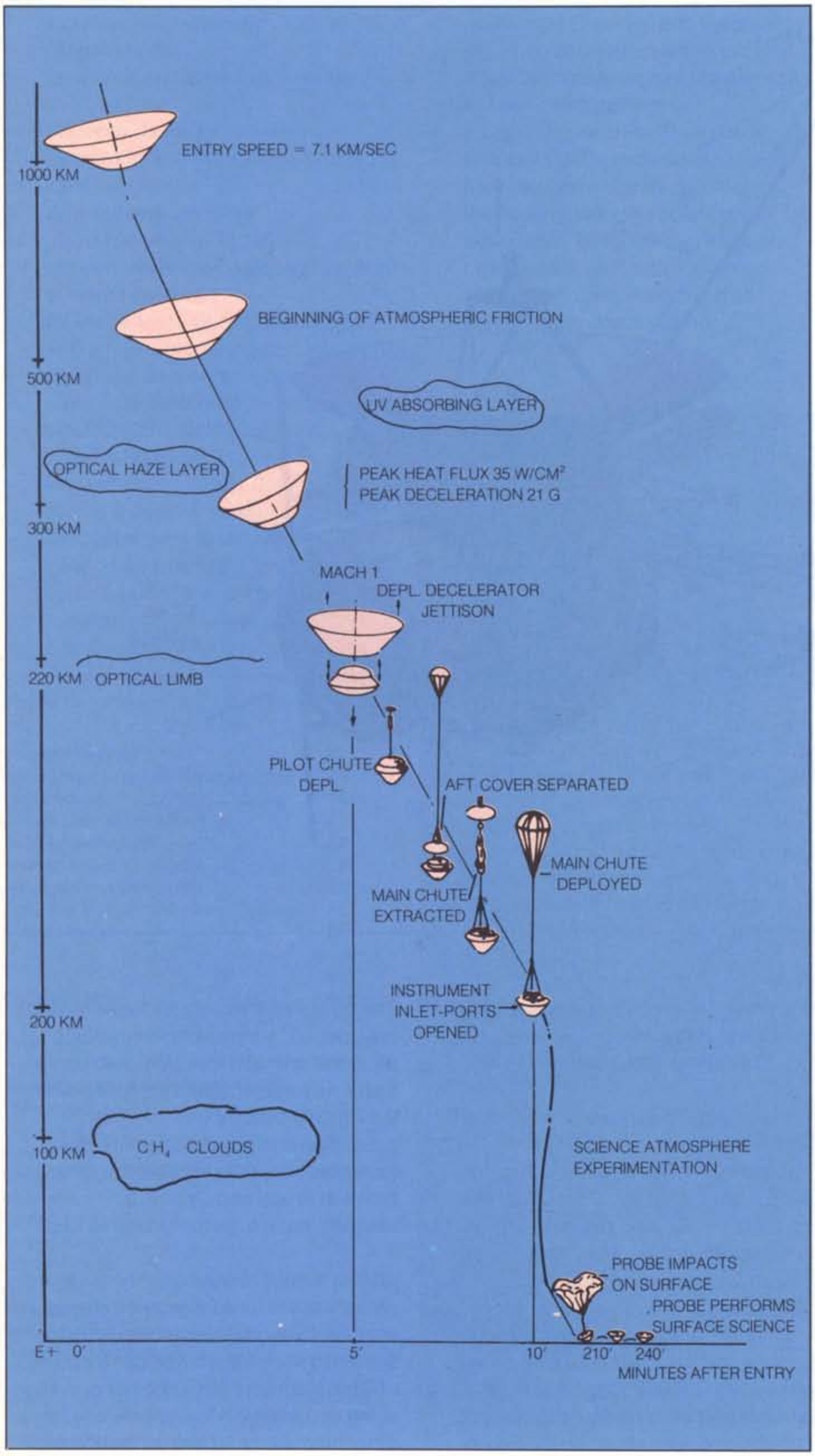


Figure 4 — Entry and descent scenario for Titan's atmosphere

the descent phase, so that compatibility between scientific measurement profiles and environmental profiles can be ensured. This implies that the Probe's behaviour and its height above Titan's surface would be sensed as inputs for full autonomous operation.]

After more than two additional hours of sampling, the descent module will impact on Titan's surface. The module's crushable structure will reduce the effects of the impact deceleration presently estimated at about 3 m/s, to a level that increases the chances of survival of the descent module's instrumentation.

Probe design

The Probe consists of two major components, the high-speed deceleration system and the descent module.

High-speed deceleration system

This is a deployable aerodynamic braking system, used only in the entry phase of the mission to achieve subsonic speed at high altitude, to allow an early start to the atmospheric measurements. A deployable system is needed due to the volume restrictions in the Shuttle's payload bay and on the Mariner Orbiter during the launch and cruise phase (Fig. 5).

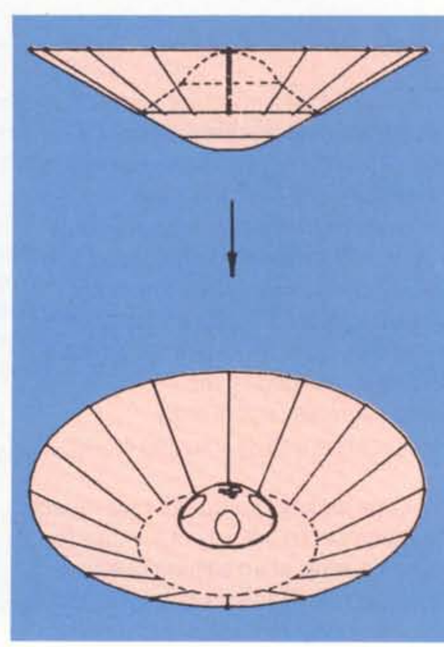
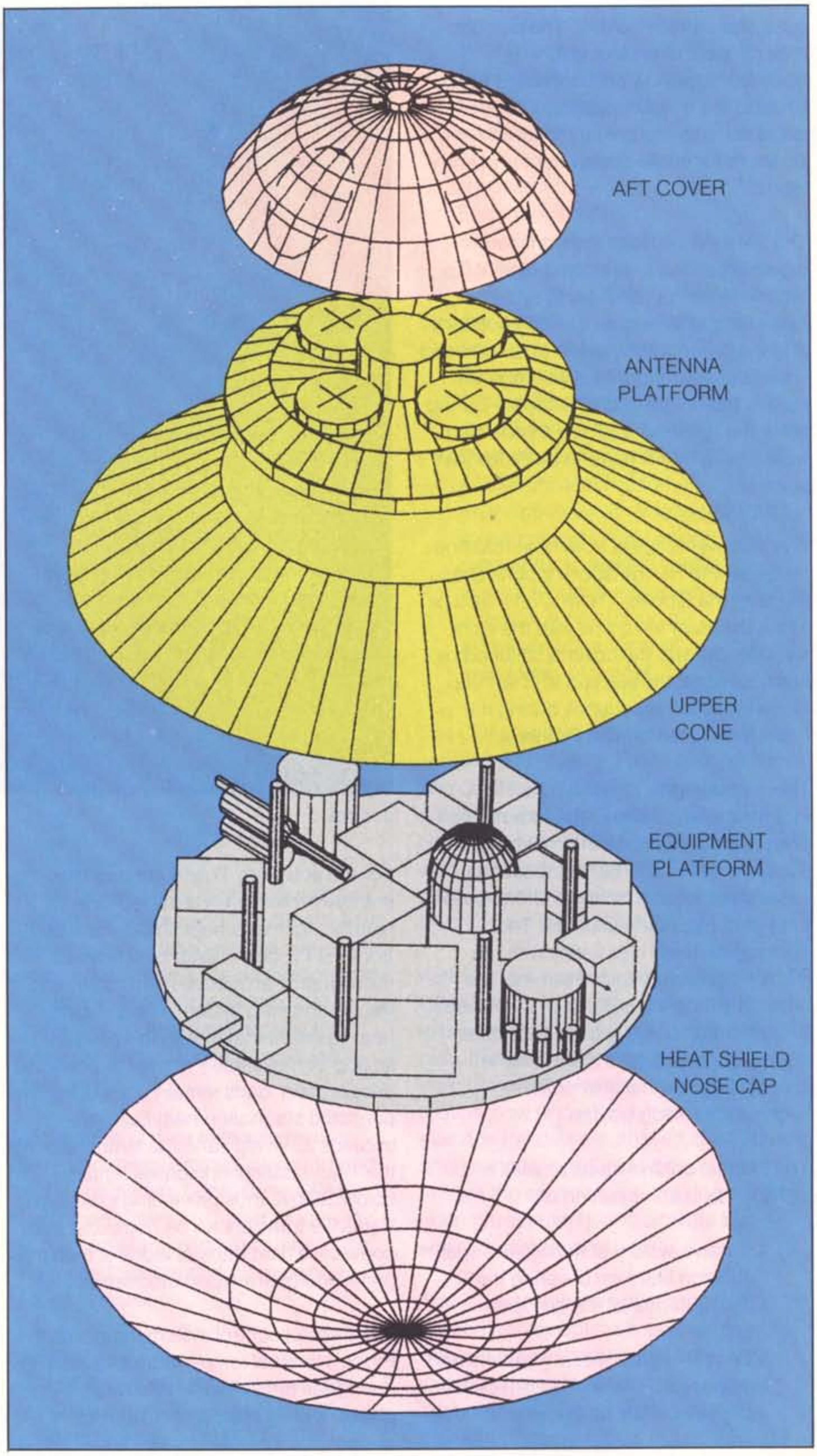


Figure 5 — The Probe's deployable aerodynamic braking system

Figure 6 – Exploded view of the Probe showing the major modules



The deployed decelerator looks like a frustrum of a cone, with 60° half-cone angle and an outer diameter of 3.3 m. The inner diameter (1.5 m) has a ring interface with the descent module, which can be parted pyrotechnically when subsonic speed is achieved. The deceleration structure consists of 16 deployable ribs, which support a high-heat-resisting carbon cloth, shortly after the Probe's release from the Orbiter.

Descent module

The descent module consists of a heat shield, its support structure, which forms the outer envelope of the Probe, the equipment and antenna platforms, and the aft cover (Fig. 6).

The heat shield is made up of a 4–5 mm thick beryllium nose cap, which acts as heat sink during the Probe entry phase. It is isolated thermally from the Probe's interior compartment. Sections of the nose cap can also be ejected in the descent phase to free the inlets and viewing ports for operation of the scientific instruments and their detectors.

The outer envelope of the Probe payload and equipment compartment consists of two conical cylinders, which are connected at their outer diameter, closed at the lower end by a thin inner nose cap and at the upper end by the antenna platform. The lower cone interfaces with the equipment platform, where most of the supporting equipment and the scientific payload are located. The cones have cutouts over the instrument viewing ports. These ports are closed by ejectable covers which are jettisoned at the start of the descent phase.

The equipment platform, carrying all scientific instrumentation and subsystem equipment, is located as low as possible in the outer envelope of the Probe for stability reasons, to keep the overall centre of gravity low. All instrument packages and the communication and data-handling subsystem are located on the top side of the platform, the power subsystem on the bottom. The platform itself consists of an aluminium honeycomb sandwich, connected by six struts to the antenna platform. These struts serve as the primary load-carrying structure for chute-deployment and entry loads.

The antenna platform supports four dipole antennas and the strip-line of the L-band antenna (an S-band system is also being assessed as a second option) and the parachute systems. In launch and cruise configuration, its outer edge is connected on the Orbiter adapter. During entry, the antenna platform is protected from aerodynamic heating by Probe's aft cover.

The aft cover is made from heat-resisting material, with RF-transparent ports over the antenna dipoles. There is an interface at the centre of the dome with the spin-eject device, and the cover is stiffened by ribs to support the ejection and spin-up loads that it will experience during the Probe's release from the Orbiter.

Thermal design

The most demanding of the four mission phases on the Probe's thermal-control subsystem seems to be the coast phase, between its release from the Orbiter and entry into Titan's atmosphere. The duration of this phase varies with the mission scenario chosen, but is of the order of 10 – 25 days. Most of the Probe's instrumentation is in a quiescent state during this phase, and therefore the spacecraft's internal environment becomes markedly colder.

The thermal control for all phases is provided by a combination of:

- a passive system of multilayer super-insulation blankets covering the sides and rear of the descent module
- a complement of electric heaters and Radio-isotope Heater Units (RHUs)
- a high-emissivity nose cap and heat shield.

Characteristics of Titan (after Lindal et al.)

Surface radius	2575.0 ± 0.5 km
Mean density	1.881 ± 0.002 g/cm^3
Rotation period (Davies et al., 1980)	15 d 22 h 41 min 26.9 s
Distance Earth – Saturn	1.278 (min) – 1.577 (max) × 10^9 km
At the surface:	
Atmosphere pressure	1496 ± 20 mbar
Atmospheric temperature	94.0 ± 0.7 K
Acceleration of gravity	1.354 ± 0.001 m/s^2

For the 6 – 7 years of the launch and cruise phase, the Probe will provide a thermal environment for its subsystems and instrumentation between the limits of −20°C and +40°C. To maintain the Probe temperature equal to or greater than −20°C during the subsequent coast phase, about 30 W of heating is required. This may be provided by Radio-isotope Heater Units to conserve the Probe's battery power, a precious resource. The RHUs would generate a constant heat throughout the mission, but temperature stability can be achieved by adaptive control.

For the entry into Titan's atmosphere, thermal protection is provided by a metallic nose cap/heat shield, insulated from the Probe's interior by a layer of microquartz, an insulated aft cover, and the aerobraking system made of high-heat-resistant material. In this phase, lasting approximately 4 min, the predicted deceleration loads remain below 21 g, the predicted stagnation heat flux never exceeds 35 W/cm^2, and the temperature of the Titan atmospheric gases remains below 5500 K, thus preventing ionisation. Radiative transfer can be neglected and convective heat transfer alone is then the prime energy-transport mechanism.

The thermal control system maintains the Probe's internal temperature around 10°C during the remainder of the descent phase, until its impact with Titan's surface.

Electrical design

The main electrical design requirements are:

- a high degree of fault tolerance, because of the uniqueness of the scientific mission
- a high degree of reliability after long periods in an inert state
- flexibility and autonomy of the Probe's management during the various mission phases, particularly during the descent phase, to cope with the mission environment and maximise the overall scientific return.

Other significant features affecting the electrical design are:

- the Probe's spin-stabilisation during the coast phase and aerodynamic stabilisation at entry and during the descent phase, so that no attitude-control system is required
- the impossibility of using solar arrays to produce onboard power, because of the low solar radiation at about 10 AU
- the automatic acquisition and tracking of the Probe by the Orbiter radio-relay receiver 10 – 25 days after Orbiter/Probe separation.

Three different options are available, in principle, as power sources: high-energy-density batteries (primary or secondary) and Radio-isotope Thermal Generators (RTGs). However, the Watt-hour requirement (about 1.3 kWh) is not large enough to justify all the problems that

Figure 7 – The clouds covering Saturn's satellite Titan are seen in their true colours in this image taken by Voyager I from a distance of 4.5 million kilometres (courtesy NASA/JPL)

using an RTG implies, such as its accommodation in the Probe's structure, ground handling, safety and cost. The baseline design therefore considers lithium-sulphurdioxide ($LiSO_2$) and lithium/thionyl-chloride batteries, which have gravimetric energy densities in the order of 200 Wh/kg and 250 Wh/kg, respectively.

The required energy of 1.3 kWh (including a growth potential of 25% and mission margin of 10%) is to be supplied by five identical batteries, weighing some 11.2 kg, which will have to be reactivated after their 6–7 years of storage during the Probe's cruise phase. During this phase, all power needs are to be serviced by the Orbiter's DC bus.

For power distribution within the Probe two AC buses fed by an arrangement of two inverters (prime and redundant) have been selected, partly because of the well-known advantages of centralisation and ease of distribution/interfacing, and partly because of the flexibility they give for payload changes during the mission's evolution.

Command and data management
The requirements on the Command and Data Management Subsystem (CDMS) during the Probe's 6–7 year journey in the interplanetary medium can be categorised according to the various mission phases:

Cruise phase
- Data processing and formatting
- Collection of housekeeping data
- Data storage
- Periodic in-orbit checkout
- Health monitoring
- Reconfiguration
- Command decoding and distribution

Coast phase
- Event monitoring
- Health monitoring
- Back-up programs

Descent phase
- Activation of subsystems
- Data storage
- Data collection and command distribution
- Data processing and formatting
- Activation/deactivation of experiments according to required measurement profile and/or detection of specified events
- System reconfiguration as part of the adaptive control concept
- Adaptive sequencing of entry/descent events.

The CDMS is split in two parts, the Orbiter complement and the Probe complement. The Orbiter complement performs the cruise-phase housekeeping, periodic checking of the Probe during this phase, and reprogramming of the Probe's CDMS complement processors via the NASA Deep-Space Network (DSN).

Activated by a sequencer, the Probe CDMS switches on all units and experiments according to a predefined plan. If altitude- and environment-sensor data are made available to the CDMS (option now under study), it can also manage the descent phase's development and timing by producing commands to release the aerodynamic braking system, open parachute(s), and activate the scientific instruments.

This would have the advantage that a descent profile optimally tailored to the descent environment could be achieved, instead of one designed for the worst-case environment as known at the moment of launch.

Data relay

The Radio-Relay Subsystem (RRS) is split into two parts: the Orbiter RRS to communicate with Earth, consisting of two (prime and redundant) receivers, a medium-gain antenna, an antenna-pointing mechanism and associated electronics unit; and the Probe RRS, consisting of two (prime and redundant) transmitters and a low-gain antenna producing a 60° pencil (conical) beam, to communicate with the Orbiter. Typical data rates could be 1 kbit/s during the first part of the Probe's descent, increasing to 2 kbit/s or more (depending on link margin) very near to Titan's surface for imaging and/or surface science.

With the 3–4 hour Earth-Orbiter-Probe link and return turnaround time, which is comparable with the Probe entry and descent time, real-time or near-real-time ground control in the Titan-approach phase of the Probe's mission is not feasible.

The technological challenge

The scale of the tasks related to the mission requirements for the Titan Probe opens up new areas of technological and engineering challenge compared with previous ESA space missions. Preliminary assessment and design studies have indicated that these areas may be exploited with the expertise and technologies presently available or under development in Europe. Some of the main areas of technological challenge are:

- Aerodynamic Deceleration system
  This system has to be stowable owing to volume and mass constraints imposed by Probe design, Orbiter-Probe configuration and composite-launch-system envelope constraints. The materials used must be selected for long life, high heat resistance, low mass and relevant material strength. Its correct functioning after 6–7 years in the interplanetary space environment is absolutely critical to the mission's success.

- Aerodynamic and Thermodynamic Performance
  Sophisticated numerical tools will be used to analyse, evaluate and trade-off the predicted performances of several optimised entry-body shapes in Titan's atmosphere.

- Materials
  Materials have to be selected for high-strength, low-mass structural elements, the thermal protection shield to withstand relatively high stagnation heat loads, long-life lightweight parachutes compatible with the mission's lifetime and operation in Titan's environment, and for high-reliability mechanisms. Materials used in the lower region of the Probe, which is expected to impact Titan's surface, must possess energy-absorbing properties to cushion the predicted 'soft' landing and enhance the chances of Probe survival after impact.

- Radio Relay Link
  This system, which would be resident partially on the Orbiter and partially on the Probe, must provide autonomous acquisition, pointing locking, and reliable transmission. The Probe-Orbiter link is mission critical and, given the 3–4 h round-trip command time from Earth, calls for autonomous, robotic operation on the part of both elements of the link.

- Primary Power Sources
  The Probe is supplied with electrical power by the Mariner Mark 2 Orbiter during the cruise phase. However, autonomous long-shelf-life, high-power-density sources must power the Probe during its final coast and descent phases to Titan's surface. Lithium based primary sources are a possible option, but the feasibility of using this relatively new technology has to be carefully analysed.

Conclusion

Although the challenges of this potential joint US–European cooperative venture may appear to the layman to take us to the frontiers of current technology, the Titan mission seems to be a realistic objective, with high potential returns and spin-offs for Europe in science, engineering and technology.

Acknowledgement

The author would like to acknowledge the contributions made by the other study-team members to the preparation of this article.

Soho and Cluster: Europe's Possible Contribution to the ISTP

A. Atzei, J. Ellwood & G. Whitcomb, Future Science Programme Studies Office, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

The Soho and Cluster missions are presently in the detailed design feasibility stage of study and will be candidates for selection as ESA-approved missions at the end of 1985. Subject to this approval, both could be launched in the 1992 to 1993 period and would operate for a minimum of two years. Soho would carry sufficient fuel to allow extension of its lifetime to six or more years, as the science would benefit significantly from observation of the Sun over at least half of the 11-year solar cycle.

The remaining missions of the ISTP are expected to be launched prior to 1992. By 1995, therefore, we could witness a major step forward in man's understanding of the processes that affect the Sun–Earth relationship and directly or indirectly influence the environment in which we live.

The International Solar Terrestrial Physics Programme (ISTP)

In recent years there have been a number of mission proposals from the international science community which have all had the one objective: to further man's understanding of the interactions between the Sun and the Earth and to extend this knowledge to the planets. Recognising this common interest, a three-cornered discussion between NASA, ESA and the Japanese Agency ISAS was held in September 1983 to define a programme that combined the individual proposals and integrated the data for mutual benefit. The resulting programme, called the 'International Solar Terrestrial Physics (ISTP) Programme', is a coordinated set of missions, with spacecraft from the USA, Japan and Europe (Table 1), all of which are intended to be launched in the coming decade.

The US contribution is expected to consist of three spacecraft called 'Wind', 'Polar', and 'Equator'. These, as their names suggest, will study the solar wind and the polar and equatorial regions of the Earth's magnetosphere. The Japanese contribution is expected to be the 'Tail' mission, which will study the physics of the magnetotail.

ESA is at present studying the remaining two mission candidates:

- Soho, a solar, heliospheric physics observatory, and
- Cluster, a magnetospheric-physics mission designed to study the Earth's magnetosphere in three dimensions

Table 1 – Optimum ISTP Programme launch and operations schedule

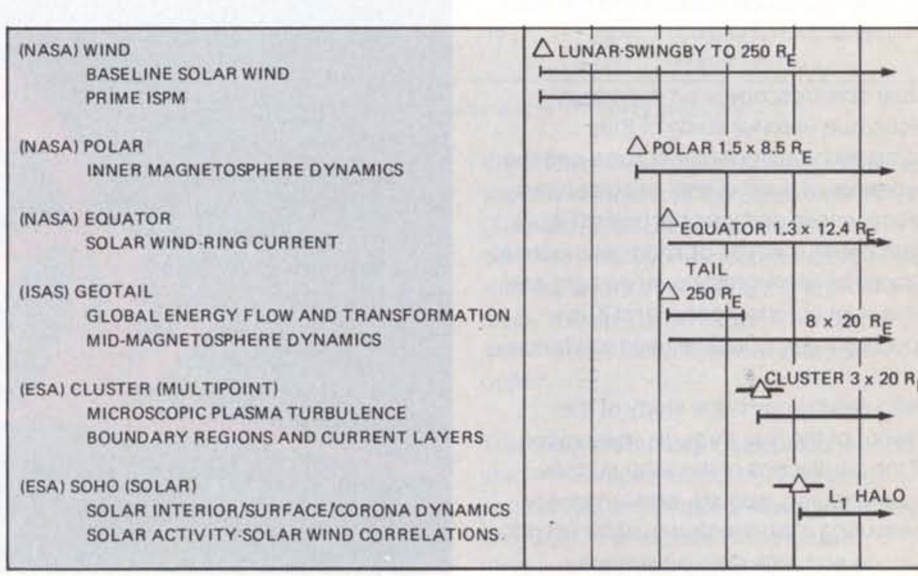


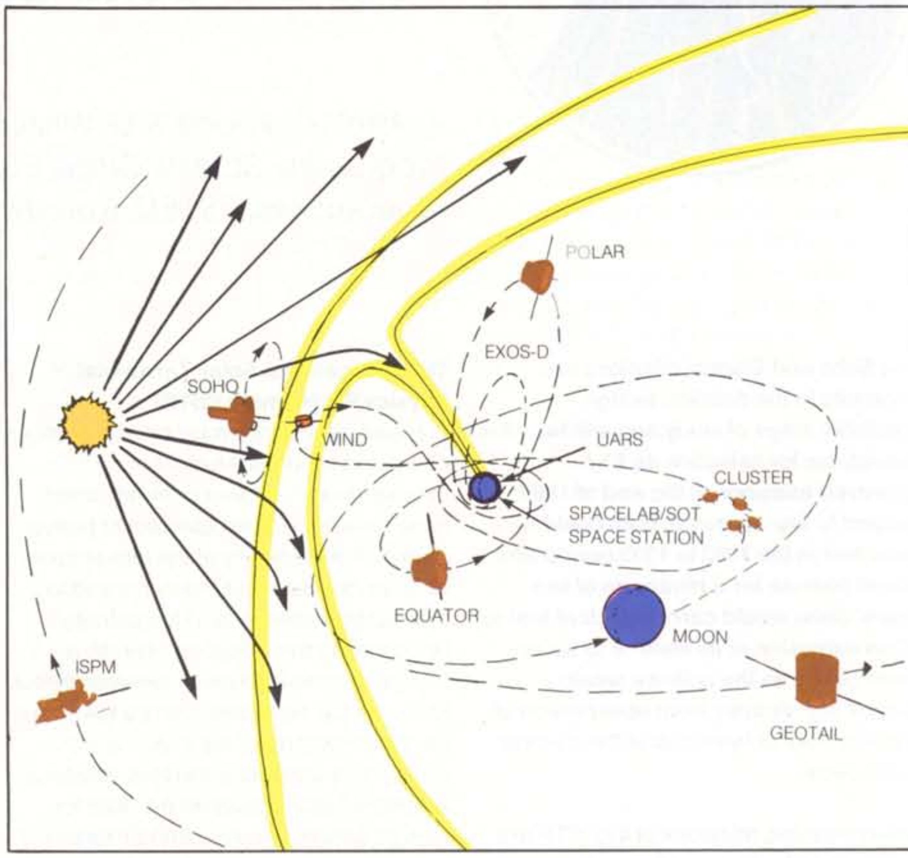
Figure 1 – The ISTP spacecraft and their orbits

Figure 2 – Solar prominences

using a cluster of four spacecraft in quasi-polar orbits.

The American, Japanese and European missions, although launched separately, will be closely coordinated and will provide data, stored in a common format, which will be accessible to all participants in the programme.

An overall impression of the ISTP spacecraft and the orbits in which they will operate can be obtained from Figure 1.



The Soho mission

The Solar and Heliospheric Observatory (Soho) is a spacecraft weighing some 1600 kg, to be stationed at the L1 libration point 1.5 million kilometres from the Earth. At this point, the gravitational pulls of the Sun and the Earth are equal and the spacecraft effectively remains stationary with respect to both bodies. It is therefore possible from this position to view the Sun continuously, without experiencing the perturbing forces and eclipses that affect an Earth-orbiting spacecraft.

The scientific mission covers three main areas of solar-terrestrial science:
- Solar spectroscopy
- Helio-seismology, and
- Study of the interplanetary medium, with particular reference to the solar wind.

Solar spectroscopy is an important technique used for study of the composition of the solar corona and the dynamics of such events as solar flares, prominences and coronal holes (Fig. 2). Instruments such as grazing- and normal-incidence spectrometers, white-light and ultraviolet coronographs, and X-ray spectrometers would be used for the task.

Helio-seismology is the study of the interior of the Sun through observation of the oscillations of the solar surface. Solar-imaging, velocity- and luminosity-measuring instruments would be used to provide accurate data on surface

Figure 3 — Computer-generated frequency spectrum for solar oscillations, based on ground-based data (courtesy of the University of Birmingham, UK)

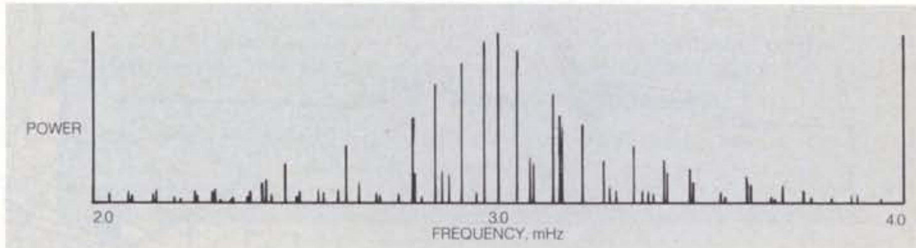


Table 2 — Soho model payload

Experiment	Mass (kg)	Power (W)	Telemetry kbit/s	Special requirements
Grazing-Incidence Spectrometer (GIS)	120	30	12	Length of instrument 2.9 m
Normal-Incidence Spectrometer (NIS)	130	76	10	Length: 2.8 m
EUV Imaging Telescopes (EIT)	16	53	0.8	
UV Coronal Spectrometer (UVCS)	165	36	5	Length: 2.8 m
White-Light Coronagraph (WLC)	64	45	4.2	Spacecraft roll to locate pylon over a solar pole Length: 2.8 m
Soft X-Ray Telescope (XRT)	45	40	10	Length: 2 m
Solar-Wind Analyser (SWA)	13	13	0.5	All spacecraft external surfaces must be conductive and grounded
Suprathermal Particle Analyser (STP)	7	5	0.1	
Energetic Particle Analyser (EPA)	8	8	0.2	
Magnetometer (MAG)	2	3	0.1	Spacecraft magnetic field 0.3 nT (boom-mounted detector)
Plasma-Wave Analyser (PWA)	6	4	0.1	EMC critical (boom-mounted detector) Two antennae pairs (40 and 20 m tip-to-tip)
High-Resolution Spectrophotometer (HRS)	31	30	0.03	Continuous data acquisition during 2 years Sun-spacecraft velocity known to better than 2 cm/s
Solar-Oscillation Imager (SOI)	30	50	160(5*)	Continuous 160 bit/s at least 3 months
Solar-Irradiance Monitor (SIM)	16	15	0.06	Continuous data acquisition during 2 years

* Low-resolution SOI considered as back up for the case of limited telemetry availability

velocities and oscillation frequencies and amplitudes. Using this data, frequency spectra for the solar oscillations can be constructed. Figure 3 shows such a spectrum compiled from ground-based measurements. Analysis of data such as these permits the scientist to construct better models of the Sun and the dynamic processes that characterise it.

Fields and particle instruments would monitor the solar wind continuously throughout the mission. The data obtained would be correlated with those from the other ISTP spacecraft, particularly that from the Wind spacecraft, thus giving a better picture of the composition and dynamic nature of the solar wind.

Table 2 lists the types of instrument that are expected to be flown on Soho, while Figure 4 shows the design concepts for two of the major spectrometer instruments. The Grazing-Incidence Spectrometer (GIS) is an instrument about 3 m long, weighing about 100 kg, designed to provide spectral images of solar features. It covers the spectral band from 65 to 1750 angstroms, with an imaging resolution of better than 1 arcsec and a spectral resolution ranging from 20 to 50 angstroms over the band. The Ultra-Violet Coronal Spectrograph (UVCS) yields spectral information from the solar corona. It concentrates specifically on measurement of the hydrogen and oxygen spectral lines in the band from 1000 to 1300 angstroms. From these measurements it should be possible to construct models of the acceleration and heating mechanisms that generate the solar wind.

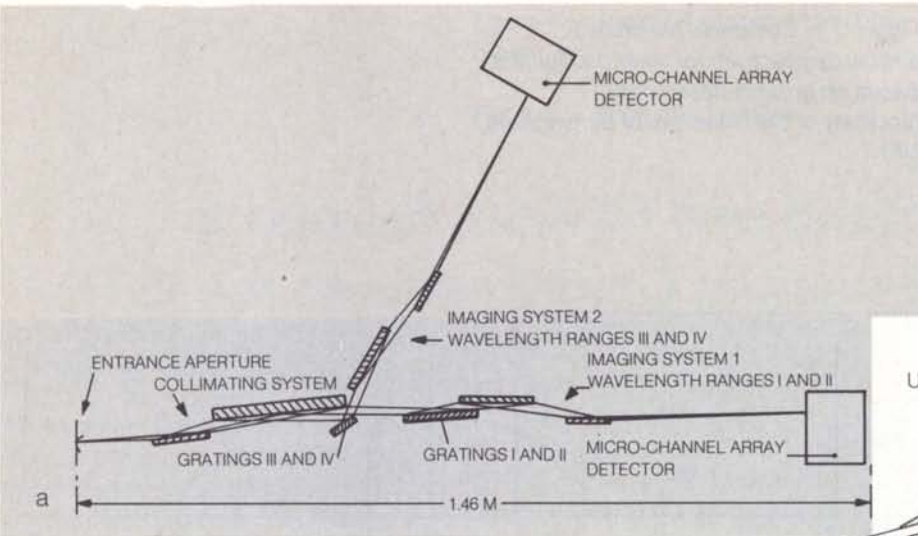
The spacecraft

The spacecraft that carries the above instruments is planned to be launched by either Ariane-4 or the Space Shuttle.

With Ariane, launch would be directly into a transfer trajectory, which would take the spacecraft to the L1 point, as shown in Figure 5. On arrival at the L1 insertion point, the onboard propulsion systems can be used to correct the trajectory and place the spacecraft into the desired orbit, which is an elongated ellipse centred on the Earth—Sun line. The spacecraft could remain in this orbit up to six years, using its onboard control systems to maintain the correct orbital parameters.

The Shuttle launch option differs in that a boost stage is required to inject the spacecraft into the transfer trajectory from the initial low-altitude orbit achieved with the Shuttle. The stage proposed for this is the Orbital Sciences Corporation TOS-S (Transfer-Orbit Stage-S), which is currently undergoing qualification for use with the Shuttle. Following the burn of this stage, the operation of Soho would be identical to that for the Ariane-launch option.

The spacecraft design is at present under study in European industry. Two prime contractors are involved, Matra in France, and British Aerospace in the United Kingdom. The designs being considered



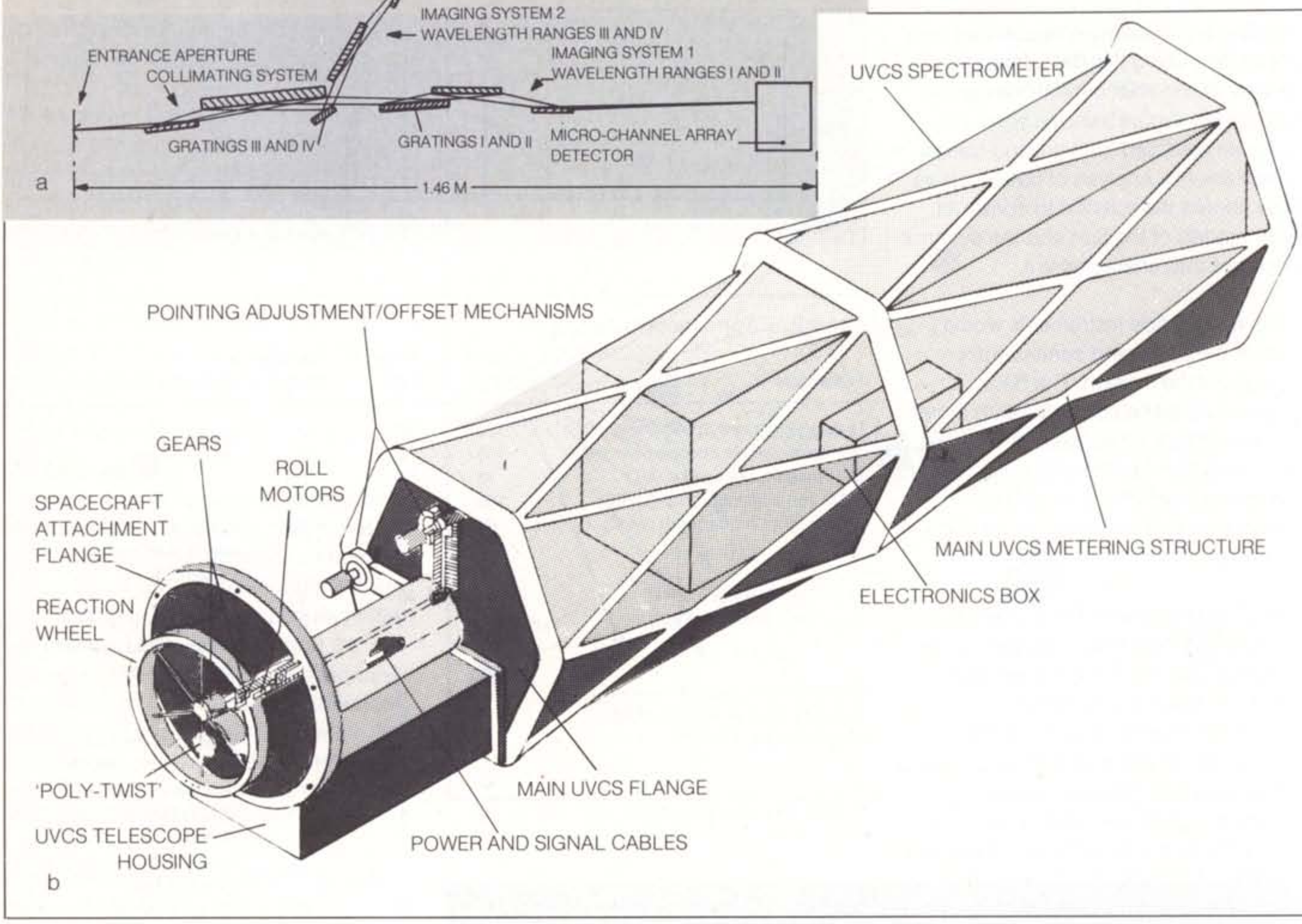


Figure 4a – Soho's Grazing-Incidence Spectrometer (configuration of optical components of focal-plane instrument)

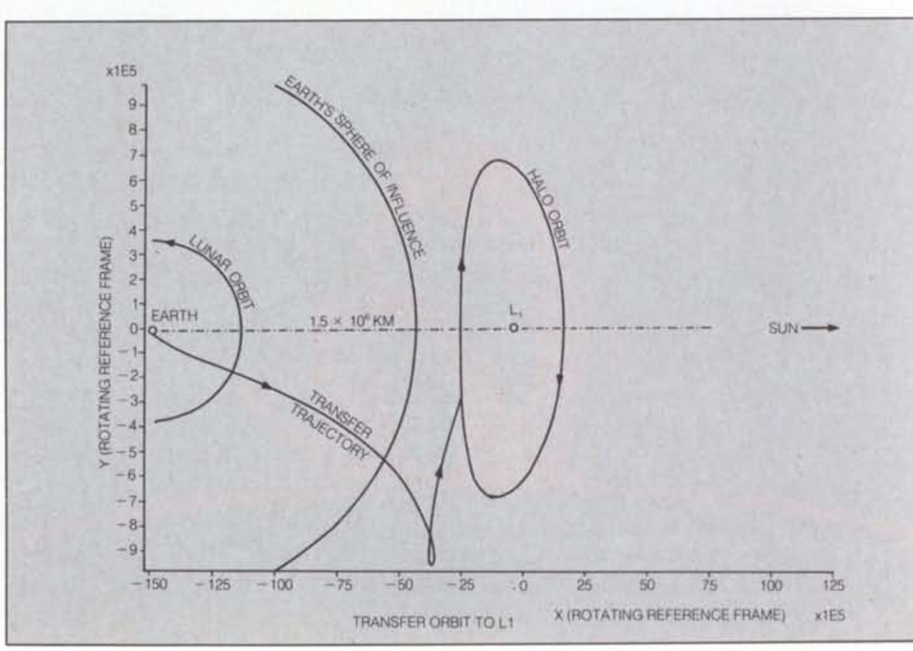
Figure 4b – Soho's Ultra-Violet Coronal Spectrograph

Figure 5 – Soho orbit-insertion strategy for an Ariane-4 launch

are similar to the ESA reference concept for the mission (Fig. 6).

The spacecraft is of modular design, with a simple interface between the service module, which contains equipment such as the spacecraft power, data-handling and attitude-control units, and the payload instrumentation module which carries all of the scientific instrumentation.

As shown in Figure 6, the spacecraft's x-axis is pointed continuously at the centre of the Sun to an accuracy of better than 10 arcsec, with a short-term stability of better than 1 arcsec. This is comparable to pointing a long pole at a matchbox which is 1 km away, and holding the tip of the pole still to within the width of the writing on the matchbox.



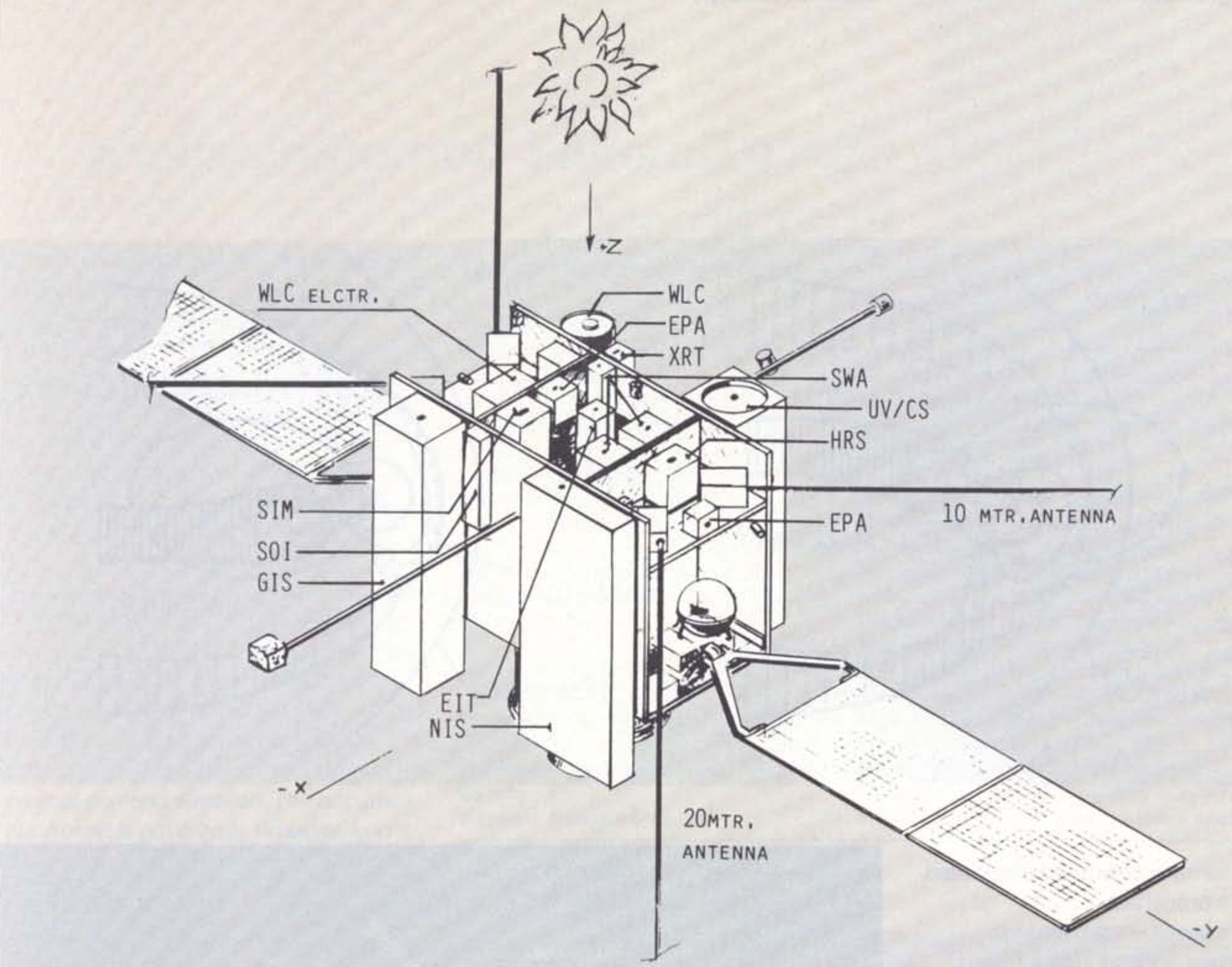


Figure 6 — The Soho spacecraft

The spacecraft is three-axes stabilised using fine gas jets or reaction wheels for attitude control and larger hydrazine thrusters for the periodic orbital station-keeping manoeuvres that are required. Attitude measurement is achieved using high-accuracy Sun sensors to provide Sun-pointing information, and star trackers to provide information about the roll angle of the spacecraft around the Sun line.

Power is obtained from two deployable solar arrays, which provide 900 W throughout the lifetime of the spacecraft. Although not strictly necessary, as Soho would be in continuous sunlight in normal operation, a small battery is carried to allow operation of the spacecraft in the early transfer trajectory and as an emergency back-up.

Communication with the Earth is via a combined S/X-band radio link, sized to give 40 kbit/s when used with an ESA ground station and 200 kbit/s when used with a NASA Deep-Space-Network (DSN) station.

Scientific operations
Some instruments have complex operational profiles (pointing, scanning, etc.). Schemes are now under study to ensure proper interaction between the Operations Centre and the scientists. Two data receiving stations, one at Carnarvon in Australia, and the other at Villafranca in Spain, are proposed. With this arrangement, coverage of up to 18.5 hours per day is possible. To allow data collection during periods of noncoverage, a small onboard memory would be carried with a capacity of about 100 Mbit. This would be used to store essential scientific data from the helio-seismology experiments.

The Cluster mission

The Cluster mission proposal is quite different from Soho. It consists of four spinning spacecraft orbiting the Earth in highly elliptic polar orbits, which are mutually inclined and changed periodically to give varying distances between the four spacecraft. The orbit configuration is chosen to allow simultaneous measurements at different spatial separations, in order to build up a three-dimensional picture of the magnetosphere. The regions of particular interest are the bow shock, the polar cusp, the magnetopause and the geomagnetic tail current.
In these regions Cluster would:

- explore the boundary regions of the Earth's magnetosphere, as an example of the interface of two cosmic plasmas, and investigate the detailed nature of the processes by which mass, momentum, and energy are transferred across boundaries such as the magnetopause;
- study the magnetic reconnection process and the small-scale magneto-hydrodynamic structures

Figure 7 – Cluster orbits in relation to the Earth's magnetosphere

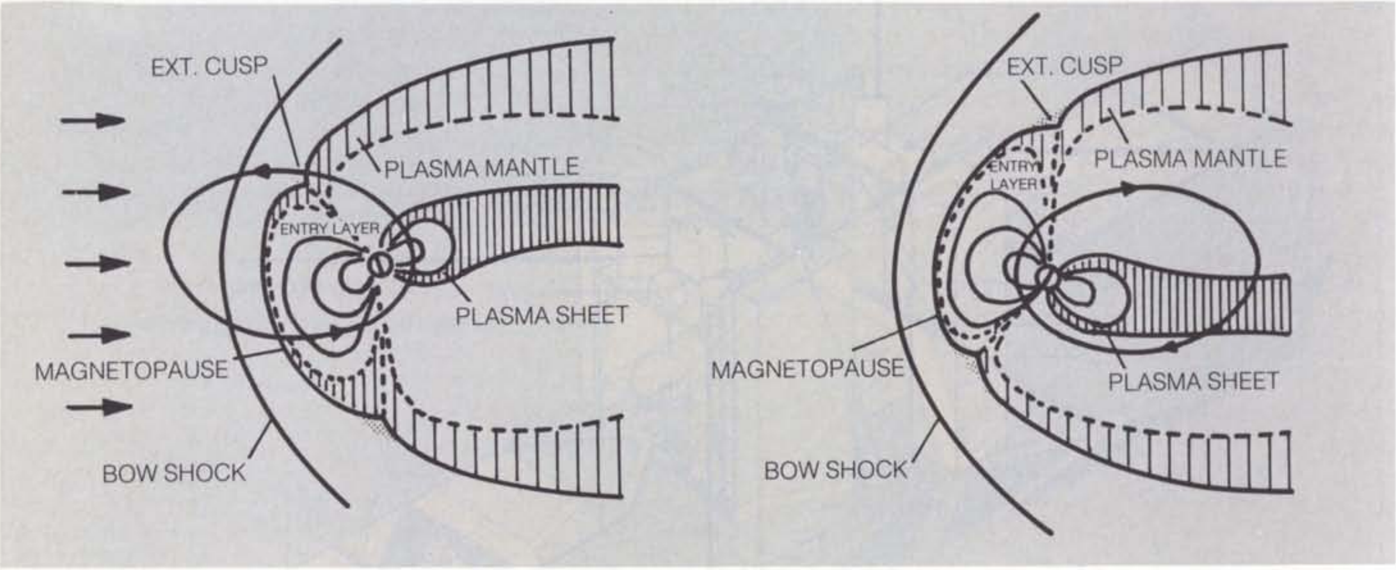
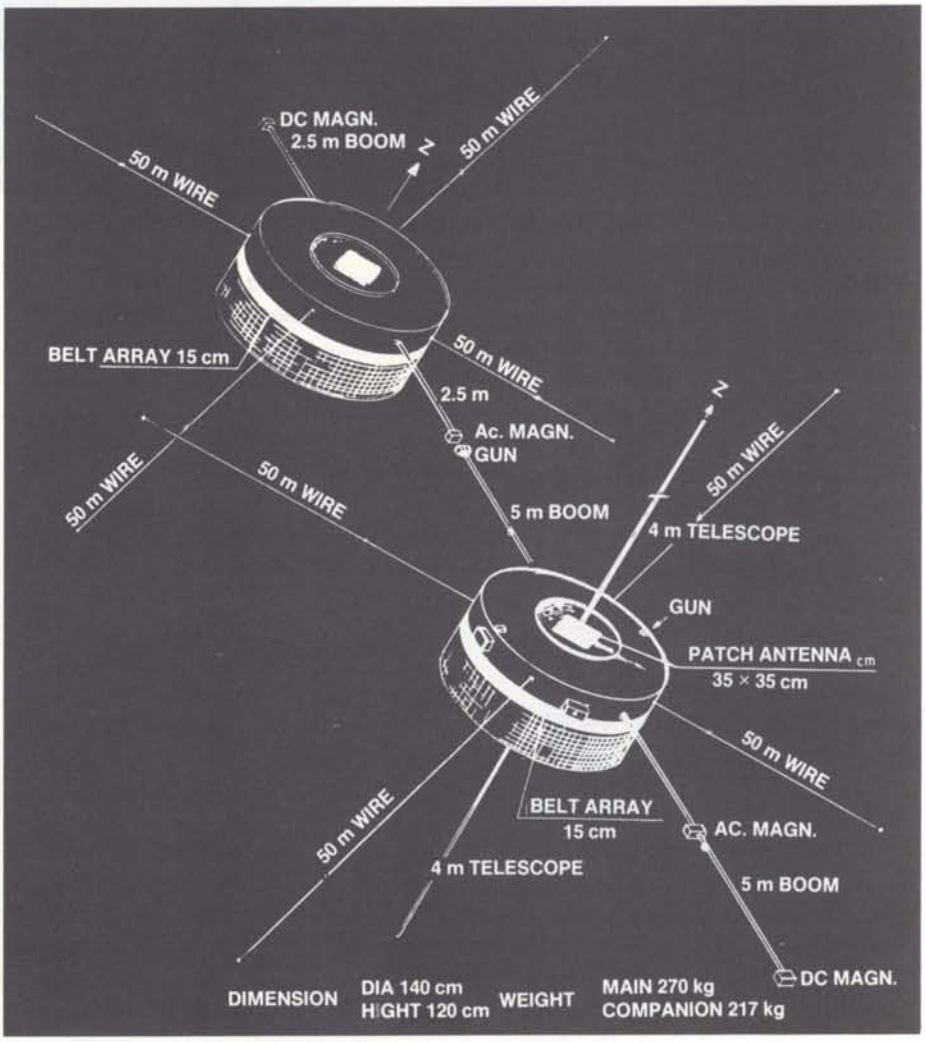


Figure 8 – The Cluster spacecraft (ESA reference concept)



and plasma acceleration associated with the processes;

- study magneto-hydrodynamic turbulence, vortex formation, and eddy diffusion, particularly in the polar-cusp and boundary regions;
- investigate the structure and properties of collisionless shock waves, including the bow shock, and the associated particle acceleration and wave generation;
- determine the small-scale structure of the solar-wind flow around the Earth; and
- utilise the four-spacecraft configuration to determine unambiguously the three-dimensional shape and dynamics of magnetic structures (ranging in scale from 0.1 to 10 R_E).

Figure 7 shows the Cluster orbits in relation to the Earth's magnetosphere.

The spacecraft

Like Soho, the Cluster mission is presently under study by European industry. Two consortia, led respectively by MBB in Germany and Saab in Sweden, are evaluating alternative design concepts for the spacecraft. These are derivatives of the ESA reference concept shown in Figure 8.

All four Cluster spacecraft are of similar design and contain a similar complement of instrumentation. The four may be launched as a single stack by either an Ariane-4 launcher or the Space Shuttle. Each spacecraft is spin-stabilised and for an Ariane launch would weigh about 700 kg, including about 250 kg of fuel. For a Shuttle launch the fuel requirements would be about 100 kg.

The spin axis of each spacecraft would be controlled to point normal to the ecliptic plane. The initial pointing is towards the north ecliptic pole. Every six months a change of 90° will be made to allow the calibration of magnetometers. After calibration the spacecraft will return to the original pointing direction. The accuracy of pointing is not critical, however, and a few degrees of variation can be tolerated. Attitude control is achieved using hydrazine or bi-propellant thrusters and passive nutation dampers, with Sun, Earth and possibly star sensors to provide the necessary attitude information.

Power is provided by a fixed solar array, which delivers around 200 W at the start of the mission. Batteries are carried to provide power during eclipse.

The data acquisition, storage and transmission is unusual in that it would be the first time that ESA has needed to operate four spacecraft simultaneously. To facilitate this task and to ensure sufficient scientific coverage, a large capacity data memory (some 500 Mbit) is included in the baseline design.

Two other significant features are:
- the long booms that are required for electromagnetic-field measurements (the longest is 100 m tip-to tip), and
- the liquid propulsion systems carried by each spacecraft for orbit manoeuvring.

Scientific operations

The spacecraft stack would be launched initially into a polar eccentric orbit by the Shuttle (and an upper stage such as the AMS), or an eccentric equatorial orbit by Ariane-4. In the Ariane case, after injection and separation of the four spacecraft, each would make a series of orbit changes using their onboard propulsion systems to achieve highly eccentric polar orbits ranging in altitude between 18 000 km and 120 000 km. The inclinations and positions of the spacecraft are chosen such that their mutual separations would range from a few hundreds of kilometres to a maximum of about 30 000 km. This controlled separation is required to permit spatially correlated measurements. Figure 9 shows the proposed sequence of events for an Ariane launch.

Table 3 — Cluster model payload

Experiment	Characteristics
Fluxgate Magnetometer	DC to 10 Hz, waveform, three-axes, boom-mounted, minimum sensitivity 0.1 nT
Search-Coil Magnetometer	10 Hz to 4 kHz, data compression, three-axes, boom-mounted
Electric Field and Wave Instrument	DC to 10 Hz, waveform 10 Hz — 4 kHz, data compression, three-axes Booms radial: two pairs 100 m wire booms axial: one pair 5 m rigid booms
High-Frequency Electric-Field Instrument	Filter-bank up to 100 kHz, with high time resolution Antennas: same wire booms as above
Plasma Analyser	Electrons and ions, ~0 to 30 keV, 3 d, 4 π coverage in ≤1 spin, separate solar-wind ion sensor
Plasma Composition Analyser	High resolution, three dimensions, ~0 eV to ~100 keV/q Mass range: 1 — ≤16 amu
Energetic-Particle Instrument	High resolution, three dimensions, electrons and ions (p., Z<2), 20 keV to 1 MeV
Electron-Beam Instrument	Electric field, DC to 50 Hz, boom-mounted
Sounder	Plasma density and high-frequency wave measurements
Wideband Analogue Data Link	Waveform up to 10 kHz, uses one pair of wire booms

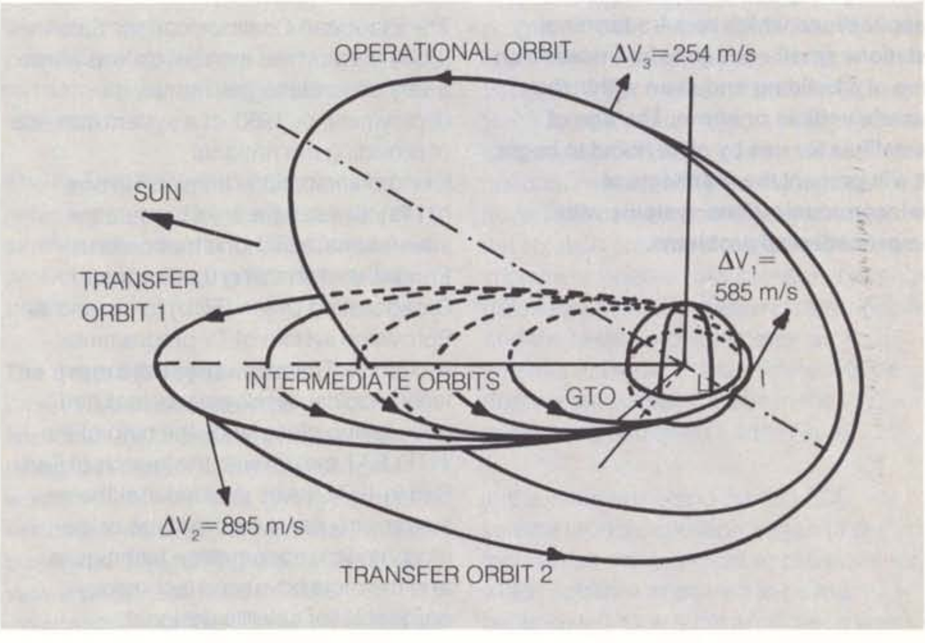


Figure 9 — Cluster orbit-insertion strategy for an Ariane-4 launch

ESA's Satellite Communications Programme

P. Bartholomé, Communications Systems Division,
ESA Directorate of Application Programmes, ESTEC,
The Netherlands

Twenty years ago, the first geostationary telecommunications satellite Syncom-3 was just coming into use. It weighed less than 100 kg and enormous earth stations were necessary to transmit and receive its signals. Since then, the size of satellites and their complexity have continued to grow, while those of earth stations have tended to shrink and they have increased in number. As this process continues, it is possible to envisage the use of satellites for applications which require terminal stations small enough to be installed on top of a building and even within the user's vehicle or home. The age of satellites for use by all is about to begin. It will present the architects of telecommunications systems with unprecedented problems.

Historical background

Nearly fifteen years ago, in July 1970, the ministerial-level Fourth European Space Conference resolved that the European Space Research Organisation (ESRO), later to become the European Space Agency (ESA), should no longer restrict its activities to the scientific exploration of space but should embark on applications programmes such as telecommunications and earth observation.

The European Communications Satellite (ECS) programme then set up was given a very concrete target, namely the deployment, by 1980, of a system capable of providing the national telecommunications administrations (PTTs) with satellite links to route the international telephone traffic within Europe, and enabling the European Broadcasting Union (EBU) to expand its Eurovision system of TV programme exchange. To catch up with the rapid technological developments that had been taking place since the birth of the INTELSAT system with the launch of Early Bird in 1965, it was decided that the new system should take advantage of the most modern transmission techniques and the most advanced technology applicable for satellite design.

The programme began to take shape in 1972 with the decision to construct the Orbital Test Satellite (OTS), an experimental satellite that would test the design proposed for the future ECS operational satellites, and would validate transmission techniques and the onboard technology. In 1973, the Marots project was added to the OTS programme. Its objective was to develop a maritime version of OTS which would be used for communications experiments with ships at sea. The experimental Marots later became the operational Marecs, serving the INMARSAT network.

The launch of the first OTS in September 1977 was ended in disaster within seconds by the explosion of the Delta 3914 launcher. Eight months later, in May 1978, the second flight unit was successfully launched and placed in geostationary orbit at 10° East. This satellite, initially designed to last three years, was operational for six years. After a very full career, it gave way to the first ECS (F1), which was launched on 16 June 1983 by Ariane L6 and handed over to EUTELSAT. ECS-F1 has now been joined by ECS-F2, launched on 4 August 1984. In December 1982, Ariane L4 placed the first Marecs (A) in orbit over the Atlantic, to be utilised by INMARSAT. Marecs-B, unfortunately lost with the failure of Ariane L5, has been replaced by Marecs-B2 which is now in service over the Pacific Ocean.

ESA is now halfway through its most recent programme, the aim of which is the development of a larger platform, Olympus (previously L-Sat), capable of satisfying more demanding requirements than ECS and Marecs in terms of payload mass, volume and power. The first Olympus, scheduled for launch in 1987, will carry four different payloads and will enable ESA to validate more advanced technology in orbit and to demonstrate new communications services. The latter will include multipoint videoconferencing and new forms of broadcasting such as pan-European television and wide-scale information dissemination.

Several ESA Member States also carry out their own national programmes. By 1970, France and Germany had already joined forces on the 'Symphonie' project, whose two experimental satellites were only recently retired after many years of service. Italy's Sirio satellite is still in active service. In 1978, France and Germany joined forces again to develop, outside the framework of ESA, a new class of satellite, large enough for high-power direct broadcasting (DBS) applications. Two DBS satellites, TV-Sat for Germany and TDF-1 for France, are now under construction for launch towards the middle of 1986. Using another version of the same platform, the Tele-X project, supported by Sweden, Norway and Finland, will serve for experiments in Scandinavia from 1987.

The initiative to use satellites for operational business networks was taken in 1978 by the French PTT which began development of a national satellite network dedicated to special services of interest to the business world, implying direct satellite access through small stations installed on or close to the users' premises. The system, called Telecom-1, will use spacecraft of the ECS class with a specially adapted payload. The first satellite was launched on 4 August 1984 by an Ariane-3, together with ECS-F2.

As was to be expected, the French move constituted the starting signal for a blossoming of activities in the field of satellite business system development. It soon became obvious that there was a demand for this kind of service on an international scale in Europe and that EUTELSAT was the natural choice to provide the necessary framework. In 1980 EUTELSAT therefore asked ESA to investigate the possibility of expanding the transponders to accommodate this new demand. Although the modifications were not feasible for the first ECS flight unit, already at an advanced stage of construction, they have been implemented on the four subsequent units.

As part of an ambitious space programme, Italy is developing Italsat, which will be the first satellite system in Europe to work exclusively in the 30/20 GHz bands. A pre-operational version is expected to enter into service in 1988.

Once the UK Government had licensed, in 1982, the British Broadcasting Corporation (BBC) to operate two satellite television channels, a joint venture company, United Satellites Ltd., was formed by British Aerospace, Marconi-GEC and British Telecom with a view to building and launching a DBS system to be called Unisat. Given the growing interest in the UK in new business services, the consortium is considering the possibility of combining the two planned missions to carry a dual payload on one spacecraft.

The Federal Republic of Germany has recently entered the race for a national satellite network with its DFS/Copernicus project, now emerging from the definition phase.

The overall European goals

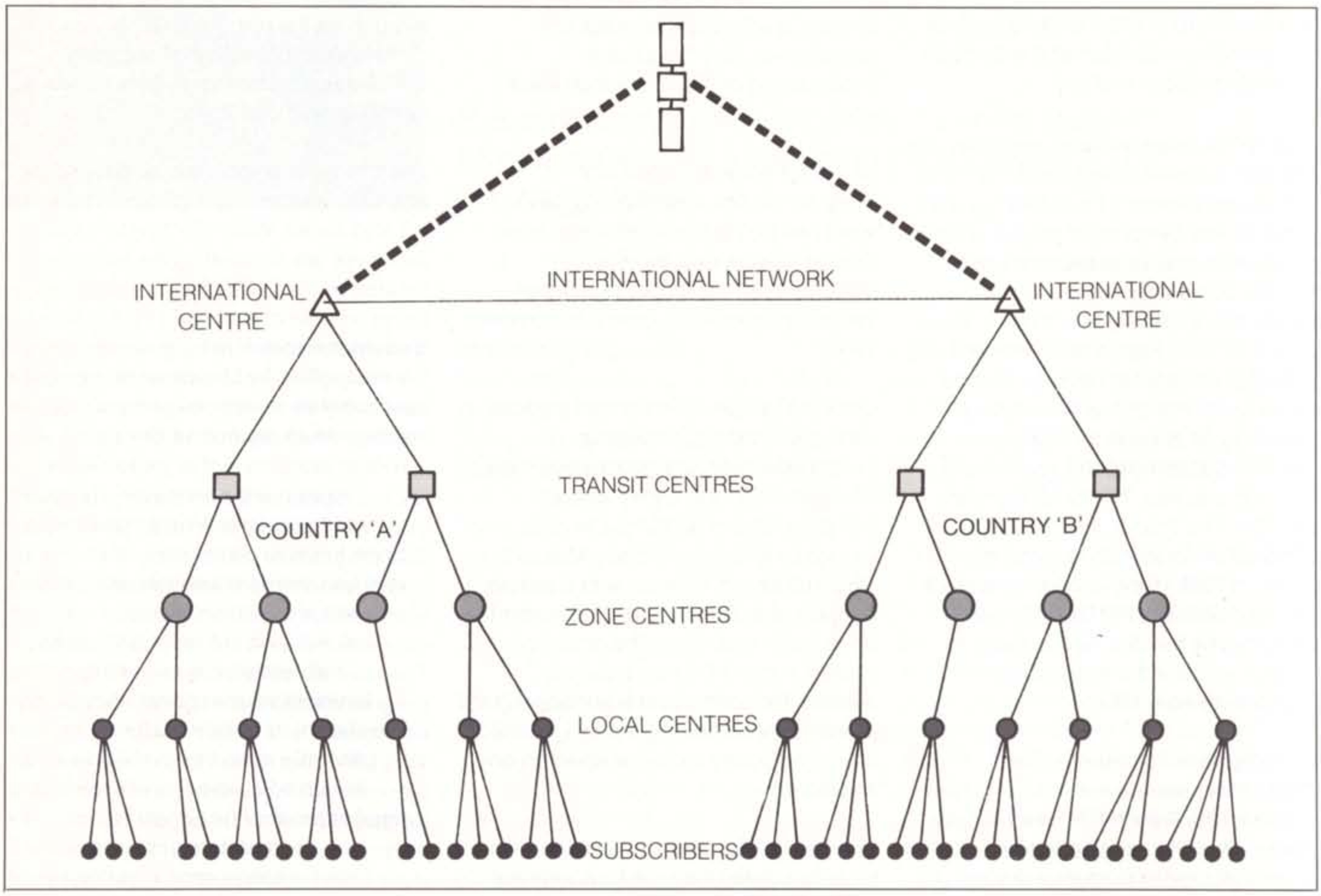
When ESA embarked on its telecommunications programme, it was thought in certain circles that its role would be limited in time, giving European aerospace industry the necessary initial boost and then retiring gracefully. This view implicitly assumed that the international competition would stand still while Europe caught up and that the techniques would not continue evolving at an accelerating pace. Over the last ten years quite the opposite has happened. The North American satellite market has developed at a much faster rate than that of Europe, with, to date, 27 domestic satellites in commercial use against three in Europe. This market, to which must be added 22 other satellites operating throughout the rest of the world, was completely captured by US industry, which was thereby able to increase even further its lead over European industry.

The new earth-station market created by all these satellites is being shared between US and Japan. Within Europe too, the Japanese are dominating the market created by the EUTELSAT system and are in the process of supplying the majority of stations. It is therefore quite obvious that the effort made by Europe so far has been insufficient as regards satellites and totally inadequate as regards earth stations.

Technological evolution over the past ten years has been considerable. When the ECS programme was set up, telecommunications satellites served as simple relays for long-distance connections, as in the INTELSAT system. The most logical application of the programme therefore appeared to be the deployment of a system similar to INTELSAT, but limited to Western Europe. Since the terrestrial network in Europe is a juxtaposition of a number of distinct national networks interconnected via trunk lines between national gateways, the solution proposed was simply to implement satellite links between these gateways, thereby increasing the capacity and the reliability of international communications. The satellite would be nothing more than 'a cable in the sky', duplicating cables on Earth (Fig. 1).

In the years preceding the first ECS satellite launch, attention began to be focused on more original applications for which satellites appeared to be much better suited. One such application was wideband communications links for business purposes, between end users with direct satellite access via small, inexpensive, private stations. Another was distribution of signals (television, data) to recipients scattered over a wide geographical area. Experiments of this nature were conducted with OTS and proved so successful that the PTTs decided to offer these new services with

Figure 1 — Cable in the sky between national gateways



the ECS satellites. ECS-F1 is almost entirely dedicated to TV distribution and it is anticipated that most of the system's capacity will in the future continue to be allocated to this service rather than trunk telephony as originally planned. Business services to end users with small stations are also expected to take an important share of the capacity of future satellites such as Telecom-1, Tele-X, Italsat, Unisat and Copernicus.

From this brief survey of past achievements can be drawn a number of important conclusions, from which lessons must be learnt before embarking on the new long-term programme that the Agency is currently elaborating.

Under the aegis of ESA, European industry acquired valuable expertise in designing and constructing communications satellites based on advanced concepts. It is supplying satellites to EUTELSAT, INMARSAT and to French, British, Italian and German governmental organisations. It is also supplying important subsystems to US companies in charge of major INTELSAT projects. It has not, however, been able to make any real breakthrough in the competitive world market, which remains more than ever dominated by the USA. Europe has achieved its independence in the field of launchers; it has not reached the same independence in the highly commercial world of communications satellites.

This unsatisfactory situation has a clear explanation. Whereas North America is a single large market where private enterprise can freely deploy all its resources, Europe is fragmented into a multitude of small markets, each strictly controlled by national operating agencies whose main concern, understandably, is to run their networks with maximum efficiency rather than risking new ventures for the good of aerospace industry. There exist at the moment no less than seven national satellite programmes in Europe, in addition to EUTELSAT. Each is centred around a specific national requirement and not necessarily the achievement of overall economic viability.

It therefore appears clear that ESA, together with all other relevant organisations in Europe, must continue to act as the driving force towards European unification in this area. Cooperation must not be limited to the will to build satellites together; it must also imply a harmonisation of the national telecommunications policies and technical standards, leading to the will to use satellites within integrated international networks. Only then will it be possible to create a European-wide market large enough to produce sufficient returns on investments.

Until now, it has been assumed that industry would automatically take appropriate steps to keep up with the demand for earth stations. However, the largest market in Europe is still confined to individual countries and is much too small to produce an adequate return on investment. Thus none of the European station manufacturers deployed the necessary level of financial effort, and most of the demand created by the EUTELSAT system is now being met by Japanese industry. Even in the largest countries, where contracts for EUTELSAT stations were preferentially awarded to local manufacturers, these manufacturers are still heavily dependent on US and Japanese sources for the procurement of critical high-technology components and subsystems.

A recent report published by the Commission of the European Communities emphasises the importance for many sectors of the European economy of investments in telecommunications. It estimates that investments in infrastructure will have a multiplicative effect of the order of 10 in stimulating investment in communications equipment and that the combination of new infrastructure and equipment will have a further order-of-2 effect in creating new service activities. This snowball effect will undoubtedly apply to future investments made by Europe in communications space segments (Fig. 2).

Investment in the earth-segment market (the inner ring in Figure 2), is given in Table 1 in the form of rough estimates for various types of satellite systems. It can be seen that, in many cases, it exceeds considerably the cost of the space segment infrastructure, which is typically of the order of 150 to 250 million ECU. If European industry continues to restrict its role to the space segment, the benefits of this snowball effect will inevitably be reaped by US and Japanese industry.

The third conclusion that can be drawn from the experience of the last ten years, is that the function of the satellite as a communications tool has changed radically. The 'cable in the sky' concept, although an essential element of the EUTELSAT network, has not shown itself to be a viable economic proposition. On the other hand, two new concepts, TV

Figure 2 – Snowball effect of investments in space-communications infrastructure

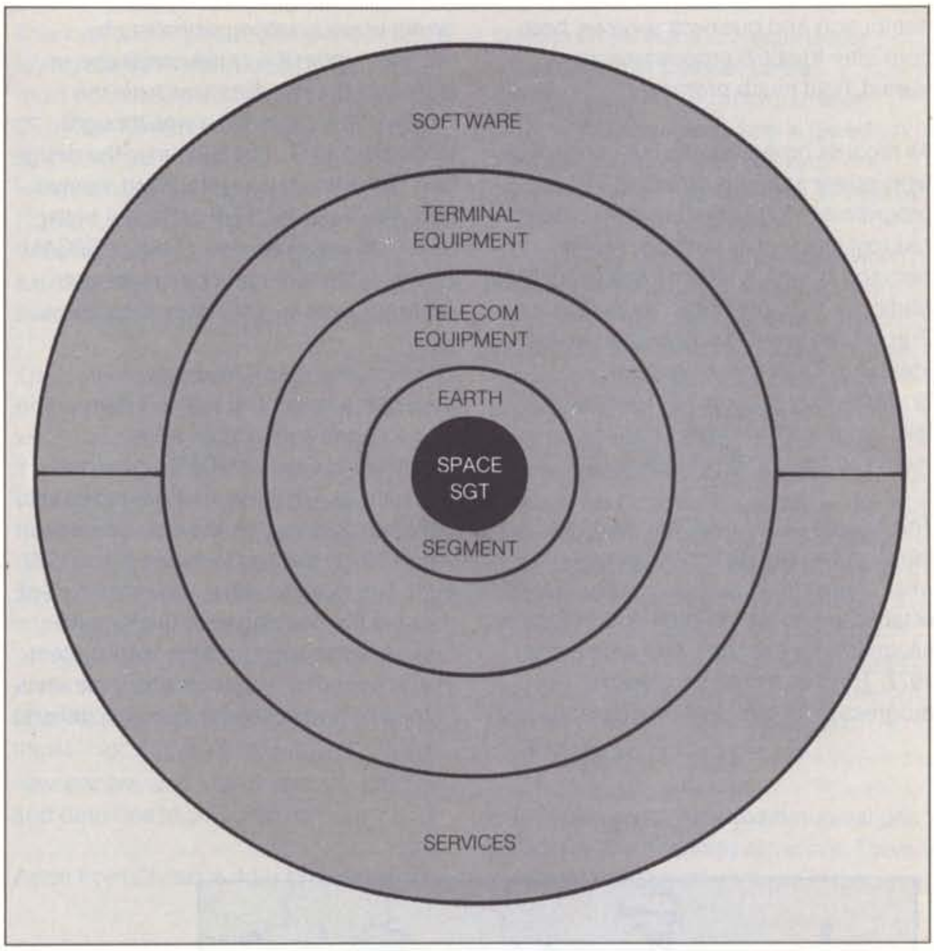


Table 1 – Outline of the European earth-station market (1985–1995)

Type of station	Market volume (Million ECU)
Large stations for network applications (e.g. Eutelsat, Inmarsat, Intelsat)	250
Small stations for network applications (e.g. Eutelsat/SMS, Telecom-1, Copernicus, Italsat, Tele-X)	500–1000
Small receive-only stations (e.g. TV-distribution, information dissemination)	2000–3000
Small mobile stations	3000–4000
DBS individual receivers	10 000

distribution and business services, both born after the ECS programme was started, hold much promise.

As regards broadcasting, the concept of high-power satellites radiating TV programmes to purely national audiences has lost much of its support, except perhaps in the UK where it seems to fill a particular requirement. Elsewhere in Europe, the satellite is now seen as the ideal vehicle for *trans-national broadcasting* (e.g. pan-European television) and for distribution to multinational cable networks.

The causes of this evolution must be found in two significant developments which have taken place since the WARC* established its plan of orbit and frequency allotments for broadcasting satellites in 1977. The first is the considerable progress in receiver technology in the last seven years, enabling signals to be received under the same conditions of quality at greater distances from the centre of the beam than was thought possible in 1977. The second is the design of a new transmission standard, named MAC/Packet, which will provide a better picture quality than either PAL or SECAM and will therefore further increase the coverage area of any national satellites.

The significance of these two developments is illustrated in Figure 3 which shows their effects in the hypothetical case of a DBS system for Switzerland. The inner contour represents the coverage area for individual reception with a 90 cm dish, as foreseen in the 1977 plan. The outer contour shows the limit of the effective coverage obtainable with current technology and the MAC system. The intermediate contours show the limits of the effective coverage if smaller (60 and 45 cm) dishes are used. The combined effect of an expansion of the coverage area and smaller antennas will undoubtedly be to increase considerably the potential trans-national audience of any national satellite.

This evolution illustrates some of the problems in making the correct choices when initiating a communications space programme; the techniques and requirements may change so fast that, by the time the end product is ready for service, it fails to meet the now current needs.

The ECS design, although optimised for the original mission, could accommodate such changes in requirements without too much difficulty. It remains true, however, that the overall design is no longer optimum. The same applies to TV-Sat and TDF-1, two DBS satellites with a long interval between conception and launch. This kind of problem can only get more serious in the future because, as will be explained later, satellites will be called upon to perform more and more complex functions and will tend to become less flexible and adaptable to changes of mission.

Europe has not fully achieved the objectives that, in 1970, were believed to be reachable within a decade. The goals for the next ten years may prove even harder to reach. Success will depend on the satisfaction of two conditions. Firstly sufficient time and care must be spent on selecting the options; this implies that the role that satellites will play in our future telecommunications infrastructure be defined without ambiguity, in close cooperation with the political decision-makers as well as the operating agencies.

Secondly, the time taken to develop a new satellite system, once the goals have been identified and agreed upon, should be as short as possible. In telecommunications,

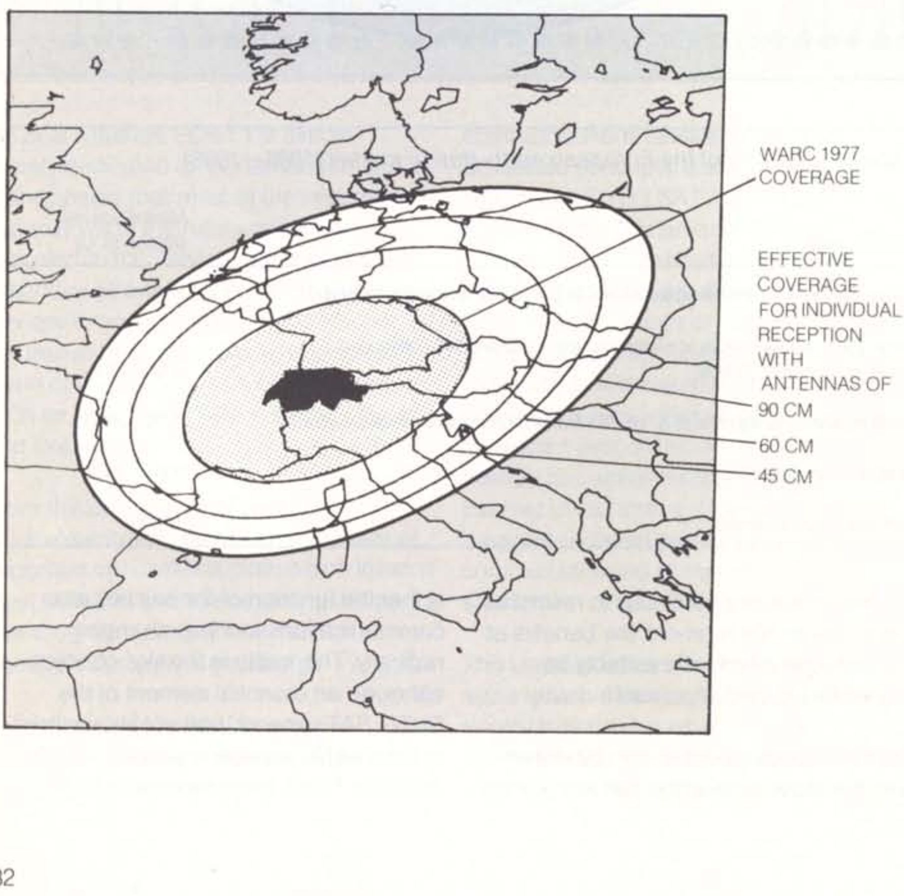


Figure 3 — Effective coverage of the Swiss Direct-Broadcast Satellite (DBS) using the MAC/Packet standard

* World Administrative Radio Conference.

evolution was slow until the advent of satellites and computers some twenty years ago. Since then the pace has accelerated enormously and will no doubt continue to do so in the future, dictated by the dynamism and mutual emulation of US, European and Japanese industry. Europe will have to learn to work much faster if it is to remain in the race at all. ESA should be regarded as a unique instrument to help Europe make the right decisions and implement them without delay.

Evolution of space communications

The days of satellites as simple microwave relays in the sky are numbered. With the development of fibre-optics technology, it is now certain that extensive cable networks will cover the surface of the Earth, criss-crossing continents and oceans. Wide-area distribution and broadcasting will, on the other hand, continue to be fields of application where satellites have a distinct advantage due to their position in space. Distribution by low-power satellites has begun well with the first ECS almost entirely used for this purpose, and the demand for additional capacity is such that the two further satellites will not satisfy it.

While distribution is of interest to a fairly limited number of users, such as cable-network operators who can afford professional receiving equipment, broadcasting by definition aims at reaching the general public. This implies that the signal relayed by the satellite must be so powerful that reception is possible with simple and inexpensive equipment, suitable for mass production.

Doubts have been expressed as to the future of satellite broadcasting, at first sight extravagant and expensive, and the opinion voiced that the development of cable networks will render broadcasting satellites useless. This opinion is based on the assumption that an entire country can be cabled in a few years, at a lower cost than that of constructing a satellite system, which is not the case. The financial and logistical demands of cable laying are such that, according to the most optimistic predictions, not more than 25 million European homes, i.e. a fifth of all the homes in Europe, will be cabled within ten years. As is apparent from Figure 4, cable cannot therefore represent a realistic alternative to broadcasting satellites, nor have a detrimental effect on their future in the short and medium term.

The potential audience of satellite broadcasting systems is considerable and will remain so for a long time to come, but it will only be captured if the service offered really is new and costs are reasonable. A satellite such as Olympus can serve the entire European continent, and offers almost limitless possibilities for improvement and expansion, in the areas of higher picture resolution, wide-screen projection, selection of multilingual sound channels and subtitles, stereophonic music, high-capacity videotex, electronic newspapers, and distribution of software and data files to personal computers.

Aside from Olympus, four broadcasting satellite projects are currently under development in Europe: TV-Sat (Germany), TD-F1 (France), Unisat (United Kingdom) and Tele-X (Sweden). Various other countries are also considering their own systems. Except for TV-Sat and TDF-1, there is no commonality nor coordination between these national projects and Europe is again depriving itself of the benefits to industry of the creation of a single large market. ESA has included in its future programme the development of satellite technology that will lead to a unified European design able to satisfy all national and multinational requirements. Elements of such a design are already incorporated in the Olympus programme and will be demonstrated from 1987 onwards in cooperation with the EBU. A complete demonstration of this concept may become the objective of a follow-on satellite, which would be launched towards the end of this decade.

In the field of mobile telecommunications, prospects are extremely attractive. There is a great unsatisfied demand in this area,

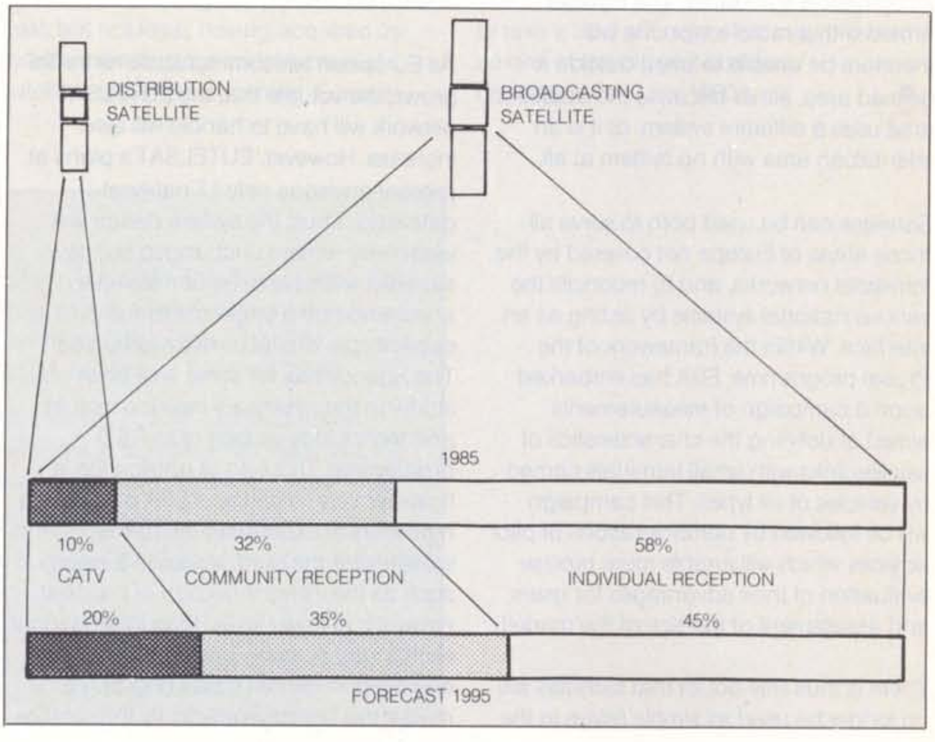


Figure 4 – Potential audience for distribution and broadcasting satellites in western Europe (125 million households)

Figure 5 — New concept of integrated space/terrestrial networks

involving travellers, in business or private vehicles, who require continual access to the public telephone network, or simply wish to receive messages or instructions. Such services are certainly available at the moment in a number of areas in Europe. However, they have the disadvantage of severe geographical limitations and, in the case of radio-telephony, of mediocre quality. The inadequacy of the frequency band available for these radio-telephony services limits their expansion. A recent technique, however, known as cellular networking, enables multiple utilisation of the UHF channels and will provide considerable improvement in the quality of mobile communications and increase network capacity.

Two major problems remain: firstly, cellular networks will initially be installed in urban areas where the demand is greatest, leaving large areas of Europe without a service for many years. Secondly, the frequencies and techniques proposed for use in the cellular networks vary from one country to another and in Europe there are already several different, incompatible standards. The traveller armed with a radio-telephone will therefore be unable to use it outside a defined area, either because the adjacent area uses a different system, or it is an inter-urban area with no system at all.

Satellites can be used both to serve all those areas of Europe not covered by the terrestrial networks, and to reconcile the various national systems by acting as an interface. Within the framework of the Prosat programme, ESA has embarked upon a campaign of measurements aimed at defining the characteristics of satellite links with small terminals carried by vehicles of all types. This campaign will be followed by demonstrations of pilot services which will enable more precise evaluation of their advantages for users, and assessment of the size of the market.

There is thus little doubt that satellites will no longer be used as simple relays in the future. The growing saturation of the frequency spectrum and of the geostationary orbit will impose the adoption of far more sophisticated techniques than has been possible so far. ESA is currently investigating new system concepts in which the satellite acts as a switching station. Signals will be received, demodulated, processed, switched and remodulated before being retransmitted to their final destination by an antenna generating a narrow beam pointed automatically in the desired direction. Present plans are to demonstrate such a system in space in the early 1990s. Users would be equipped with terminals small enough to be installed on cars, lorries, boats and planes.

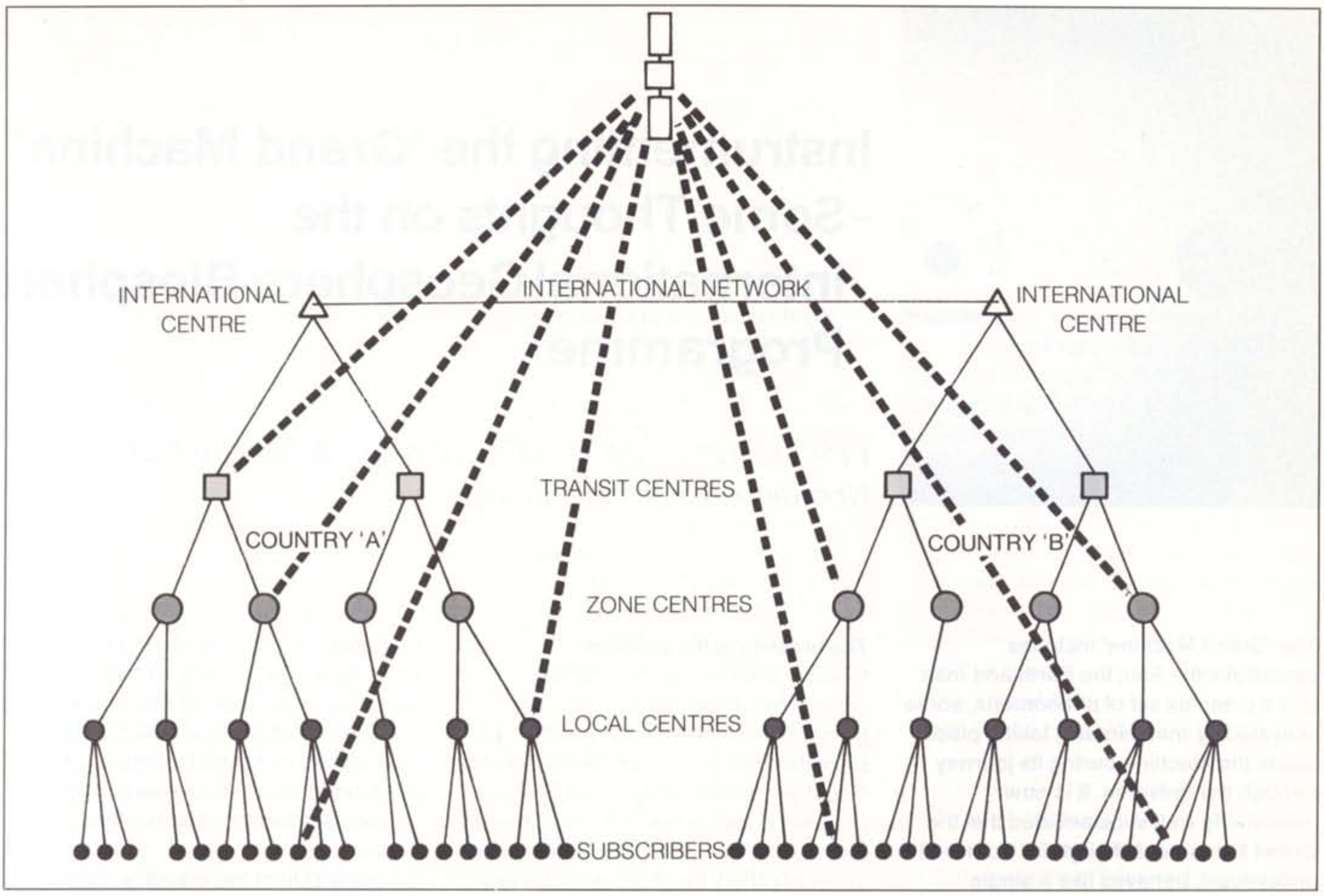
The most critical area for the future of satellites will undoubtedly be that of public telecommunications between fixed stations (the Fixed-Satellite Service). At the international level, satellites have so far been used to interconnect national networks through gateways, i.e. single-point interfaces in each country, generally associated with an international exchange, as used by both INTELSAT and EUTELSAT.

As European telecommunications traffic grows, the volume that the EUTELSAT network will have to handle will also increase. However, EUTELSAT's plans at present envisage only 17 national gateways. Thus, the system design will essentially remain unchanged but new satellites will have to be conceived to accommodate a larger transmission capacity per orbital position occupied. The Agency has for some time been studying the necessary new techniques and technology as part of its R&D programme. This field of application is however very limited and ESA is exploring new ways of expanding the role of satellites for the fixed service in Europe, such as the interconnection of national networks at lower levels than international exchanges, possibly down to the level of end users in certain cases (Fig. 5). To realise this objective efficiently the satellite would have to become, as for the mobile service mentioned earlier, a switching station in space, constituting a node of the European network. At this point, the combination of both fixed and mobile services into a single satellite system suggests itself quite naturally, and the concept that finally emerges is a satellite handling a variety of traffic streams, ranging from the international trunk to a single channel emanating from a particular user in a private vehicle.

Such a project is very ambitious and would constitute a real challenge for Europe, not only because it would require significant breakthroughs in both microwave and digital large-scale integration technology, but also because it would demand an unprecedented level of cooperation between ESA, industry and the operating agencies in order to define and implement the system. This project is currently under study in the framework of ESA's long-term programme.

It was pointed out earlier that the lack of attention given in Europe to the EUTELSAT earth-station market has resulted in an almost complete take-over by Japanese industry. The risk is great that this situation will repeat itself in the area of domestic TV receivers when the first DBS satellites become operational in 1986. ESA is now proposing to give advice to interested Member States on how to redress the balance and to introduce more technical cohesion and dynamism into the activities of their industry. One important aspect will be to identify areas of technology where effort is needed to gain independence from foreign sources and where there is complementarity between expertise and know-how available in the different European States.

As future satellites cease to be 'transparent' relays and become active nodes in the communications network, the design of satellites and earth stations will have to be much more closely related than at present. In fact both parts of the system will definitely need to be conceived



together. Failure to give proper attention to this sector would lead to very wasteful expenditure in space development.

Conclusion

Europe is now faced with a formidable challenge on three levels. The first is to make the proper choices and to decide together at a European level on the role that satellites will play in the future telecommunications infrastructure, be it national or international. Without a common and coherent policy, there will never be a home market large enough to make European space products competitive. Secondly, once these objectives have been defined, they must be realised with maximum speed. Unless Europeans learn to work together much faster, their satellite systems will be obsolete before they are put into service. Last, but not least, having acquired its independence in the construction of satellites and their launching, Europe must also acquire the independant means to use them. This will require a concentrated effort to create a genuine 'common' market for telecommunications equipment, and the appropriate steps must be taken to capture and retain this enormous market.

The challenge is great, but if Europe fails to take it up it will miss what may prove to be one of the biggest business opportunities of the 1990s.

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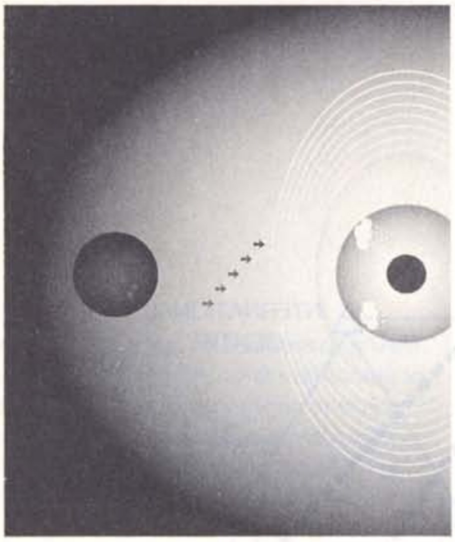


Instrumenting the 'Grand Machine' -Some Thoughts on the International Geosphere-Biosphere Programme*

Prof. M. Trella, ESA Technical Director & Director ESTEC, Noordwijk, The Netherlands

The 'Grand Machine' includes essentially the Sun, the Earth and man and a complex set of phenomena, some activated by man himself, taking place inside the Machine during its journey through the Universe. It is now reasonably well substantiated that the Grand Machine, although far from well understood, behaves like a single integrated system under dynamic conditions. This article reviews the importance and immediate consequences of an integrated approach to the definition and implementation of a plan for providing suitable instruments for measuring and interpreting the behaviour of the various components of the 'Machine'.

* Based on a paper presented at the 20th General Assembly of the International Council of Scientific Unions (ICSU) Symposium on Global Change, Ottawa, 25 September 1984

The urgency of the problem

One of the many merits of the first generation of major research programmes carried out in the 25 years since the inauguration of the International Geophysical Year (IGY) is that they have provided evidence and substantiation of the need for the wider international and interdisciplinary programme that is now being proposed. The risk with isolated research work directed toward specific features of Solar Terrestrial Systems, of the Oceans and the Atmosphere, of the Lithosphere and the Biosphere, is that it will provide only fragments of truth or doubtful answers, unless specifically formulated to provide results in a 'format' that allows correlation with other results, with other manifestations of the same phenomenon, and with the other phenomena at work inside the Grand Machine.

The very complexity of the problem hopefully serves to endorse the need for dialogue within the scientific community and amongst various disciplinary groups and to expand the basis of participation. In direct relationship to the population explosion, its needs and its habits, there are now measurable effects that undermine our earlier confidence that man will remain the happy and privileged guest in the gardens of a very tolerant and generous Nature. Rather, he is altering his own habitat as an active and reactive agent in the dynamics of the system, and is therefore contributing to a sizeable degree to a new geophysical and biophysical state of the Grand Machine. This also adds a new dimension to our ecological problems, with the recognition that not only is man poisoning his immediate surroundings, but this perturbation is travelling steeply upward and thereby affecting in a global manner the behaviour of certain elements of his life-support system that were hitherto considered stable and immutable.

Since the start of the industrial revolution, man has poured some 100 billion tons of carbon into the atmosphere by burning fossil fuels, probably 90% of it during in the last 30 years. Similarly, the growth of the methane content in the atmosphere by 1.5% per year is exhibiting an exponential trend. Consequently, sizeable anthropogenic effects in the Grand Machine have characteristic response times of the order of a few years. The problem is not so much the ultimate capacity of Nature to cope with these perturbations, but its stability. We cannot answer today the question of whether or not we live in a stable system, whether or not manmade effects can trigger macroscopic modifications or act as a catalyst in magnifying mechanisms, or whether or not the process is reversible.

The very existence of these questions renders the proposed programme not simply interesting, but desperately urgent. It is not reasonable to establish a target date by which a significant improvement in our present understanding must be achieved much beyond two decades from now. On the one hand, this kind of time scale will tend to discourage the immediate intellectual investment required, on the other such a period is not unduly long bearing in mind that in several domains an iteration of two

Figure 1 — Major features and attributes of the IGBP

generations of instruments should be allowed for, and the lead time generally allowed for the implementation of individual major projects is of the order of ten years.

Based on the above considerations, it is possible to derive the following major conclusions:

- The identification of an elliptical domain embracing the complete geosphere and biosphere (elliptical being synonymous with interconnected, in the sense that a perturbation at one point travels throughout the domain), considering in particular possible anthropogenic perturbations with important effects on the system, is per se of political relevance and public interest. The scientific community should make the conclusions known in simple, easily understandable terms.
- The nature of the problem and the urgency of its solution require the adoption of all possible methods that offer the best prospects for a convergence of results. Whilst still relying on the spontaneous and voluntary nature of this venture, a system approach based upon an overall plan for the work to be undertaken on a global scale is an indispensable first step.

The many dimensions of the problem
Figure 1 is an attempt to summarise the major features and attributes of the proposed programme; the IGBP should provide a synthesis at any given moment across this multi-dimensional matrix, which is as yet by no means complete. It would clearly be wrong to assign a leading role to a specific discipline or nation or to a particular profession, or to consider the role of the Sun more important than that of the atmosphere in the Grand Machine, or the space segment more important than the ground segment or the data generation more important than its interpretation. In other words, the driving element should always be the best approximation to the synthesis of the system. The existence of an overall system architecture will prevent the risk of creating a second Tower of Babel, where it was assumed that merging all the languages would form a new unified language – the result was unintelligible to all!

A 'lighthouse' for the IGBP
The IGBP is only feasible given very wide international and interdisciplinary participation on a voluntary basis. It would be a great mistake to limit the freedom of research and the autonomy of decision of individual participants in the programme.

Nevertheless, the system approach, required for the reasons outlined above, must have a 'centre'. The major obstacle in the programme will probably not be financial. Substantial resources have been devoted in the last 20 years to research activities in several domains that are now regarded as integral parts of the Grand Machine. It can therefore be reasonably assumed that similar levels of resources will be forthcoming in the future. This being the case, the major challenge will be to provide a common polarisation of effort towards a single overall design within the strategic plan.

Disregarding for the moment the institutional aspects of the problem, the function of the programme 'centre' should be that of a central 'beacon' to orient the work to be undertaken in the next 22 years (two eleven-year solar cycles). It should not have executive responsibility, but should act as an intellectual and cultural authority, serving as a reference point for all participants in the programme. To serve such a function, the IGBP 'lighthouse' should be entrusted with responsibility for providing two master documents: (a) The Master Model of the Grand Machine, and (b) The Master System Architecture.

The Master Model of the Grand Machine
This model should contain the description

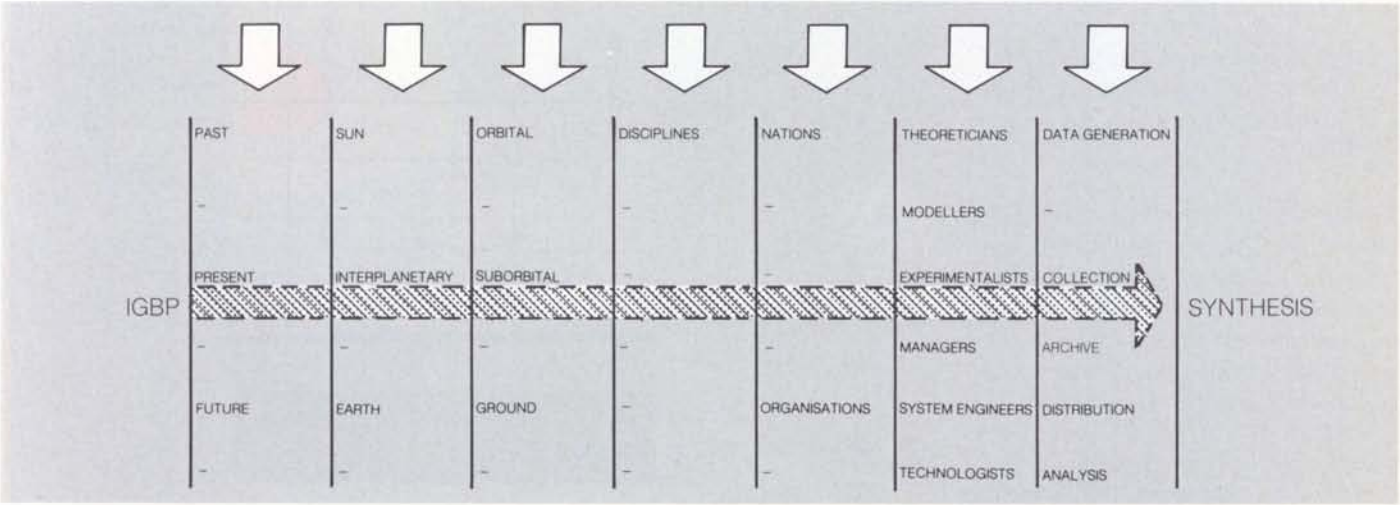


Figure 2 – Constituent elements of the 'Grand Machine' (two dimensions)

of the elements of the Grand Machine – Sun, Earth and Man – the interactive mechanisms between them, the functions, modes of operation, and degrees of freedom that can be excited and their characteristic physical properties. At any given moment, this master description should be based on the best available current knowledge of the various phenomena and the most valid hypotheses in both qualitative and quantitative terms. In particular, the characteristic timescale, dimensions and intensity of each phenomenon should be identified. It should be a living document, kept up to date and approved by a comprehensive and representative group of eminent scientists. The document will then derive its authority from the authorship and the fact that it represents the consensus of a wide scientific community.

There is currently no such document available, though three very useful inputs are already available:

- 'Toward an International Geosphere–Biosphere Programme', Report of National Research Council Workshop, Woods Hole, Massachusetts, July 1983.
- 'The Proposed IGBP: Some Special Requirements for Disciplinary Coverage and Program Design', by J.G. Roederer, Proc. ICSU Symposium on Global Change, Ottawa, September 1984.
- 'Solar Terrestrial Relations: Investigations from Space', by R.M. Bonnet, Proc. ICSU Symposium on Global Change, Ottawa, September 1984.

A major difficulty stems from the dynamics of the Grand Machine itself. It is not, as the sketch of Figure 2 implies, simply a one-dimensional system, which can be a very poor representation of the situation at local noon (disregarding in particular the 'lateral' transfer and boundary conditions). This illustration does, however, serve to introduce the characteristic regions and their respective properties and functions, the interactive mechanisms and the transformation processes by which a perturbation originating from the interior of the Sun or Earth, from man or from a component of the atmosphere or ocean, can penetrate upwards through some or all of the overlying elements, eventually being amplified there or perhaps alleviated.

This over-simplistic picture must be completed with the additional two dimensions and the diurnal and annual and higher order (Milankovitch) dynamics of the Earth (Fig. 3).

A 'tolemaic' reference frame (Sun rotating about the Earth) is probably the most suitable for fixing in space the geography of the Earth's surface and the locations of sinks and sources of the biosphere, oceans, atmosphere and lithosphere. In particular, it allows fixed space coordinates for the origins of anthropogenic perturbations. The Sun then has three velocity components, to represent the diurnal rotation of the Earth and the inclination of the ecliptic plane, the annual revolution with appropriate eccentricity, and other perturbations of the Earth's motion. Moreover, the bow shock and magnetosphere will appear anchored to the rotating Sun – Earth axis.

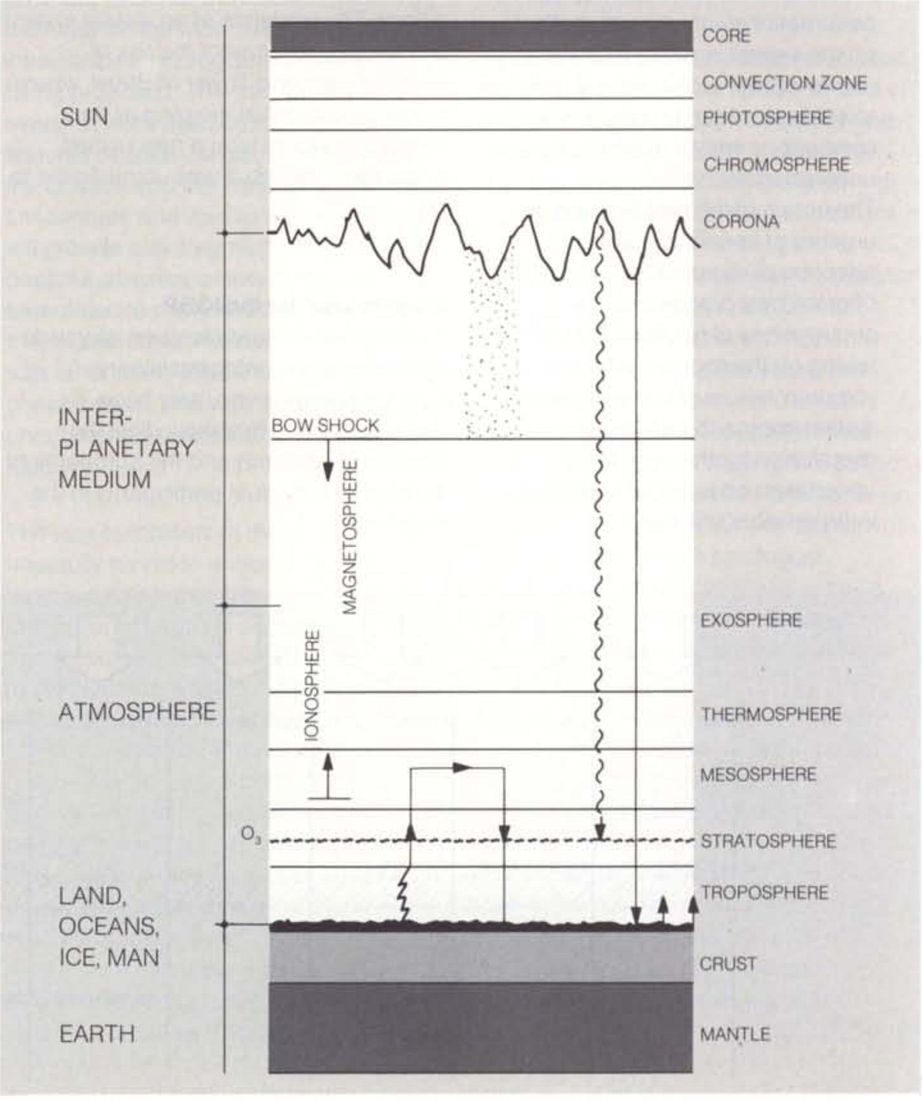
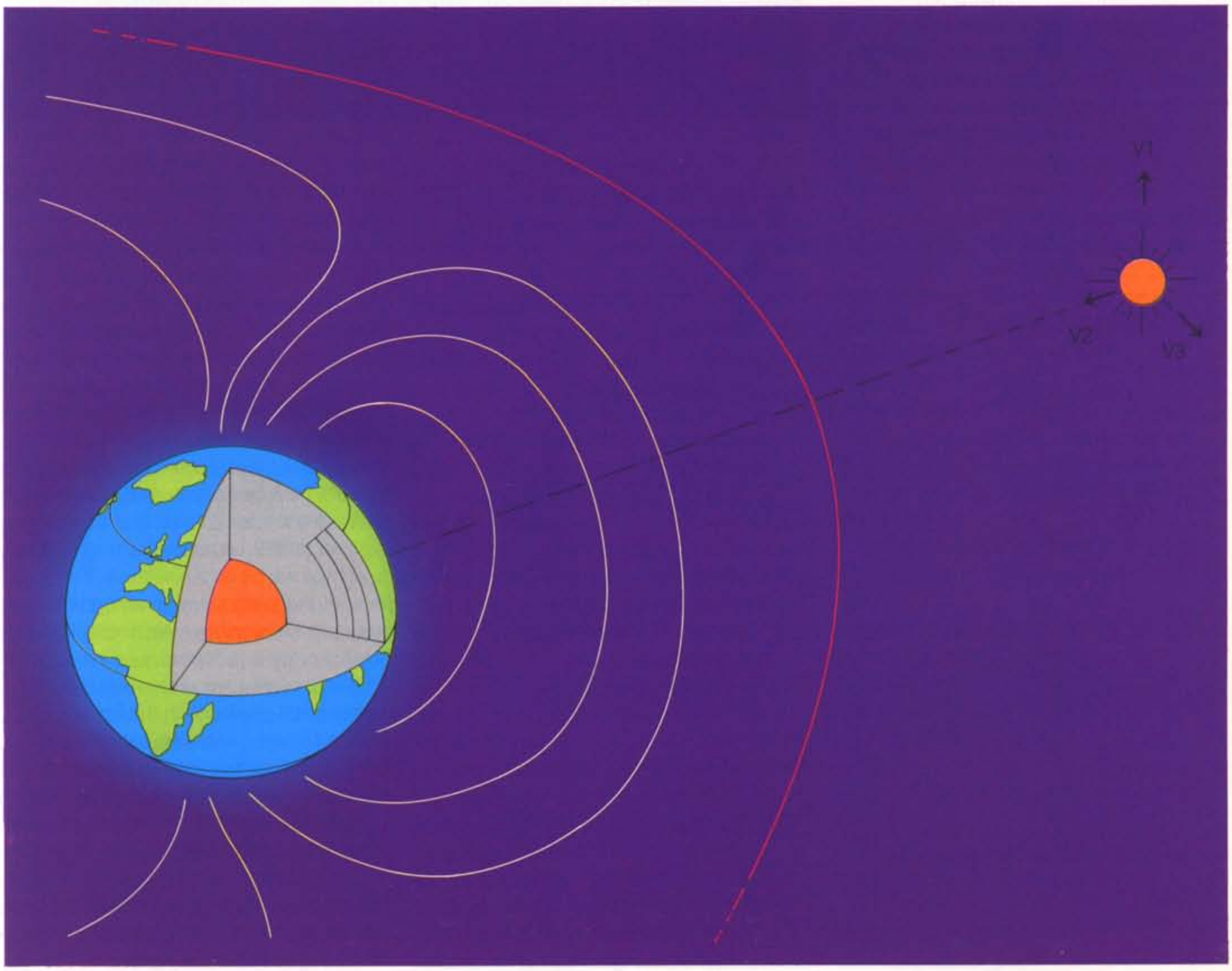


Figure 3 – Some elements of the 'Grand Machine' in three dimensions

The description of the physical model in a synthetic, synoptic form is a prime objective of the IGBP: the first issue of this document is needed as a matter of urgency and represents the first task for the international interdisciplinary cooperation. The model will initially contain several grey areas and black boxes, to be removed in subsequent iterations. One of the most important problems will be to isolate those phenomena that can be decoupled from the others, in order to linearise the system as far as possible. The master model will serve as a reference document for all participants, but also as a multidisciplinary textbook for the education of further potential participants.

The Master System Architecture
It should contain descriptions of what, where, when and how data related to the physical properties of the Grand Machine have been, are being, will be or should be generated, collected, distributed, analysed and stored. The descriptions of the available instrumentation systems and the data system infrastructure, both in operation and planned, will reveal where the major gaps are, prevent useless duplication, facilitate compatibility of measurements and their integration into the overall design, serve as a basis for the planning of further valuable contributions, and highlight opportunities for cooperation. New initiatives should be notified, as soon as decided upon, to the IGBP centre for incorporation into the master document.

There are currently between 30 and 50 major projects and programmes in operation or planned which involve research in relevant aspects of the Grand Machine. The architecture of the IGBP should be designed using such projects as the very solid foundation that they represent. It should identify what technical



facilities are missing in terms of either instrumentation or data management, for exploring and monitoring the scientific phenomena that are not yet fully understood, for integrating existing information with new data with the appropriate time and space resolution, and for allowing the correlation and synthesis of the results.

The space segment

The feasibility of a programme as ambitious as the IGBP will hinge on the availability of the latest, extremely powerful technological means for the solution of some of the most critical problems, including the most advanced technologies in such domains as informatics, telecommunications and space. Without in any way contradicting the previous conclusion regarding programme drivers, some thought must be given to what the space segment of the IGBP should look like in order to arrive at a first assessment of whether or not the technology can cope with the requirements; of where the greatest challenges will occur; and of what the overall size of this new venture might be expected to be.

The space segment can contribute to the generation, collection and distribution of the data. Orbital instruments can measure the in-situ properties of the interplanetary medium and part of the atmosphere in a unique way, and orbital observatories can look at the Sun and the Earth, both land and oceans, with high resolution and with a unique synoptic quality. In addition, data-relay and telecommunications satellites can form an integral part of the information network, for the collection of data generated at remote sites and their delivery to users for pre-processing, interpretation, and redistribution.

Tables 1 and 2* summarise some results of analyses conducted for two particular domains of the Grand Machine, with suitable instruments and appropriate orbits. The possibilities of accommodating several compatible instruments on single platforms, either as complete payloads of IGBP-dedicated satellites or as experiments onboard satellites providing other services (e.g. meteorology, earth observation, etc.) has also been studied.

* From 'Overview Study of the Sun/Earth Machine', ESA Contract Report by General Technology Systems Ltd. (GTS), London.

Consideration of the characteristics of the end-to-end data-management system, taking into account the need for real-time and near-real-time availability of many data, the expected number, likely equipment and geographical distribution of the user centres, permits a first quantitative estimate to be made of some important features for the space segment. These are summarised in Figure 4. In spite of the preliminary and approximate nature of the analysis, the numbers indicated are believed to be of the correct order of magnitude: 30 to 50 satellites operating simultaneously, with 200 to 300 instruments, delivering 200 – 500 Gbits/day of data after pre-processing.

One conclusion that can be derived therefrom is that the space segment needed for the IGBP will certainly be an order of magnitude larger than those conceived so far for such international scientific programmes as the Global Atmospheric Research Programme (GARP), the International Halley Watch (IHW), or the International Sun-Earth Explorer (ISEE) missions. The major challenge will be organisational, calling for a sound system design and good planning. No significant technological obstacles are anticipated, and expected state-of-the-art advances in several domains associated with the Space Station, tethered satellites, satellite-to-satellite communications, data storage, etc. are likely to provide novel means for investigating some as yet totally unexplored phenomena.

The data-management architecture of the system, of which the space segment will form a part, will require a great effort from

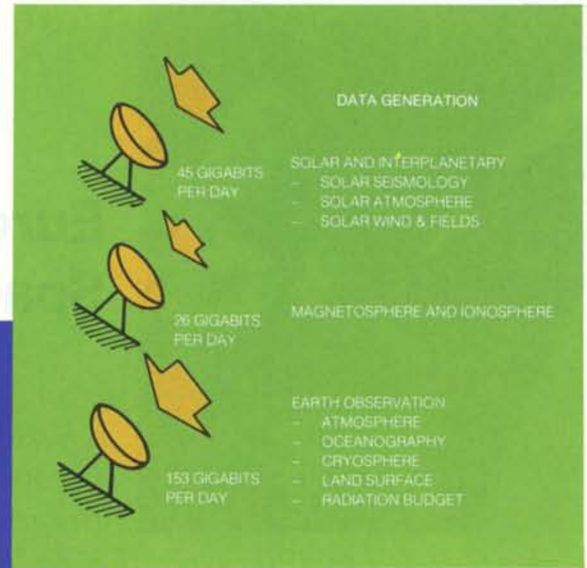
Table 1 – Magnetospheric and solar-wind fields

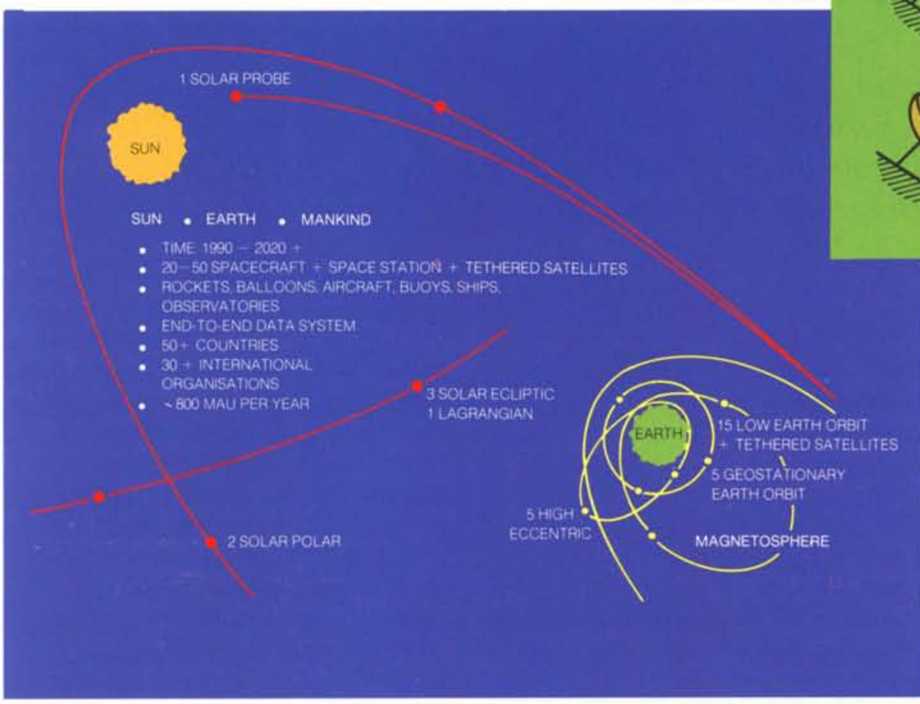
Instruments	
Triaxial Fluxgate Magnetometer	Radio-Science Experiments
Search-Coil Magnetometer	Ion-Injection Experiments
Electric Fields & Plasma-Waves Sensor	Electrostatic Analyser
Electron-Beam Experiment	Plasma-Ion Composition
Plasma-Density Sounder	Suprathermal & Low-Energy Particles
Radio Receiver	Energetic Charged Particles & Cosmic Rays
Spacecraft	**Location**
Three-Axis or Spin-Stabilised	Highly Eccentric Orbit
	Lagrangian Point

Table 2 – Cryosphere

Instruments	
Optical Imager	Synthetic-Aperture Radar
Infrared Imager	Radar Altimeter
Laser Altimeter	Multi-Beam High-Resolution Radar Altimeter
Passive Microwave Multifrequency Imager	Advanced Platform Location & Interrogation System
High-Resolution Microwave Multifrequency Imager	
Spacecraft	**Location**
Three-Axis Stabilised	Polar Orbit

Figure 4 — Envisaged space segment for support of the IGBP





the outset since it alone, if not well designed, could jeopardise the whole programme. The most critical aspects are likely to be the system's configuration, rather than the data rate, and the flexibility that will be required during the exploratory phase of the programme. Easy access should be ensured to the system's many instruments and to the many users, even during the periods of peak demand corresponding to specific campaigns. It will not be easy to establish the extent of the true requirements for real-time data availability, which will greatly influence system performance.

It is likely that the data network would benefit greatly from a geostationary 'Data Relay Belt', based on a ring of data-relay satellites in geostationary orbit, interconnected to provide a common bus for the data-management system. The first generation of such satellites will become available in the early 1990s for other users. It is extremely desirable that the specific requirements of the IGBP be incorporated as soon as possible in the planning for these relay satellites. Such requirements could become drivers for a subsequent system, for which large-capacity in-orbit storage and very-high-rate laser communications will also allow important simplifications onboard the instrument carriers.

Conclusions

Assuming that the 'Grand Machine' behaves as a single integrated system, and given the urgency with which we need to understand its behaviour, physical modelling of the Machine and a centrally formulated system architecture are indispensable if the existing cultural barriers between various disciplines are to be overcome. The importance of an integrated systems approach, guided by a central 'lighthouse', to the solution of the problems associated with the nature, dimensions and time scale of the Grand Machine should not be underestimated.

Preliminary analysis of the space segment needed for the IGBP serves to highlight the magnitude and difficulties of the new venture. It would be at least an order of magnitude larger than anything else attempted so far in the framework of a cooperative space programme. The major challenges remain the Programme's system design and organisation, as significant technological obstacles are not anticipated. The essential infrastructure of the Programme is the end-to-end data management architecture, of which the space segment is a part. This requires an important design effort, in view of the specific requirements derived from the system topography. The data network would benefit greatly from the availability of an Earth-encircling belt of geostationary telecommunications satellites of the kind presently being studied by ESA.

When Homo Sapiens first appeared on our planet some 150 000 years ago, man manifested his superior intelligence through two distinct new attitudes: he understood the value of collective actions in cooperation with others and he understood the value of technology, albeit stone-age rather than space-age at that time. Hopefully the intervening centuries have not so dulled that sense of mutual purpose that our predecessors exhibited, that we will fail to realise and capitalise upon the far-reaching goals and returns of the IGBP!

Europe should certainly take an active part in any well-conceived initiative to advance man's understanding of the mechanisms that ensure the continuation of life on Earth.

European Aspects of Using the Space Station

K.K. Reinhartz, Systems Engineering Department, European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands

In January 1984, President Reagan formally announced his decision to direct NASA to develop a permanently manned Space Station and at the same time invited international participation in the programme. Europe welcomed this invitation and in June 1984 the ESA Council passed a resolution to initiate a Preparatory Programme as part of the Columbus Programme, with the goal of preparing Europe for possible participation in the development, utilisation and operation of the Space Station. A final decision on European participation and its extent is expected at the end of 1986.

A major consideration in Europe's deliberations is the extent to which the development of the Space Station System, with both manned and unmanned elements in low Earth orbit, will benefit future space users in science, applied research and industry. Will the development of this new space infrastructure only support technological advances in space engineering, or will it lead to a new era in the scientific and commercial uses of space? These questions have been asked frequently, not only in Europe, but also in the United States. For a number of reasons it is not as easy to answer them in the Space Station context as in other areas of space utilisation. Most other space programmes start from a specific scientific or commercial objective, and the spacecraft is designed specially for the mission in mind. Typical examples would be a telescope to observe stars in a particular part of the energy spectrum, or a communications satellite to provide a well-defined number of telephone or television channels.

A Space Station, by contrast, is a large multipurpose facility which is not designed for a specific mission, nor even for a specific user group. Like other large investments in infrastructure, e.g. airports, roads, railroads and space launchers, a Space Station must meet identifiable short-term needs, but its real justifications can only come from the uses that its existence will help to create.

Despite these uncertainties, it is necessary, of course, at this stage to investigate all potential uses of the Space Station, to define the short- and medium-term applications, and to try to estimate the long-term uses. These data are needed both to guide the design engineers who will develop the Space Station and to ensure that the Station will provide the resources and facilities that are likely to be needed by future users to perform basic and applied research, and eventually commercial exploitation, efficiently and at a minimum cost. The data are also needed to help potential users to prepare themselves for the availability of the Station.

ESA recognised the need to develop a utilisation programme for a Space Station very early and studies were already started in 1982 as an essential element of the Space Transportation System Long-Term Preparatory Programme. The development of the infrastructure, the scientific and technical preparation of experiments, and the design of payload facilities must be well coordinated to ensure efficient use of the facility. The studies started in 1982 therefore have three major objectives:

- to identify uses and users of a Space Station, with particular emphasis on applications likely to benefit most from the new possibilities a Space Station is expected to offer
- to analyse and quantify the resources, facilities and services that a Space Station should provide to support future users
- to assist potential users in defining auxiliary activities necessary for the use of the Space Station, such as preparatory research, conducted either on the ground or in space.

Figure 1 — The anticipated functions of a Space Station facility

- ON-ORBIT LABORATORY
  - Science and Applications
  - Technology
- PERMANENT OBSERVATORY(S)
- TRANSPORTATION NODE
- SERVICING REPAIR FACILITY
  - Free Flyers
  - Platforms
- MANUFACTURING FACILITY
- ASSEMBLY FACILITY

A Space Station is a Multi-Purpose Facility

The elements and functions of a Space Station

The Space Station will be a permanent multipurpose facility in low Earth orbit, involving both manned and unmanned elements, which will significantly enhance current space operations.

The Space Station is foreseen as an evolutionary facility that will eventually serve a number of diverse functions, including acting as:
- a laboratory in space, for the conduct of science and the development of new technologies
- a permanent observatory, from which to observe the Earth and the Universe
- a transportation node where payloads and vehicles are stationed, processed and deployed to their destinations
- a servicing facility, with which payloads and vehicles are maintained, repaired and refurbished
- an assembly facility with which large space structures and systems are assembled and checked out
- a facility to enable manufacturing in space, where the unique space environment enhances commercial opportunities
- a storage depot where payloads and parts are kept in orbit for subsequent use, and
- a staging base for possible future missions, such as a permanent lunar base, a manned mission to Mars, a manned survey of the asteroids, a manned scientific and communications facility in geosynchronous orbit, or unmanned planetary probes.

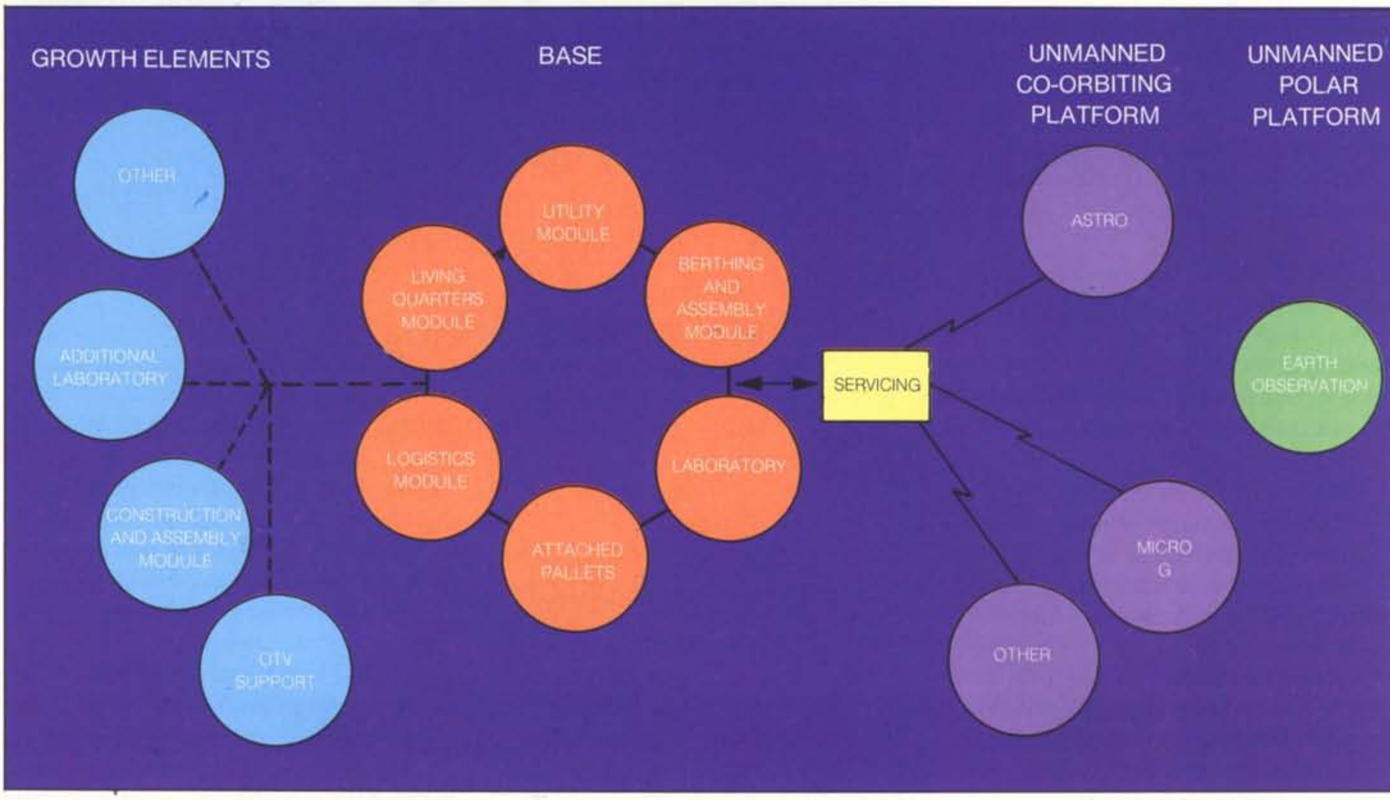
The major elements and functions of the Space Station have been defined, but the final configuration is still to be selected. In its initial configuration, the Station is expected to consist of a manned facility in an approximately 400 km high orbit inclined at 28.5° to the ecliptic, an automated co-orbiting platform, one or more automated platforms in a near-polar Sun-synchronous orbit, and an orbital manoeuvring vehicle capable of servicing free-flying spacecraft (Fig. 2).

One configuration being considered is the 'power-tower' concept shown in Figure 3. With a total length of approximately 120 m, it has large solar panels to convert sunlight into electrical energy (about 75 W continuous power) and smaller radiator panels to dissipate heat. A Space Shuttle is shown docked to one of five pressurised modules that will provide living and laboratory space for six to eight people. The spine-like structure that runs the length of the facility is equipped with instruments. A co-orbiting platform that will be serviced by the Station is shown in the bottom right corner of the illustration.

The manned module of the Space Station resembles Spacelab, Europe's existing contribution to the US Space Transportation System. It is to be expected that any European contributions to the Station will be based on the knowledge and experience gained in the Spacelab Programme. From a utilisation point of view, however, there will be significant differences. In the case of Spacelab, a payload is installed on the ground, launched into orbit, operated for a period of 7 to 10 days, and returned to Earth for modifications, changes and replacements. In the case of the Space Station, a payload must be designed to operate over much longer periods. Currently it is assumed that the Shuttle will visit the Station every 90 days to deliver supplies and exchange crews. During these visits the Shuttle can also deliver new facilities to the Station for a major reconfiguration or the replacement of payload facilities. It will be essential, however, that these facilities be designed for on-board maintenance and servicing during the intervals between Shuttle visits.

Figure 2 — The manned and unmanned elements of the Space Station

Figure 3 — NASA's 'Power Tower' Space Station, used as a baseline for further studies



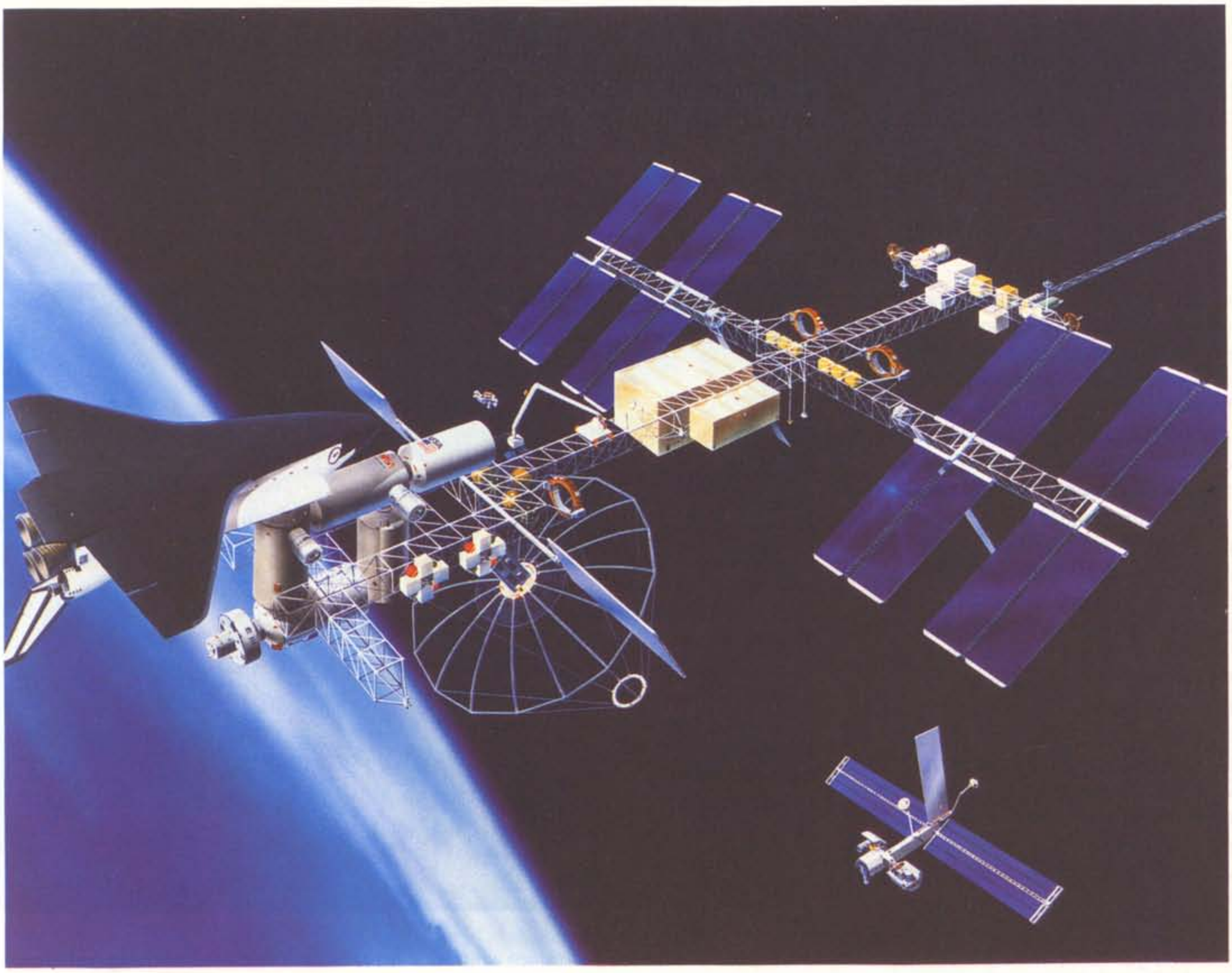
Another new aspect of space operations will be an extensive service capability for the co-orbiting platforms forming part of the Station, and for free-flying spacecraft in other low Earth orbits of similar inclination. To some extent this capability already exists with the Shuttle, well-known examples being the repair of the Solar Maximum Mission spacecraft and the recent recovery and return of two communications satellites that had failed to reach geostationary orbit. The current servicing possibilities are very limited, however, and it is expected that the Space Station will greatly enhance these capabilities and allow extensive maintenance, repair and reconfiguration of spacecraft either at the Station itself or remotely by using unmanned servicing vehicles operated from the Space Station as a base.

The Space Station elements in low Earth orbits with low inclination are planned to be supplemented by serviceable platform(s) in near-polar, Sun-synchronous orbit, which will be of particular interest for Earth observation. These 'polar platforms' are expected to use the same technology as the co-orbiting platforms, particularly as regards servicing and maintenance. Due to the excessive amount of propulsive energy that would be needed to transport a polar platform to the Space Station, it will not be possible in this case to use the servicing capabilities there. Servicing and maintenance will have to be performed from the Shuttle, probably using a Shuttle-based orbital manoeuvring vehicle.

Identifying users and their needs

The various elements of the Space Station could become of interest to a wide variety of users. To ensure that a wide range of potential users are involved and their requirements taken into account, a number of different approaches are being followed by the Agency:

- Since 1982, ESA has placed a series of three study contracts on 'European Utilisation Aspects of Low Earth Orbit Space Station Elements'. These studies were performed by DFVLR with support from a European industrial team with representatives from MBB/ERNO, Aeritalia, British Aerospace, Dornier System and Matra. Recently, at the start of the third phase in November 1984, this team was joined by Fokker (NL) and the Rutherford Appleton Laboratory (UK).
- In November 1983, a 'Space Station User Panel' was formed to advise the Agency on all aspects of the scientific use of the Space Station. This interdisciplinary group consists of a number of prominent European scientists, nominated by the scientific advisory bodies to the Agency. The disciplines represented include life sciences, materials science, fluid physics, astrophysics, solar-system science and Earth observation. The panel is presently chaired by Prof. H. Schnopper from the Danish Space Research Institute. The Panel's specific tasks are to:
  - assess the value of different concepts in providing and



stimulating opportunities for the European user community
- provide liaison with the discipline-oriented advisory bodies
- make recommendations for further study, and
- advise on which activities should be performed in Europe prior to the availability of a Space Station in order to maximise the return from the Space Station for European users.

- Representatives of those departments in ESA who may be involved in the future use of the Space Station give advice, provide liaison with their discipline, and organise specialised support to the on-going studies. In addition contacts have been established with interested national space agencies in Europe.

The user studies started in 1982 with the wide distribution of a questionnaire both to scientists who had already participated in space activities and to scientists and industrial firms who had no previous involvement in the space programme, but were considered potential future Space-Station users. The recipients were asked to indicate their interest in using a Space Station and to identify their requirements as far as possible.

The questionnaire produced a large number of mission proposals, mainly from scientists already involved in European space projects. A number of scientists, however, could not foresee a significant benefit from a Space Station in their discipline. Personal contacts indicated that, outside the groups already involved in space activities, very little is known about the status of these activities in Europe and the possible benefits the space environment would offer. In particular, industrial firms who might be interested in commercial Space-Station operations were concerned about a number of aspects:
- space operations are very expensive
- technical and administrative interfaces between potential users and government agencies providing flight opportunities are complicated
- the duration of individual space projects, with up to 10 years between initial studies and flight, is much too long
- there is no established institutional, legal, financial and planning framework which would allow industry to assess benefits and penalties in the longer term.

During Phase-2 of the Space-Station user studies, which lasted from September 1983 to June 1984, a selected number of potential uses of the Space Station were investigated in more detail. The effort to establish contacts with new user groups was actively continued, but again did not lead to specific results. As part of a longer term strategy, major emphasis was then laid on preparing information on the current status of and previous results from the relevant European space activities.

A brochure titled 'The Space Station – A Gateway to the Future' was prepared and

Figure 4 – Spacelab-1 Payload Specialist Ulf Merbold working with the Gradient Heating Facility, which forms part of the Materials Science Double Rack (MSDR)

widely distributed*, addressing potential users not familiar with space programmes. It summarises the existing and future facilities for research in space, the major results of space research and applications to date, and gives a number of examples, mostly in the area of microgravity research, where a Space Station is expected to make a major contribution to the further advancement of pure and applied research and may eventually lead to commercial applications. A more detailed report*, titled 'Preliminary Results of Microgravity Research', prepared before the results of the first Spacelab flight became available, addresses scientific specialists in life sciences, biology, and material science, who are experts in their disciplines, but have not yet been involved in space activities. It gives an overview of scientific work on the effects of microgravity in these disciplines.

The dialogue with potential industrial users is currently only in its infancy. Not only will time and a better information flow be needed, but also a new approach from ESA and the national agencies to simplify the access to space experiments and provide European industry with frequent, predictable flight opportunities under well-defined commercial, legal and technical conditions.

At the end of 1984, during the current Phase-3 of the Space Station utilisation studies, agreement was reached between the Space Station User Panel, the Agency and the DFVLR study team on a set of reference-model missions believed to be representative of the needs of future European users. These model missions will be used to introduce user requirements into the preliminary design studies of the Space-Station Programme with the aim of creating a user-friendly system. The models cover the period until the year 2000, but emphasis is on the early operational phase scheduled for the period 1992–1995. A summary description of the model missions and their payloads is given in Table 2.

Different needs in different disciplines
The dialogue with potential users of a Space Station showed that the interest and the requirements of scientific and technical disciplines in using the Space Station elements are very different from discipline to discipline.

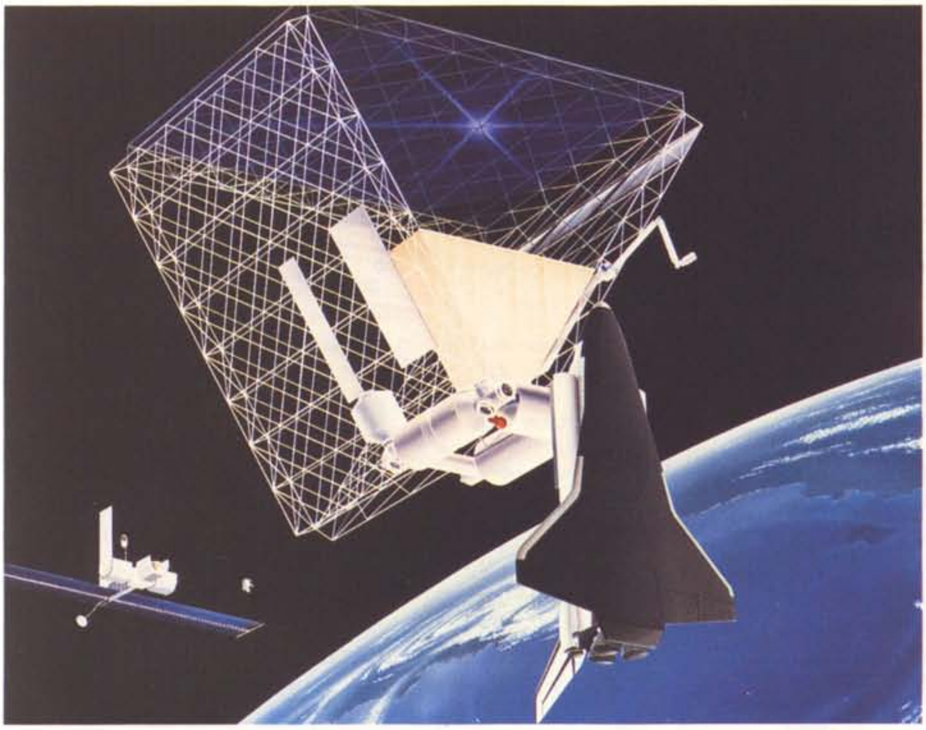
The life-sciences community has a very strong interest in using the Space Station, and in particular the pressurised manned modules. Life sciences need the station because many of the phenomena of interest require a pressurised laboratory and long-term observations in a microgravity environment. Only a permanently manned Space Station can provide this facility. As a first step, one part of a life-sciences laboratory has already been defined. The research areas to be covered are wide-ranging, including: human and animal physiology, cell biology, plant physiology, protein growth, preliminary demonstrations of bioprocessing techniques, and radiation biology. In addition some areas of the life sciences are interested in using platforms, mainly for studying effects of the space environments, e.g. radiation, on biological specimens and processes.

The materials-science disciplines have also expressed very strong interest in using a manned laboratory, as the rapid human intervention it allows is considered of great importance in materials-science research and development. Much higher power levels than present facilities can offer are also needed. Unmanned automatic platforms, serviced at regular intervals from the Space Station, are expected to be used once a process has been developed and manufacturing can start using automated facilities. Unmanned platforms will also be needed for research when extremely low gravitational disturbance levels are required, which may not be achievable on a manned platform.

As a first step, one element of a materials-science laboratory has already been identified, occupying about half a Space-Station laboratory module. Typical payload elements proposed are crystal

* Copies are available from the author

Figure 5 — Artist's impression of a large space structure tended by the Space Shuttle



growth and gradient-heating facilities, containerless processing equipment, and fluid-physics facilities. After a few years of research, a full-sized laboratory module should be added for the optimisation of manufacturing processes by operating pilot 'production-line' facilities in space. In addition, a representative automatic production facility for a co-orbiting platform has been identified, in order to derive the appropriate resource requirements for this type of facility. Similar to the life sciences, regular maintenance as well as removal and resupply of consumables will be needed, together with the exchange of complete facilities or parts thereof.

In the domain of the classical space sciences, astrophysics and solar-system exploration, a European long-term plan has recently been completed which identifies four major missions, the cornerstones of the programme until 2000, and a number of smaller missions.

None of the major missions is Space-Station dependent, although it is recognised that the Station's existence may have a significant influence on the space-science programme. Given the scientific objectives of the current plan, there are few obvious benefits in using the manned Station or the co-orbiting platforms as a carrier. Automated free-flying satellites are preferred by most scientists in these disciplines. There is, however, strong interest in exploring the Space Station's servicing capabilities for maintenance, exchange of instruments and replenishment of consumables, e.g. cryogenic coolants. One space observatory presently under development has already been designed for in-orbit maintenance and refurbishment, namely the Space Telescope. This large observatory, built by NASA with hardware contributions from ESA and to be launched in 1986, will initially be serviced by the Shuttle and later by the Space Station.

To introduce the requirements of typical servicing functions for scientific spacecraft, two model missions have been selected: a submillimetre infrared telescope, and a mission to collect primordial material from primitive bodies such as asteroids. The telescope will require the replenishment of the liquid hydrogen and helium used as coolants for its sensors, the exchange of instruments, and maintenance. For the 'primitive-body mission', the Space Station will be used as a transportation node for the flight from Earth to the asteroids and back.

In the medium term, the interest of the Space Station for future European communications satellite programmes will probably be limited to its occasional use for technology development, because communications satellites will continue to use the 36 000 km equatorial orbit. One exception is communications in the Arctic and Antarctic regions. In the longer term, the Station may serve as an assembly and transportation node during their transportation to geostationary orbit.

The Space Station is, however, expected to be of considerable interest for technology development and testing. For example, it will offer facilities for assembling large structures in the absence of gravity, which cannot be built or tested on the ground. It is also expected that there will be many other new technologies that will need the Space Station for development and testing prior to operational use. Facilities for in-orbit technology development should be available to European industry to allow it to maintain competitive capabilities for the year 2000 and beyond. The model missions selected include testing of advanced servicing concepts and deployment, assembly and measurement of different structures.

The Earth-observation disciplines are mainly interested in the use of a polar Sun-synchronous orbit. With the possible exception of occasional use of the Station in a 28.5° inclined orbit for instrument development or testing, there is little interest in its other elements. All Earth-observation missions presently under consideration can be flown on more or less conventional, free-flying spacecraft.

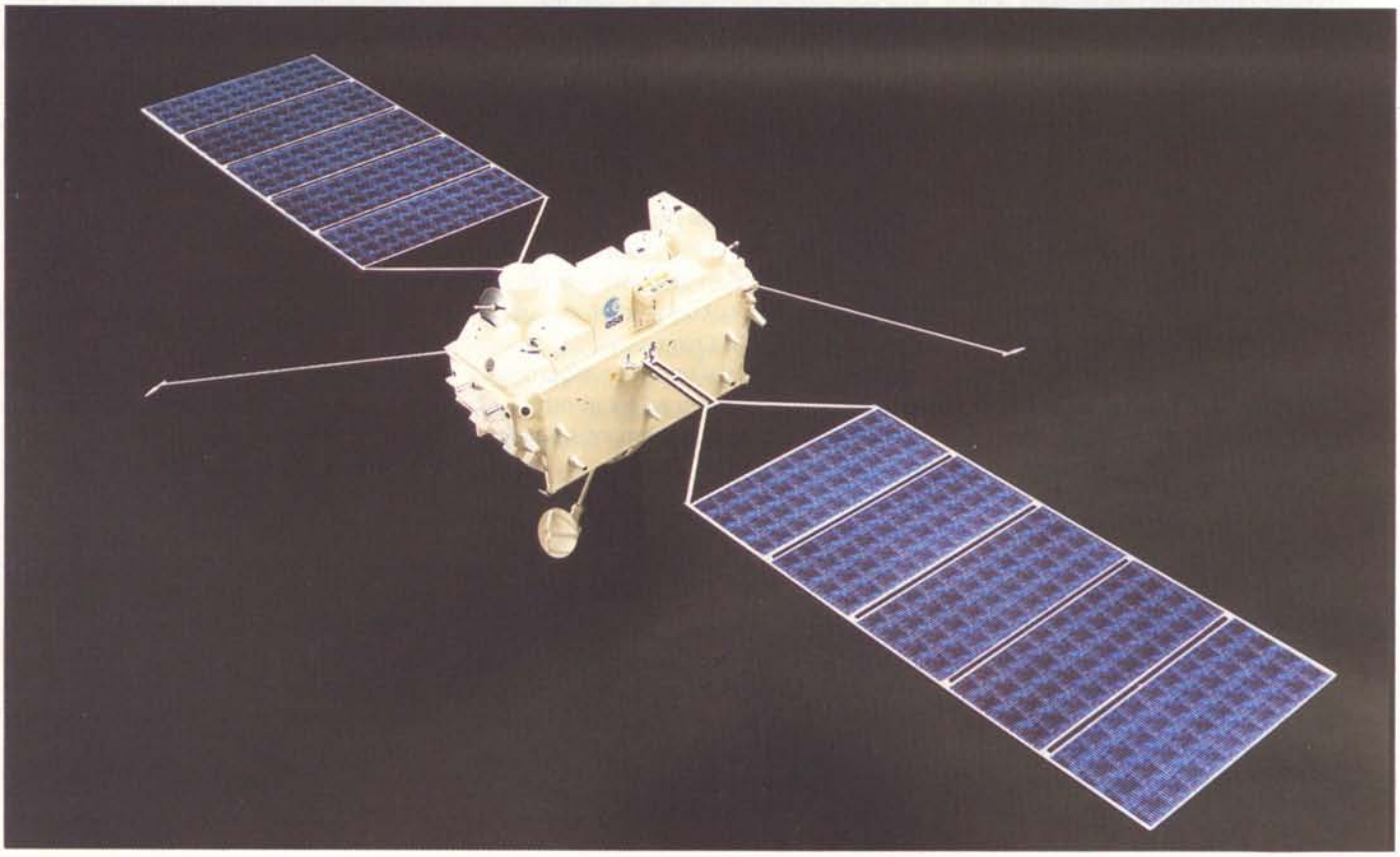


Figure 6 – Artist's impression of the European Retrievable Carrier (Eureca)

However, most such missions could also be flown on polar platforms of the Space Station System, making use of its service functions to extend lifetimes and reduce overall costs.

A summary of the degree of interest of different disciplines in using the Space Station and its elements is given in Table 1.

Table 1 – The usefulness of Space-Station elements for different disciplines

		Space-Station System Elements			
Discipline	Activity	Manned station	Coorbiting platform	Polar platform	Servicing autonomous spacecraft
Material sciences	Research	+ +	0	–	–
	production	+ +	+ +	–	–
Life sciences	Research	+ +	0	–	–
	bioprocessing	+ +	+ +	–	–
Space science	Research	0	0	0	+
Earth observation	Research	0	–	+ +	+ +
	operational	–	–	+ +	+ +
Technology	Development	+ +	+	–	–
Communication/ navigation	Development	0	–	0	–
	operational	–	–	0	–

+ + = very useful
+ = useful
0 = useful for a few application only
– = not useful

From model missions to requirements
Following the selection of representative model missions and the definition of their scientific and/or technical objectives, it is necessary to derive quantitative requirements in a format suitable for introduction into the Space-Station design process. Since the latter is the responsibility of NASA, it is essential that the European mission requirements be dovetailed with the NASA requirements as soon as possible, to ensure that the Space Station will be able to fulfil future European needs (Table 2).

Most of the NASA studies to date on the use of the Space Station have been conducted in-house, and a Mission Requirements Working Group has been formed with three discipline panels: Science and Applications, Commercial Utilisation, and Technology Development. These panels are responsible for interfacing with their respective user communities in order to analyse and assemble potential missions that would be supported by a Space-Station System. The information gathered (see table at foot of page), is assembled into a computerised database at NASA's Langley Research Center, where it is used to derive an operational performance envelope for the Space-Station System (rather than the conventional point design requirements used for conventional mission definition). NASA has also created a task force of scientific users of the Space Station, as an external advisory committee, chaired by Prof. Peter M. Banks from Stanford University. It consists of about twenty US scientists and several international observers, including European representatives.

The main interface between ESA and NASA as far as utilisation aspects are concerned is through the NASA Mission Requirements Working Group. European representatives, together with Japanese and Canadian representatives, have taken part in a number of NASA's Mission-Requirements Workshops, in which the resource requirements of the model missions proposed by the various disciplines have been discussed and analysed in detail.

A major problem is the fact that it is very difficult to quantify requirements at a time when the technical definition of many model missions is still very superficial. Most potential users are very reluctant to quantify their requirements at this time. The NASA database is, of course, still in the process of evolution and will be updated at regular intervals as new model missions are identified and others are modified or cancelled.

Table 2 – European Model Missions

	Objective	Start of operations
Material Sciences		
Material-Science Research Laboratory	Basic research in material sciences in a manned module	1992
Microgravity (Hands-On)	Production of materials for industrial research in a manned module	1996
Microgravity (Automated)	Production of materials on a Co-orbiting Platform with regular service by the manned station	1992
Life Sciences		
Life-Science Research Facility	Manned laboratory with a wide range of life-science research facilities	1992
Exo- and Radiation Biology	Life-science research payload on a Co-orbiting Platform with frequent servicing by the manned station	1992
Production Bio-Processing	Automated production facilities for bio-processing on a Co-orbiting Platform serviced by the manned station	1995
Exo- and Radiation Biology	Life-sciences payload for Polar Platform	1992
Astronomy and Solar-System Science		
Planetary-Science Mission Support	Space Station to support free-flyer mission as transportation node	1997
Far-Infrared/Submillimetre Space Telescope	Space Station to support free-flyer mission during assembly and test, cryogenic coolant replenishment, servicing	1995
Earth Observation		
Morning Platform Payload	Serviceable instrumentation on Polar Platform, predominantly for land observations	1992
Afternoon Platform Payload	Serviceable instrumentation on Polar Platform, predominantly for ocean/ice/atmosphere monitoring	1995
Communications		
Arctic/Antarctic Mobile Radio	Mobile radio transponder on Polar Platforms for telephone and radio data services	1992
Technology Development		
Robotic Servicing	Testing of advanced servicing concepts using the manned station	1993
Fluid-Transfer Management	Testing of advanced fluid-transfer concepts for propellants and pressurised gases using the manned station	1993
Large-Structure Deployment/Assembly	Testing of new structural concepts for large antennas, solar concentrators and support structures	1993
Tether System Application	Verification of the performance of tether systems as power source and attitude-control devices	1994

Typical input items for the Langley database

- Project name and code
- Flight and operation schedule
- Description
- Orbit
- Pointing/orientation
- Power requirements
- Thermal condition required
- Data processing and communication requirements
- Equipment characteristics, including location
- Crew requirements for nominal operation and for servicing
- Logistic requirements for consumables and configuration changes
- Special notes, e.g. contamination risk, storage needs

Future activities

Phase-3 of the study of 'European Utilisation Aspects of Low Earth Orbit Space Station Elements', started in

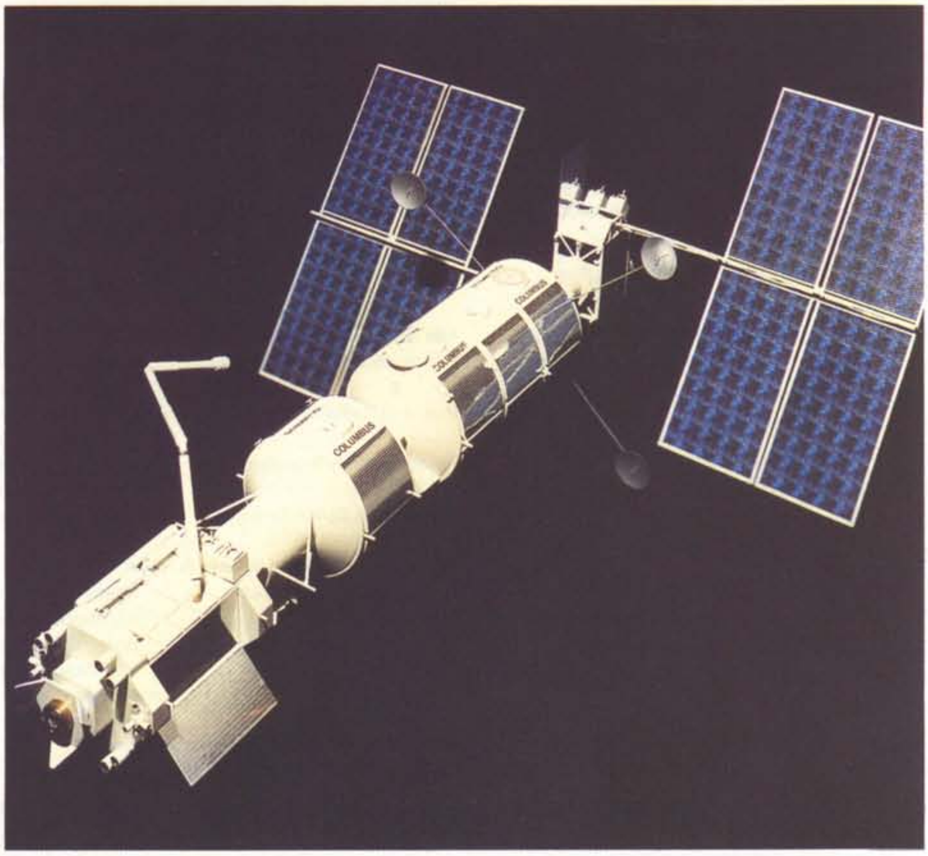


Figure 7 — Artist's concept of the Columbus manned station, with service vehicle docked

November 1984 and scheduled to end in September 1985, will continue to search for new Space Station uses and potential users. Major tasks will also be to start the conceptual design of a limited number of payload elements selected from the current set of model missions, and to initiate an assessment of user needs for operational interfaces. The continuous operation of multipurpose laboratories in space, either in a manned pressurised module or on an automated platform, with regular servicing requirements, will undoubtedly require novel approaches, both in-orbit and on the ground.

During 1985, preparations for the utilisation of the Space Station will be twofold: detailed preparation for the initial period of Space Station operations on the one hand, and continuation of the investigation of long-term aspects on the other. The long-term activities will consider not only the utilisation of the different parts of the US Space Station System, but also additional European infrastructure elements in low Earth orbit, which are expected to become operational after 1995, such as the Ariane-5 launcher, a manned transport vehicle, and automated or man-tended platforms.

A significant part of the European Phase-B activities for the Columbus programme, to start in April 1985, are expected to be devoted to the preparation for European utilisation of the Space Station. This effort, which has not yet been defined in detail, should include scientific studies to support user groups in defining missions in more detail, the preliminary design of facilities and instruments, and the development of the associated technologies.

As a first step in preparing for the initial Space-Station utilisation phase, an ESA Inter-Directorate Working Group for Space Station Utilisation has recently been formed to prepare a coordinated European utilisation plan based on the inputs from the user communities and the funding authorities. It is also planned to establish a Space Station Utilisation Working Group, composed of delegates from the Agency's participating Member States, similar to the Payload Working Group for the European Retrievable Carrier (Eureca) programme. The major tasks of this group would be to select major multiuser facilities and instruments for the initial phase, to prepare for the funding decisions for the development of these facilities, and to prepare for the decisions concerning the implementation of the initial phase, including organisation of mission and payload control centres, data distribution, etc.

The Space Station will offer users and potential users new capabilities and more resources than previous space projects, particularly in the areas of microgravity research and applications. However, its operation will also be expensive. To use it and any future European elements in low Earth orbit in a cost-effective manner, the users, in European science and industry and space agencies, must work together in planning and implementing a coordinated utilisation effort.

This effort must not be limited to providing new facilities. Even more important may be the need to train more scientists in the use of space for their particular disciplines for basic research and for commercial applications. One laboratory module on the Space Station will offer more than a hundred times more experiment time in a pressurised laboratory in space, compared to Europe's past or planned use of Spacelab.

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

In Orbit / En orbite

	PROJECT	COMMENTS
SCIENTIFIC PROG.	ISEE-2	
	IUE	
	EXOSAT	
APPLICATIONS PROGRAMME	OTS-2	1.5 YEAR HIBERNATION PHASE
	MARECS-1	
	MARECS-2	LIFETIME 5 YEARS
	METEOSAT-1	LIMITED OPERATION ONLY (DCP)
	METEOSAT-2	
	ECS-1	LIFETIME 7 YEARS
	ECS-2	LIFETIME 7 YEARS

Under Development / En cours de réalisation

	PROJECT	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE	LIFETIME 11 YEARS
	ULYSSES	LIFETIME 4.5 YEARS
	HIPPARCOS	LIFETIME 2.5 YEARS
	GIOTTO	HALLEY ENCOUNTER MARCH 1986
	ISO	LAUNCH 1992
APPLICATIONS PROGRAMME	ECS-3, 4 & 5	
	OLYMPUS-1	LIFETIME 5 YEARS
	ERS-1	LAUNCH MAY 1989
	METEOSAT-P2/LASSO	LAUNCH JUNE 1986
	METEOSAT OPS PROG.	
SPACELAB PROGRAMME	SPACELAB	
	SPACELAB FOP	ADDITIONAL HARDWARE STAGGERED DELIVERIES
	IPS	
	SLP REFLIGHTS	
	MICROGRAVITY	
	EURECA	THREE-MONTH RETRIEVAL PERIOD
ARIANE PROGRAMME	ARIANE LAUNCHES	
	LARGE CRYO. ENG.	IN COURSE OF APPROVAL
	ARIANE 4	FIRST FLIGHT MID-JUNE 1986
	ELA 2	

= DEFINITION PHASE · > PREPARATORY PHASE · ▨ MAIN DEVELOPMENT PHASE · # STORAGE · ◇ HARDWARE DELIVERIES

~ INTEGRATION · ↑ LAUNCH/READY FOR LAUNCH · • OPERATIONS · - ADDITIONAL LIFE POSSIBLE · ↓ RETRIEVAL

Geos

On rappelle que depuis janvier dernier Geos-2 a été transféré de l'orbite des satellites géostationnaires, menacée d'encombrement, vers une orbite plus haute où il dérive lentement à raison d'environ 3,5° par jour, revenant ainsi tous les trois mois en vue de la station sol de l'ESOC pendant une durée de quatre semaines. En raison du bon état de santé du satellite et de sa charge utile, joint au désir des scientifiques d'amasser des données sur une fraction aussi grande que possible du cycle solaire ainsi qu'au souci de favoriser la réussite de l'expérience AMPTE ('Active Magnetospheric Particle Tracer Experiment'), l'Allemagne et la Suisse ont accepté de prolonger d'un an le financement des opérations, à compter d'août 1984, dans le cadre d'un projet spécial. Cette prolongation recouvre en fait quatre périodes d'acquisition successives: août-septembre 1984, décembre 1984 - janvier 1985, mars-avril 1985 et juillet-août 1985. L'attitude du satellite peut en principe être ajustée de manière à permettre durant ce laps de temps une réception continue de la télémesure par l'intermédiaire de l'antenne directive UHF.

La dernière en date de ces périodes d'acquisition (du 20 août au 20 septembre) a eu une importance considérable du fait des lâchers de substances chimiques effectués à partir du satellite AMPTE les 11 et 20 septembre. Après avoir tenté sans succès le 6 septembre une manoeuvre d'orientation afin de se placer dans les meilleures conditions d'observation possibles, on n'a pas été en mesure d'obtenir le degré de chevauchement voulu. Ainsi, le lâcher du 11 septembre a eu lieu à 7 h 25 min TU mais Geos-2 n'a commencé à recueillir des données à son sujet qu'au moment de midi.

Geos-2 sera à nouveau visible dans la période du 10 décembre 1984 au 10 janvier 1985. L'épuisement des réserves d'hydrazine ne permettant pas d'envisager une manoeuvre de retournement pour empêcher les mâts du satellite de faire ombre sur le générateur solaire, on a décidé d'orienter ledit satellite de telle sorte que son axe de rotation soit perpendiculaire à l'écliptique. Dans ces conditions, l'ESOC annonce un degré de couverture quotidien d'environ 60% pour toutes les périodes d'acquisition à venir. Entretemps, on a procédé avec succès à la manoeuvre requise. Le prochain lâcher dans le cadre de l'expérience AMPTE (comète artificielle) est prévu pour le 25 décembre à 12 h 18 min TU et l'attitude actuelle de Geos-2 devrait permettre de recueillir simultanément des données sur ce phénomène.

ISEE

Cette mission conjointe ESA-NASA mettant en jeu un total de trois engins spatiaux a débuté en octobre 1977 et continue aujourd'hui encore à fournir des données d'excellente qualité.

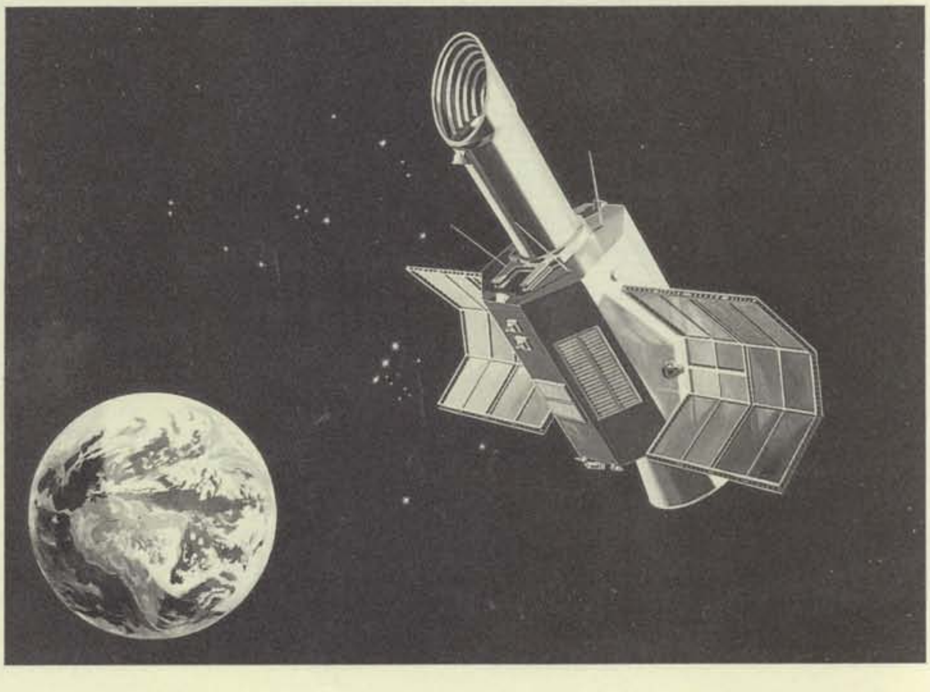
ISEE-3, rebaptisé ICE (de l'anglais 'International Cometary Explorer'), poursuit son voyage vers la comète Giacobini-Zinner, dont il traversera la queue en septembre 1985. Une série de réunions sont prévues à l'intention des chercheurs concernés, pour leur permettre d'exploiter au mieux les moyens de télémesure disponibles et de tirer le maximum de profit scientifique d'une charge utile qui n'était pas initialement destinée à l'étude des comètes.

Le couple ISEE-1/ISEE-2 poursuit sa collecte de données. L'alimentation électrique d'ISEE-2 donne des signes de faiblesse et pourrait exiger par la suite un certain partage du temps d'observation entre les différentes expériences.

IUE

Désormais largement entré dans sa septième année de fonctionnement en orbite, le Satellite d'exploration internationale dans l'ultraviolet est toujours en état de marche. Depuis qu'on a changé de tube de prise de vues principal pour l'enregistrement des spectres aux grandes longueurs d'onde, on n'a plus eu besoin de toucher aux instruments scientifiques ni aux équipements de servitude.

Les performances du satellite durant son dernier passage en éclipse, où l'ombre était particulièrement prononcée, ont été satisfaisantes. Les batteries et les panneaux solaires fonctionnent dans les limites prévues, venant ainsi confirmer les estimations de l'année dernière concernant la durée de vie prévisible du satellite. Un système de secours permettant le cas échéant de faire fonctionner celui-ci avec deux gyroscopes seulement a été mis en place dans les deux stations sol. D'autre part, on a procédé avec succès à l'installation d'un nouvel ordinateur au sol. Le nouveau système joue pleinement son rôle au service des opérations en temps réel et des besoins de traitement des images depuis mars 1984.



Artist's impression of the Ultraviolet Explorer Satellite (IUE)

Vue conceptuelle de l'IUE

Geos

It will be recalled that in January 1984 Geos-2 was moved from the densely populated geostationary orbit into a higher and slightly synchronous orbit, where it now drifts at a rate of about 3.5° in longitude per day, becoming visible to the ESOC ground station for four weeks every three months. In view of the good health of both spacecraft and payload, the wish of the scientists to obtain data over as much of a solar cycle as possible, and the desire to support the current AMPTE (Active Magnetospheric Particle Tracer Experiment) project, Switzerland and Germany agreed to finance a year's extension, starting in August 1984, in the framework of a special project. In fact, this extension consists of four acquisition periods, in August/September 1984, December 1984/January 1985, March/April 1985 and July/August 1985. The attitude of the Geos spacecraft can, in principle, be adjusted so that continuous telemetry reception from the directional UHF antenna is obtained during these periods.

The last acquisition period (20 August – 20 September) was of considerable importance because of the chemical releases from the AMPTE spacecraft on 11 and 20 September. An attitude manoeuvre attempted on 6 September to maximise coverage for these events was unsuccessful and the desired overlap was not achieved. For example, the AMPTE release on 11 September occurred at 7.25 UT and Geos-2 data acquisition did not start before noon on that day.

Geos-2 will be visible again in the period 10 December 1984 – 10 January 1985. The shortage of on-board hydrazine does not permit an inversion manoeuvre. Therefore, to avoid boom shadows on the solar array around the winter solstice, it has been decided to place Geos-2 into an attitude with its spin axis perpendicular to the ecliptic plane. For this attitude, ESOC predicts a daily coverage of about 60% for all forthcoming acquisition intervals. The necessary manoeuvre has been carried out successfully in the meantime. The next AMPTE release (Artificial Comet) is planned for 25 December at 12.18 UT and the current attitude of Geos-2 should permit simultaneous data acquisition.

ISEE

Good-quality data is still being returned by this three-spacecraft joint NASA/ESA mission, begun in October 1977.

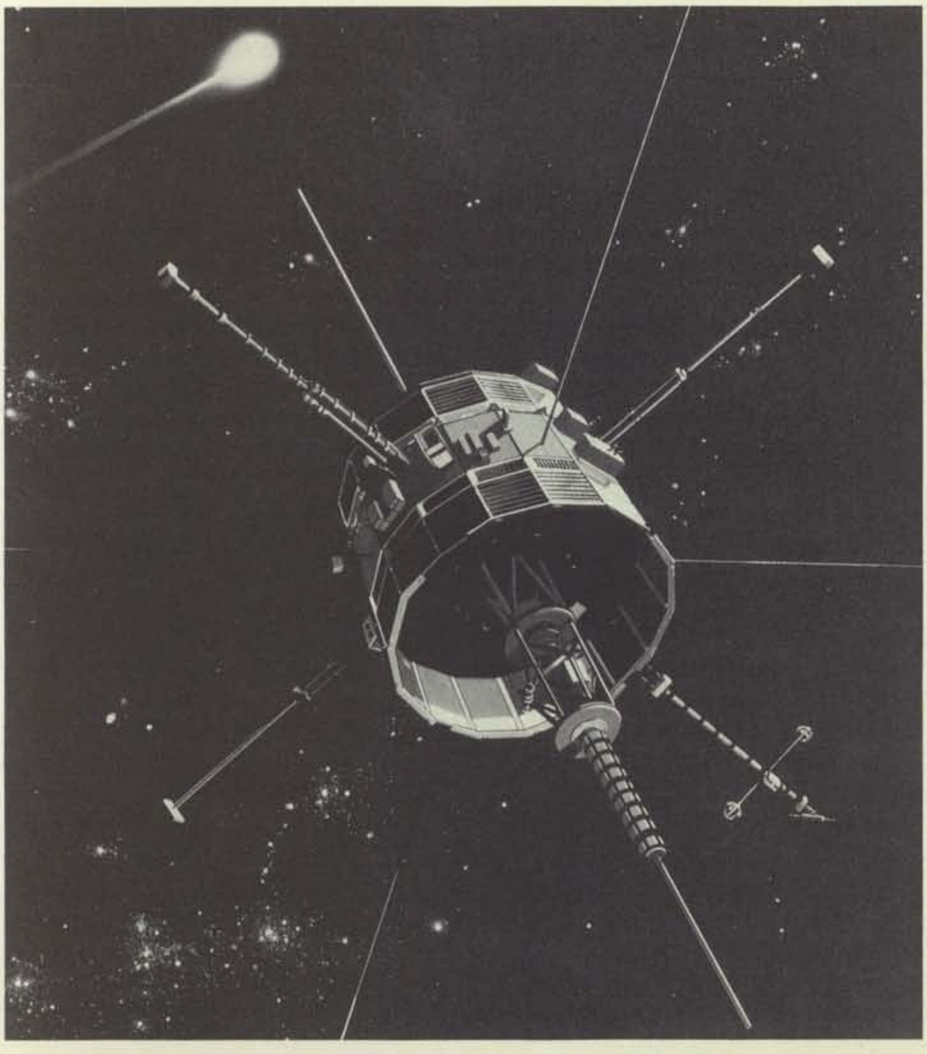
ISEE-3, renamed ICE, is continuing its journey towards comet Giacobini Zinner. The spacecraft will cross the tail of the comet in September 1985. A series of meetings are scheduled for investigators on ICE in order to make the best use of available telemetry and in order to obtain the maximum of science from a payload not developed for cometary science.

The ISEE-1/ISEE-2 spacecraft pair are continuing their data collection. There are some signs that the power on ISEE-2 is getting low and may eventually require some sharing of observation time between experiments.

IUE

Well into its seventh year of orbital operations, the International Ultraviolet Explorer satellite is still fully operational. After the change of the prime operational camera for the long-wavelength spectrograph, no further ground-commanded changes have been required either in the scientific instruments or in the spacecraft support subsystems.

The performance of the spacecraft through the most recent, very deep, solar shadow has been good. Batteries and solar panels are performing within the predictions, supporting the expected lifetime estimates made last year. A backup system, which would make it possible to operate on two gyros only, has been installed at both ground stations. The installation of a new ground computer system has been successfully completed. The new system has fully



Vue conceptuelle du satellite ISEE-3

Artist's impression of the ISEE-3 spacecraft

A en juger par les perspectives qui s'offrent, l'année 1985 ne devrait pas imposer de restrictions à la souplesse du mode d'exploitation actuel. Le logiciel d'ordonnancement a subi de larges modifications afin de faciliter la prise en compte des besoins correspondants eu égard aux contraintes présentes et futures du satellite. Ces modifications avaient également pour but de faciliter la coordination des observations avec, notamment, le satellite Exosat. On a ainsi pu réaliser avec le concours de ce dernier toute une série d'observations, dont certaines portant sur des phénomènes imprévus tels que l'explosion d'un objet du type BL Lac ou l'apparition d'une nova. On a également procédé avec succès à d'autres observations en vue de redéfinir la fonction de transfert d'intensité des deux tubes de prise de vues pour les grandes longueurs d'onde; les résultats de ces observations sont en cours d'examen pour la réduction des données.

Les rapports présentés à la réunion de mai 1984 entre les trois agences participantes sur les derniers temps d'existence et le ralentissement d'activité du satellite ont précisé les différents sujets de préoccupation. On est en train de mettre en place un Comité consultatif tripartite chargé de formuler des recommandations sur les priorités à observer.

La publication de travaux scientifiques consacrés aux résultats d'IUE se maintient à un niveau élevé, preuve que le satellite continue à fournir un apport vital aux astronomes.

Grâce à lui on a récemment pu observer une nova à évolution lente, de surcroît avant qu'elle ait atteint son maximum. Le fait mérite d'être signalé puisque toutes les novas observées jusqu'alors par l'équipe responsable des 'cibles occasionnelles' étaient des novas rapides. Parmi les nombreuses contributions scientifiques auxquelles IUE continue à donner lieu, citons la preuve que le vent stellaire associé aux étoiles précoces a un caractère variable et discontinu, ainsi que la diminution d'éclat spectaculaire dans l'ultraviolet (plus de trois magnitudes) d'une des galaxies de Seyfert ayant la plus forte luminosité intrinsèque.

Exosat

Lancé à la fin du mois de mai 1983, Exosat fonctionne maintenant depuis plus de 18 mois.

Les performances de l'appareillage moyenne énergie et du spectromètre à scintillateur gazeux s'avèrent excellentes, avec notamment une bien meilleure sensibilité qu'on ne l'escomptait avant le vol grâce à l'obtention de niveaux de bruit de fond beaucoup plus faibles. Après avoir connu quelques problèmes dus aux effets thermiques, le réseau multiplicateur à canaux du télescope LE1 fonctionne à présent avec une efficacité de 100% tout au long de l'orbite du satellite. Les trois instruments embarqués — télescope basse énergie, spectromètre à scintillateur gazeux et ensemble de détecteurs moyenne énergie — ont tous accompli un travail scientifique de premier ordre.

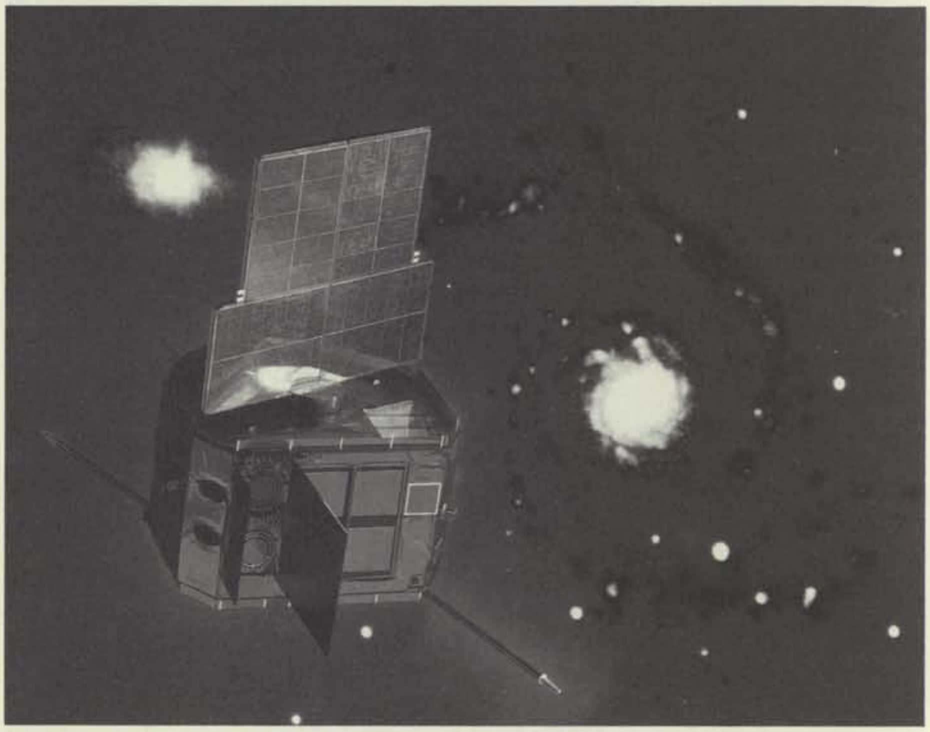
L'observatoire a déjà à son actif plus de 1000 observations portant sur une variété de sources de rayonnement X, des trous noirs présumés aux amas de galaxies en passant par les étoiles à neutrons. Le temps d'observation disponible ne suffit pas, et de loin, à satisfaire la demande.

On a apporté des modifications aux moyens de traitement en temps réel de l'observatoire et aux programmes d'application dont disposent les observateurs à bord du satellite. L'important travail de perfectionnement du logiciel d'analyse en mode interactif en vue d'offrir à ces derniers un service supplémentaire, notamment lorsque l'institut dont ils relèvent est dépourvu de moyens logiciels d'envergure pour l'exploitation des données Exosat, est désormais presque achevé. Le nouveau système interactif sera accessible aux observateurs à titre d'essai à compter du 1er décembre 1984.

L'observatoire poursuit le cours normal de ses opérations, le délai de diffusion des bandes numériques destinées aux observateurs restant inférieur à 30 jours. L'analyse scientifique automatisée des bandes d'observation définitives va bon train.

En août 1984 a été lancée la troisième offre de participation au programme d'observation du satellite à l'intention de la communauté scientifique mondiale. Cette offre vaut pour une durée d'un an, jusqu'en 1985. Elle devrait susciter un très large écho, en particulier aux Etats-Unis, vu les résultats captivants d'ores et déjà obtenus et l'intérêt précédemment manifesté par les astronomes du monde entier à l'égard de la mission.

Une fraction appréciable (pas moins de



Exosat

supported real-time operations and image-processing requirements since March 1984.

The present outlook for 1985 is that no restrictions will have to be imposed on the present flexible mode of operations. Extensive modifications to the scheduling software have been made to allow easier handling of scheduling requirements under present and expected future spacecraft constraints. These modifications were also aimed at facilitating the scheduling of coordinated observations with, for example, Exosat. Extensive coordinated observations have been made with both spacecraft, including some of unpredicted phenomena such as a BL Lac object in outburst and a nova. Observations to re-determine the intensity transfer function for both long-wavelength cameras have been successfully completed and are under study for implementation in the reduction processing.

Reports on the late life and rundown of the satellite, presented at the May 1984 three-Agency meeting, have identified the areas of concern. A three-Agency Advisory Committee is being formed to make priority recommendations.

The production of scientific papers based on IUE results remains at its previous high level, showing that the satellite is still supplying a vital service to the astronomical community.

It has recently been possible to observe a slow nova with IUE, and in addition to observe it before maximum. This is important since all previous novae observed by the 'target of opportunity' team have been fast novae. Among the many important scientific contributions IUE keeps producing, the evidence that the stellar wind in early-type stars is variable and discontinuous, and the spectacular decrease in the UV brightness of one of the intrinsically brightest Seyfert galaxies by more than three magnitudes merit special mention.

Exosat

Exosat, launched at the end of May 1983, has now been operational for more than 18 months.

The medium-energy experiment and gas-scintillation spectrometer performance is excellent, with a much improved sensitivity over pre-flight estimates as a result of the much lower background levels achieved. The channel multiplier array on the LE1 telescope, after some problems resulting from temperature effects, is now performing with 100% efficiency throughout the orbit. All three instruments – the low-energy telescope (LE), the gas scintillator and the medium-energy detectors, have performed front-line science.

The observatory has performed over 1000 observations of X-ray sources to date, ranging from candidate black holes and neutron stars to clusters of galaxies. Demand from scientific customers to use Exosat far exceeds the time available.

Changes in the real-time facilities at the observatory and the on-board application programmes available to observers have been completed. The major upgrading of interactive analysis software to provide an additional service to observers, in particular those without major Exosat software facilities at their home institutes, is almost complete. This interactive system will be available to observers on a trial basis from 1 December 1984.

The observatory continues its routine operations, with the delay in the issue of data tapes to the observer maintained below 30 days. The automatic scientific analysis of all observers' final observation tapes is proceeding smoothly.

The third announcement of opportunity (AO3) to participate in the Exosat observation programme was issued to the worldwide community in August 1984. This AO covers a one-year observing period, through 1985. Based on the exciting scientific results obtained to date and the previous degree of interest in the mission shown by the whole astronomical community, the response is expected to be very large indeed. A particularly strong interest from the USA is anticipated.

A significant fraction (30%) of Exosat's results have been obtained while the observatory was coordinated with IUE or ground-based facilities. Despite the operational problems encountered in the first few months of the mission, a major success has been the continuing flexibility displayed by the observatory in performing coordinated observations. In fact, Exosat continues to perform simultaneous observations regularly with most types of ground-based facilities, and coordinated observations with the IUE and Tenma satellites are commonplace. The detected multi-frequency results published so far clearly indicate the worth of such observations.

Fully calibrated Exosat data from an observation enter the public domain one year after that observation. Such data will be available for the first time in April 1985, and measures to handle the anticipated demand are in the final stages of definition.

Marecs

The Marecs-B2 launch campaign proceeded according to schedule, with electrical performance checks, alignment checks, proof pressure testing, solar-array installation, hydrazine filling, apogee-boost-motor installation, weighing, dynamic and static balancing and finally integration of both spacecraft into the Sylda dual-launch structure, which was then installed on the launch vehicle (see pages 78-85).

Lift-off occurred at 22 h 14 min Kourou local time on 9 November (i.e. 1 h 14 min GMT on 10 November). The flawless powered flight of the Ariane-3 launcher permitted accurate insertion of Marecs-B2 into transfer orbit. After spin up to 65 rpm and optimisation of spin-axis orientation, the European MAGE-2 apogee boost motor was successfully fired and injected the spacecraft into a near-synchronous orbit, with a slow eastwards drift towards its final orbital longitude of 177.5°E.

The spacecraft was then despun and the solar arrays successfully deployed. The complex sequence of Earth acquisition was then initiated, ending when the spacecraft was three-axis-stabilised with its antennas pointing towards the Earth and its solar arrays rotating about an axis perpendicular to the orbit plane.

During the drift phase, the platform and payload were successfully commissioned. Final operating longitude was reached on 20 December and operational service for INMARSAT over the Pacific Ocean was due to start on 1 January 1985.

Marecs-A, launched on 19 December 1981, has successfully completed its third year in orbit without incident and no sign of degradation.

30%) de l'ensemble des résultats a été acquise avec le concours d'IUE ou d'observatoires au sol. Malgré les problèmes d'exploitation rencontrés dans les tout premiers mois de la mission, la souplesse dont Exosat n'a cessé de faire preuve en la matière constitue un important succès. Le satellite continue d'ailleurs à coopérer régulièrement avec toutes sortes de moyens au sol, et les observations effectuées en conjonction avec IUE et le satellite japonais Tenma sont monnaie courante. Les travaux déjà parus au sujet des rayonnements ainsi détectés à plusieurs fréquences attestent la valeur de ce genre d'observations.

Leur étalonnage une fois terminé, les données d'observation recueillies par Exosat tombent dans le domaine public au bout d'un an. Ces données commenceront à être disponibles en avril prochain, et on achève actuellement de définir des mesures permettant de faire face à la demande qu'elles devraient susciter.

Marecs

La campagne de lancement de Marecs B2 s'est poursuivie conformément au calendrier, avec les opérations suivantes: vérification des performances électriques, contrôles d'alignement, timbrage, installation du générateur solaire, remplissage des réservoirs d'hydrazine, installation du moteur d'apogée, pesage, équilibrage statique et dynamique et, pour finir, intégration avec l'autre satellite sur la structure de lancement double Sylda, qui a ensuite été mise en place sur le lanceur.

Le décollage a eu lieu le 9 novembre à 22 h 14 min, heure locale de Kourou (soit le 10 novembre à 1 h 14 min GMT). Le fonctionnement impeccable de la fusée Ariane-3 durant le vol propulsé a permis une insertion très précise de Marecs B2 sur son orbite de transfert. Après mise en rotation à 65 tr/mn et ajustement de l'orientation de l'axe de spin, le moteur d'apogée européen MAGE-2 a été mis à feu avec succès, venant placer le satellite sur une orbite à défilement lent en direction de l'est.

On a alors arrêté la rotation du satellite et les panneaux solaires ont été déployés, puis a débuté la séquence complexe des opérations de pointage des antennes vers la Terre avec stabilisation triaxiale du satellite, les panneaux solaires tournant autour d'un axe perpendiculaire au plan de l'orbite.

Au cours de la phase de dérive, la plate-forme et la charge utile ont été mises en ordre de marche avec succès. La longitude finale de mise à poste (177,5°E) a été atteinte le 20 décembre. L'entrée en service pour le compte d'INMARSAT au-dessus de l'Océan Pacifique est prévue pour le 1er janvier 1985.

Marecs-A, lancé le 19 décembre 1981, a bouclé sa troisième année en orbite sans aucun incident ni aucun signe de dégradation.

Hipparcos

Les difficultés industrielles apparues au cours de la période ont engendré une certaine incertitude pour ce qui regarde l'avenir immédiat. La faillite de l'un des contractants et les conflits du travail auxquels se sont heurtés deux autres d'entre eux ont obligé à revoir tout le programme d'activité et à définir des mesures correctrices. On est sur le point d'arriver à une solution ferme, avec la perspective de pouvoir respecter les délais d'ensemble au niveau système.

Par ailleurs, les choses progressent de manière satisfaisante. Les équipements destinés au modèle mécanique et au modèle thermique du satellite commencent à faire leur apparition et des éléments majeurs tels que la structure du télescope sont en cours d'assemblage. Le Programme de soutien relatif à la partie optique, qui avait connu quelques retards en raison des problèmes rencontrés avec certains fournisseurs d'équipements de la charge utile, a finalement débuté en octobre. Ce démarrage tardif ne devrait pas avoir de répercussion sur le calendrier d'ensemble.

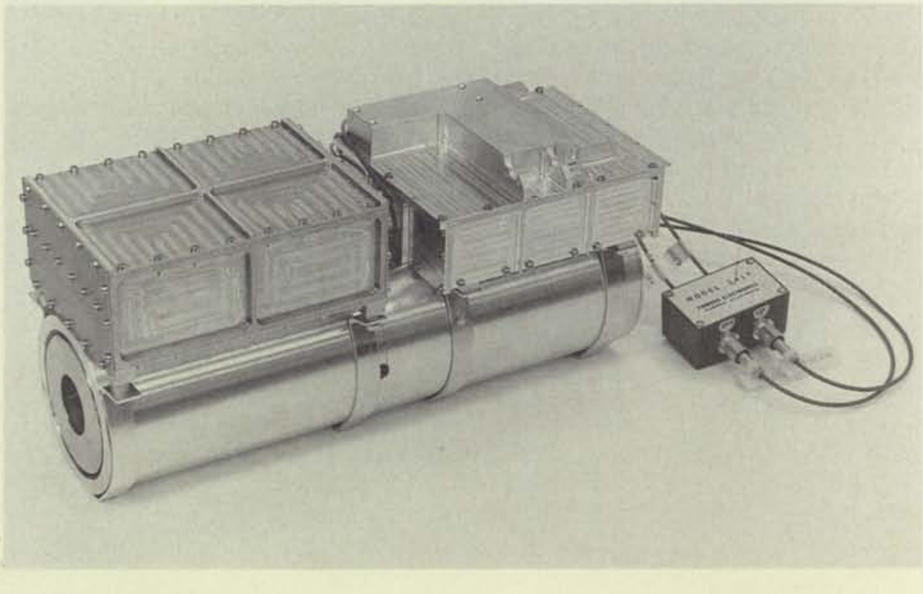
Une série pilote de grilles modulatrices au plan focal a été achevée, deux des grilles ainsi réalisées manifestant des caractéristiques très encourageantes. Ceci est considéré comme un grand pas en avant dans la validation de la technologie de réalisation du motif de grille.

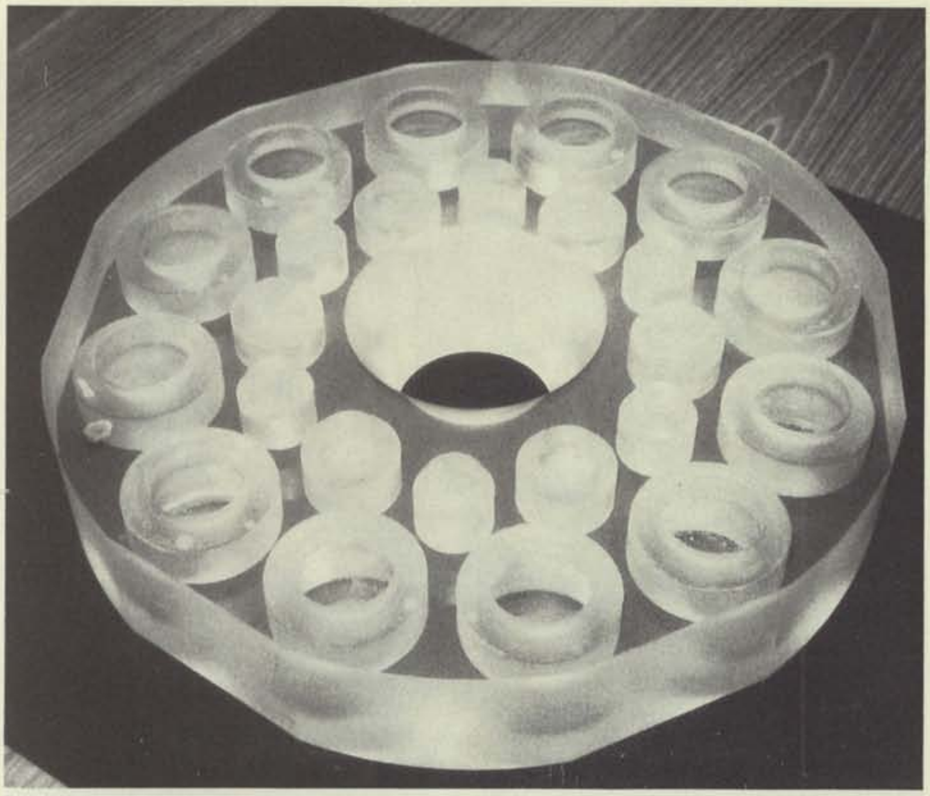
En octobre, l'Equipe scientifique du programme Hipparcos a tenu sa dixième réunion, au cours de laquelle les consortiums (FAST et NDAC) chargés d'étudier la réduction des données ont présenté leurs conceptions respectives de la réduction des abscisses stellaires le long d'un grand cercle balayé, qui marque une étape importante dans les activités de réduction des données.

Les pourparlers ayant trait au contrat principal sont sur le point de se terminer. Le maître d'oeuvre a fini de négocier avec ses sous-contractants et est à même de confirmer les accords décisifs auxquels il est parvenu avec chacun d'eux. Il sera tenu compte des implications de ces accords dans la rédaction du contrat principal, que l'on espère conclure avant la fin de l'année.

The Main Detector Assembly for Hipparcos

Ensemble du détecteur principal d'Hipparcos





Miroir repliable destiné au programme de soutien optique d'Hipparcos

Flat folding mirror to be used in the Hipparcos Optical Support Programme

Hipparcos

Industrial difficulties occurring during the period have injected some measure of uncertainty into the near-term schedule. Bankruptcy of one contractor and industrial disputes at two others have necessitated re-evaluation of the overall plan and the formulation of corrective actions. A firm solution is nearing conclusion, with the expectation of maintaining the overall schedule objectives at system level.

In other areas, progress is satisfactory. Items of hardware for structural/thermal models are beginning to appear and major items, such as the telescope structure, are being assembled. The Optical Support Programme, which suffered some delays due to difficulties with payload hardware suppliers, started during October. The delayed start is not expected to have an impact on the overall schedule.

A pilot series of focal-plane modulating grids have been completed, with two of the grids exhibiting very encouraging characteristics. The result is regarded as a major step forward in the validation of the technology employed for the writing of the grid pattern.

The tenth meeting of the Hipparcos Science Team (HST) was held during October. At the meeting the data-reduction consortia (FAST and NDAC) presented their respective approaches to the performance of the reduction of the stellar abscissae along a scanned great circle, the implementation of which completes a major milestone for data-reduction activities.

Discussions and negotiations on the prime contract are nearing completion. The contractor has now completed negotiations with his subcontractors and the consequences of the agreements reached are being incorporated into the prime contract, with the objective of concluding the contract before the end of this year.

Giotto

System-level testing on the flight-model spacecraft has continued throughout the summer and autumn in the Intespace facilities at CNES, Toulouse. The test programme was initiated with a two-week solar-simulation test for verification of the thermal subsystem during all mission phases, including encounter. This was followed by hot and cold soaks for stressing the spacecraft in thermal vacuum over a period of about 10 days and was completed with acoustic, random vibration and three-axis sine vibration testing. All tests have been successfully performed and the performance of the spacecraft is providing confidence in the success of the mission.

Analysis of the solar-simulation results indicates that the spacecraft is slightly warm compared with predictions, and this is the subject of investigation, which will be followed by appropriate thermal trimming.

Subsystem and experiment performances throughout the test phases have been very good.

During the next phase of the programme experiment units will be exchanged according to an agreed programme, whereby experimenters will be furnishing their fully calibrated instruments. The programme will then be completed with mass-properties, alignment, mass-balancing and demagnetisation activities.

A revised delivery date of 1 March 1985 is now the project baseline. Arrival in Kourou for the launch campaign is scheduled for the end of April with a two-month launch campaign leading up to a launch-window opening in the first week of July 1985.

Olympus

The payload-analysis work is nearly complete and the overall payload Development Baseline Review (DBR) is now expected to be held before the end of the year (1984). The second part of the system-level DBR, between the Prime Contractor and ESA, will be held early in 1985.

Fitting of the dynamically representative dummy equipment into the structural-model spacecraft modules is now nearly complete, and final integration of these modules to form the complete spacecraft is planned for December. Testing of the

Giotto

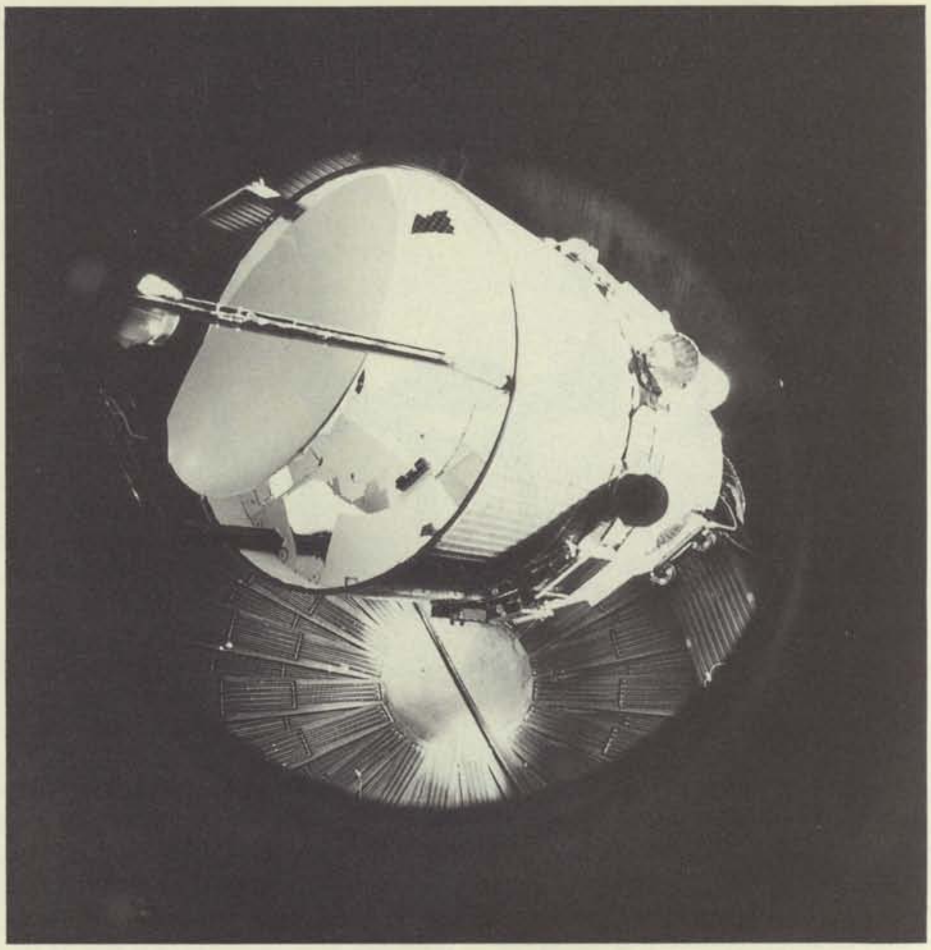
Les essais d'ensemble du modèle de vol du véhicule spatial se sont prolongés tout l'été et l'automne durant dans les locaux d'Intespace au centre du CNES, à Toulouse. La campagne a débuté par un essai de simulation solaire de deux semaines destiné à vérifier le comportement du sous-système de régulation thermique à tous les stades de la mission, y compris au moment du survol de la comète. Elle s'est poursuivie par un séjour sous vide à haute et à basse température pendant 10 jours environ et a pris fin par des essais de bruit acoustique et de vibration sinusoïdales sur trois axes. Tous ces essais ont donné des résultats satisfaisants et laissent bien augurer du succès de la mission.

L'analyse des essais de simulation solaire a fait apparaître que le véhicule spatial devenait légèrement plus chaud que prévu; on se penche actuellement sur le problème, après quoi on procèdera aux rectifications voulues.

Les performances des sous-systèmes et de l'appareillage scientifique se sont révélées très bonnes à tous les stades des essais.

Dans la phase suivante du programme, les blocs d'expérience seront échangés selon un plan convenu contre des instruments dûment étalonnés fournis par les expérimentateurs. Pour terminer, on procèdera alors aux opérations de mesure des caractéristiques massiques, d'alignement, d'équilibrage et de démagnétisation.

La date de référence pour la livraison est maintenant fixée au 1er mars 1985. L'arrivée à Kourou est prévue pour la fin avril, avec une campagne de lancement d'une durée de deux mois menant à une fenêtre de tir dont le début se situe dans la première semaine de juillet.



The Giotto spacecraft (flight model), photographed at Intespace in Toulouse

Modèle de vol de la sonde spatiale Giotto (photo prise chez Intespace à Toulouse)

Olympus

Les travaux d'analyse de la charge utile sont presque terminés et la Revue d'ensemble des bases de référence pour le développement de la charge utile devrait se tenir en principe avant la fin de l'année. L'Agence et le maître d'oeuvre se réuniront début 1985 pour la seconde partie de la Revue des bases de référence au niveau système.

Le montage sur les modules composant le modèle mécanique du satellite d'équipements factices représentatifs du comportement dynamique des équipements réels est presque fini; l'intégration définitive desdits modules est prévue pour le mois de décembre. Les essais du modèle mécanique débuteront en janvier par une recherche des modes propres; la série complète des essais dynamiques aura lieu plus tard dans l'année au Canada.

Le modèle thermique du satellite a été terminé en septembre et subit actuellement des essais de simulation solaire au niveau système. La première série d'essais a été menée à bien et on est en train de reconfigurer le satellite pour la série suivante, qui devrait s'achever avant la fin de l'année.

Les modèles technologiques des différents sous-systèmes de la charge utile sont en grande partie terminés et les contractants responsables de la charge utile ont commencé à procéder aux essais. La structure du modèle technologique du satellite est maintenant prête et on a installé les équipements du sous-système d'alimentation, dont les essais sont en cours. La fabrication du reste des équipements de la plate-forme et de la charge utile se poursuit. La phase d'intégration principale devrait débuter avant la fin de l'année avec la mise en place du câblage destiné au module de servitude.

Le modèle de qualification du générateur solaire est désormais terminé et ses essais d'ambiance sont en cours.

Les appels d'offres concernant les équipements de la station sol ont été lancés de manière progressive depuis le mois de juillet; d'autres sont en préparation. Les réponses aux premières invitations à soumissionner ont été reçues et sont en cours de dépouillement.

structural model will start in January with the modal-survey test, to be followed later in the year by the full series of dynamic tests in Canada.

The thermal-model spacecraft was completed during September and is now undergoing system-level solar-simulation tests. The first series of tests has been completed satisfactorily and the spacecraft is now being reconfigured for the second series, which is expected to be completed before the end of the year.

The engineering models of the payload subsystems are largely complete and testing has been started by the payload contractors. The structure for the engineering-model spacecraft is complete and power subsystem equipment has been installed. Subsystem testing of this equipment is in progress. Manufacture of the remaining platform and payload equipment is proceeding. The main integration phase is planned to start before the end of the year with the installation of the service-module harness.

The qualification model of the solar array has been completed and is now being subjected to its environmental test programme.

Invitations to Tender (ITT) for ground-station equipment have been issued progressively since July and others are being prepared. Responses to the first items issued have been received and are being evaluated.

ERS-1

The Programme Declaration, which was finalised at the meeting of the Remote-Sensing Programme Board in July 1984, has meanwhile been subscribed to by participating states to a level of about 97%. The Industrial Policy Committee at its end of November meeting approved the Agency's request to place the contract for the main development phase (Phase-C/D) with Dornier.

During the last few months, activities have concentrated on contractual negotiations, and on advancing the status of the design and associated documents. For this purpose a number of meetings have been held with Dornier and co-contractors, and the technical baseline has been sufficiently well defined to enable Phase-C/D activities to start.

Advanced procurement has been initiated for certain long-lead items. The possibility has been discussed with CNES of establishing a joint procurement scheme for parts that are common to ERS-1 and Spot-2.

Dr. J.J. Burger, formerly manager of the Space Telescope Project, has been appointed Project Manager for ERS-1.

Meteosat

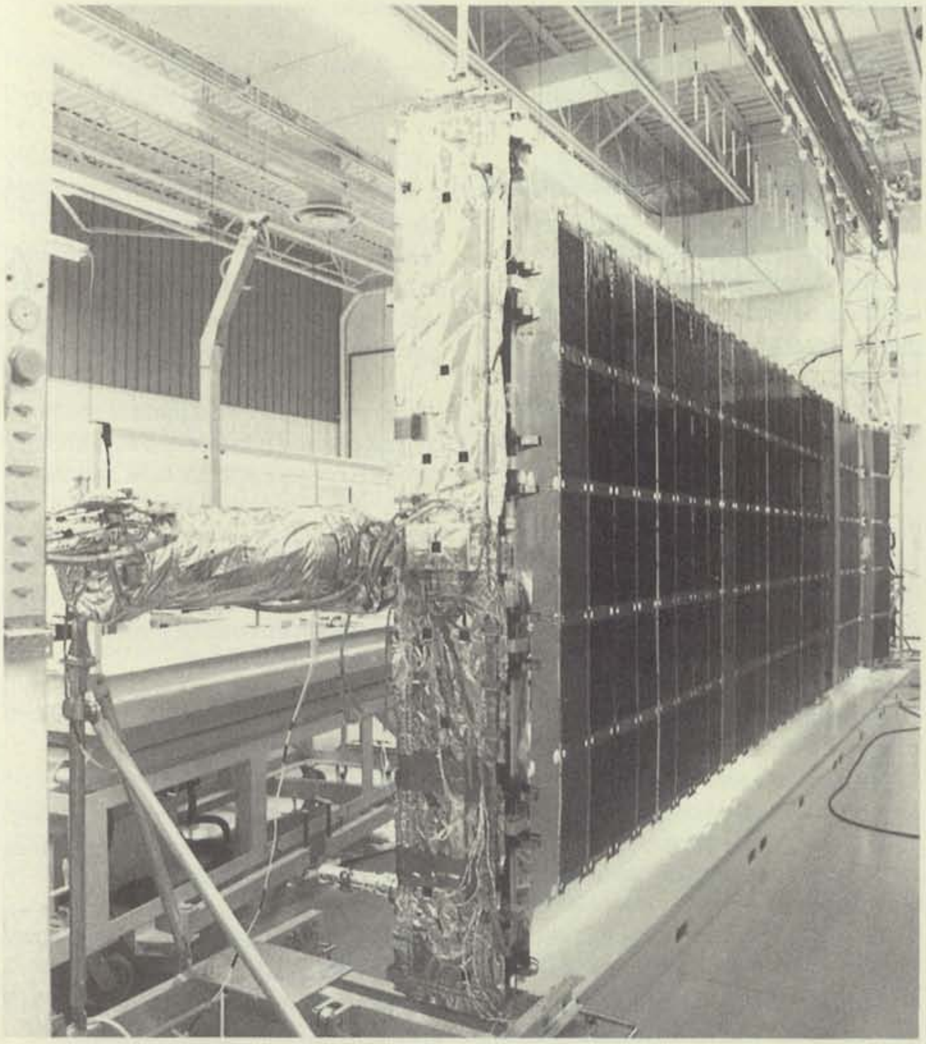
Preoperational programme

The preparation of Meteosat-P2 for launch with the first Ariane-4 flight in June 1986 is progressing on schedule. Inspection of the model following storage since 1981 revealed defects in some of the solar cells. These defects show up as a whitish discolouration along the cell edges. The cause of this is currently under investigation. Replacement of coaxial cables and connectors, foreseen in the preparation activities, has been completed, as have the modifications for installation of the LASSO payload.

In November, the satellite was connected to the electrical ground-support equipment, developed under the Meteosat Operational Programme. A test on the model in launch- and transfer-orbit configurations indicated normal performance.

LASSO

The development of the LASSO (Laser Synchronisation from Stationary Orbit) payload for installation on Meteosat-P2 is progressing on schedule. The manufacture of the box that will



Réseau solaire du modèle de développement d'Olympus

Olympus development model solar-array wing

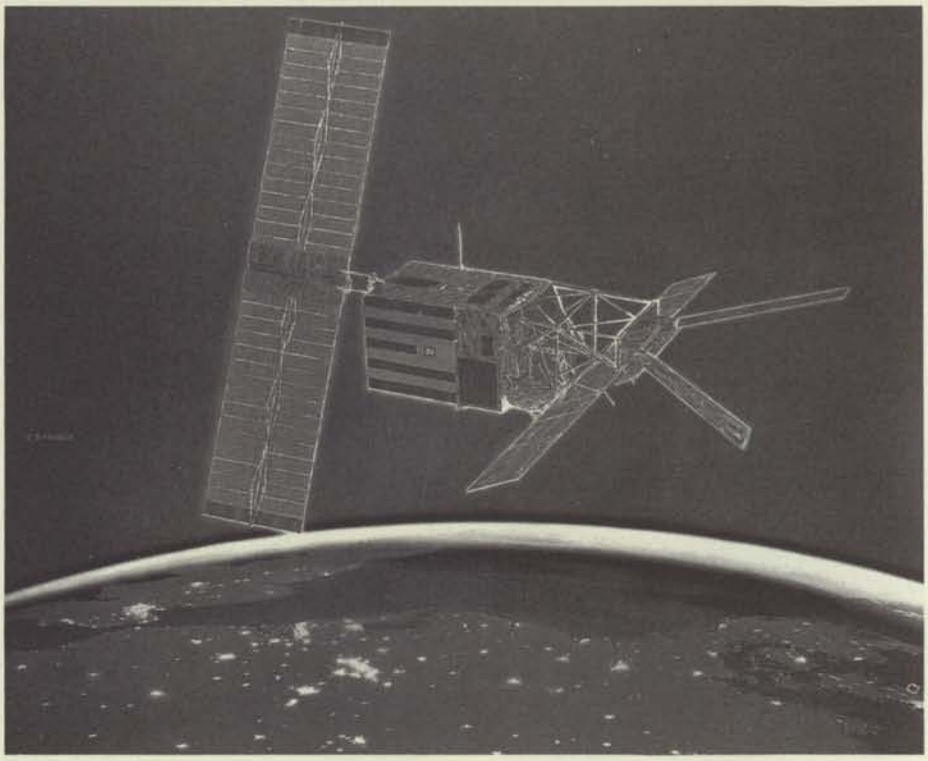
ERS-1

La Déclaration relative au programme ERS-1, mise au point lors de la réunion du Conseil directeur du programme de télédétection en juillet 1984, a entretemps reçu l'adhésion des Etats participants à hauteur d'environ 97%. Le Comité de la politique industrielle, à sa réunion de fin novembre, a approuvé la demande de l'Agence visant à passer contrat avec Dornier pour la phase de réalisation principale (phase C/D).

Les activités de ces derniers mois ont été essentiellement consacrées à la négociation du contrat ainsi qu'à faire progresser l'état d'avancement de la conception et des documents connexes. A cette fin, un certain nombre de réunions ont eu lieu avec Dornier et ses co-contractants et la base de référence technique a été définie à un point suffisant pour permettre le démarrage des activités de phase C/D.

On a lancé par avance les approvisionnements pour certains éléments à long délai de fourniture. D'autre part, on a discuté avec le CNES de la possibilité de mettre sur pied un plan d'approvisionnement unique pour les éléments communs à ERS-1 et à Spot-2.

Le Dr J.J. Burger, qui dirigeait auparavant le projet de Télescope spatial, a été nommé chef du projet ERS-1.



ERS-1 emerging from eclipse over Europe in mid-June 1990 (artist's concept)

ERS-1 émergeant d'une période d'éclipse au-dessus de l'Europe à la mi-juin 1990 (vue conceptuelle)

Météosat

Programme préopérationnel

La préparation de Météosat P2 en vue de son lancement dans le cadre du premier vol d'Ariane 4 en juin 1986 se déroule conformément au calendrier. Un examen du modèle après son entreposage en 1981 a révélé des défauts au niveau de certaines cellules solaires. Ces défauts se présentent sous forme d'une décoloration blanchâtre affectant le bord des cellules. Leur cause fait présentement l'objet d'une enquête. On a procédé comme prévu au remplacement des câbles et connecteurs coaxiaux, ainsi qu'aux modifications requises pour la mise en place de la charge utile LASSO.

En novembre, le satellite a été relié au matériel électrique sol mis au point dans le cadre du programme Météosat opérationnel. Un essai du modèle en configuration de lancement et de vol en orbite de transfert a fait apparaître des performances normales.

LASSO

L'élaboration de la charge utile LASSO (destinée à la synchronisation d'horloges par laser depuis l'orbite des satellites géostationnaires) en vue de sa mise en place sur Météosat-P2 se déroule conformément au calendrier. On a entamé la fabrication du boîtier-support des équipements de la charge utile, et la fabrication des exemplaires de vol des trièdres rétroréfléchissants est presque terminée. Le bloc détecteur, le bloc de datation et le bloc abritant l'oscillateur ultra-stable, déjà qualifiés aux niveaux de vibration de Sirio-2, ont été testés avec succès dans l'ambiance plus rigoureuse du satellite Météosat.

Programme opérationnel

Le lancement de Météosat F1 remonte au 23 novembre 1977. Bien qu'il ait été conçu pour durer trois ans seulement, ce premier satellite a continué à assurer sans dégradation aucune sa mission de collecte de données jusqu'au mois d'août dernier. Il est alors apparu qu'il avait épuisé ses réserves d'hydrazine, si bien qu'on a décidé de recourir à l'azote sous pression pour prolonger sa durée de vie par une correction de poste dans la direction est-ouest.

Cette correction a été effectuée avec succès et les premiers résultats montrent que le satellite restera en vue des plates-formes de collecte de données correspondantes jusqu'à l'automne 1985.

Des négociations ont été entamées avec la NOAA en vue de l'utilisation de GOES-4 par les plates-formes européennes de collecte de données entre la fin présumée de la durée de vie utile de Météosat F1 et l'entrée en service de Météosat P2, dont le lancement doit avoir lieu d'ici la mi-86.

Une anomalie survenue dans la chaîne de transmission d'ordres le 5 septembre dernier a eu pour effet de faire basculer temporairement Météosat F2 dans un mode de fonctionnement non autorisé; 16 heures plus tard les choses étaient rentrées dans l'ordre. Depuis lors, toutes les opérations du satellite, y compris l'extraction des données météorologiques, se sont poursuivies sans encombre.

La pénurie de moyens financiers dont souffre le programme a été résolue grâce au report de certains paiements à l'année 1985. D'autre part, la politique de diffusion et de facturation des produits météorologiques a été revue et approuvée par les Délégations lors de la dernière réunion du Conseil directeur du programme. Enfin, les entrevues pour le mechanically support the LASSO equipment in P2 has begun, and the manufacture of the flight-unit corner cubes for the retro-reflector is nearly complete. The detection, time-tagging and ultra-stable oscillator units, which were qualified to the Sirio-2 vibration levels, have been successfully re-tested under the higher Meteosat levels.

Operational programme

The Meteosat-F1 spacecraft was launched on 23 November 1977. Although designed for an operational lifetime of only three years, it continued to support the data collection mission without any sign of degradation until August 1984. By then it became apparent that the spacecraft had run out of hydrazine fuel and it was decided to perform an east-west manoeuvre using the pressurising gas (nitrogen) in order to extend its lifetime.

This manoeuvre was successfully executed and initial results have shown that the spacecraft will remain within the field of view of the associated Data Collection Platforms (DCPs) until Autumn 1985.

Negotiations have been initiated with NOAA on the use of GOES-4 to support the European DCPs between the anticipated end of operational life of the Meteosat-F1 satellite and the time when the Meteosat-P2 spacecraft becomes operational. The latter is presently scheduled to be launched by mid-1986.

An anomaly in the ground-command chain on 5 September 1984 drove the Meteosat-F2 satellite into a non-approved mode of operation. However, the spacecraft was successfully retrieved within 16 hours. Since then all operations, including the extraction of meteorological data, have proceeded entirely satisfactorily.

The funding shortfall affecting the programme has been resolved by delaying some payments into 1985.

The distribution and charging policy for Meteosat products was reviewed and approved by the delegations at the last Operational Meteosat Programme Board.

Interviews to select the Programme's legal adviser were held on 8 November and the selected candidate will take up duty in January 1985.

Space segment

Several key events have taken place in the development of the space segment:

- The Electrical Ground Support Equipment (EGSE) has been shipped from MBB (Germany) to SNIAS, (France), the first subsystem to be delivered.
- The test equipment for the Mission Performance Transponder has been completed at ANT (Germany).
- The Critical Design Review for the Radiometer has been held at Matra (France).
- The prototype of the Visible Detector has been delivered by Centronics (UK).

In addition, the effect of a six-week lock-out at ANT has been absorbed through recovery activities and will have no impact at system level, and the space-segment development effort is on schedule despite the difficulties of the past three months.

Ground segment

The ground-segment upgrading and refurbishment activities are progressing according to plan, two major contracts having been approved by the Operational Meteosat Programme Board in November, for the ground station in the Odenwald (Germany) and for the S-band network extension.

Spacelab

Follow-on Production (FOP)

As all system-level hardware built by the Spacelab Consortium under the prime contractorship of MBB/ERNO was delivered to NASA/KSC in August 1984, the electrical and mechanical Ground-Support Equipment (GSE) funded by NASA under the FOP contract is now being disposed of. Contract change requests have been issued to ERNO for delivery of most of the GSE to NASA and dismantling and packing are underway.

Hardware malfunctions experienced with the High-Rate Multiplexer have been analysed and repair/modification is in progress. Performance failures in an Input/Output Unit and a computer are still under investigation.

Customer acceptances are conducted frequently for ship-short items from previous deliveries and for spares ordered by NASA. The contract with NASA now also includes a service for NASA-funded repairs by the Spacelab Consortium of Spacelab hardware in use at Kennedy Space Center.

Detailed discussions have been held between NASA, ESA and ERNO with the objective of introducing simplifications into the technical and financial parts of the FOP contract and, thereby, tailoring the contractual requirements more accurately to the type of hardware to be procured in the future. It is planned to negotiate the first procurement under the revised conditions in February 1985.

Assembly of the Instrument Pointing Subsystem (IPS) at Dornier is proceeding as replanned, with a projected delivery date of 30 April 1985 (contractual delivery date is 31 December 1984). Most of the FOP hardware is at the prime contractor's premises.

IPS

IPS has now completed all qualification and acceptance testing. A specific set of tests on mechanisms and software still remains. A Flight Acceptance Review was conducted successfully in October and early November 1984.

A set of IPS flight and ground-support hardware and software as needed for the Spacelab-2 mission was shipped to Kennedy Space Center in November for integration into the Spacelab-2 flight unit. Integration will be completed by mid-December and testing will take place from mid-December to mid-January 1985.

A final set of tests on hardware and software not needed for Spacelab-2, which was not yet ready in November 1984, will be completed between now and April 1985. This will conclude the main development phase of the IPS project, except for Spacelab-2's launch and mission support.

Microgravity

Fluid Physics Module

The flight unit of the Fluid Physics Module (FPM) has been refurbished and improved after its return from the first Spacelab Mission. It has since been delivered to MBB/ERNO for reflight on the German Spacelab D1 mission. Two crew training sessions have been held with the experimenters and the crew member, using the FPM engineering model.

recrutement d'un conseiller juridique attaché au programme ont eu lieu le 8 novembre dernier; le candidat retenu prendra ses fonctions en janvier prochain.

Secteur spatial
Plusieurs événements majeurs ont jalonné la mise en place du secteur spatial:
- *envoi à MBB (Allemagne) par la SNIAS (France) du matériel électrique de soutien au sol, premier sous-système à être livré;*
- *achèvement chez ANT (Allemagne) de l'équipement de test destiné au répondeur de bord;*
- *revue critique de définition du radiomètre chez Matra (France);*
- *livraison par Centronic (Royaume-Uni) du prototype de détecteur en lumière visible.*

Par ailleurs, les effets d'un lock-out de six semaines chez ANT ont pu être rattrapés et n'auront pas d'incidence au niveau système. Le développement du secteur spatial reste dans les délais en dépit des difficultés de ces trois derniers mois.

Secteur terrien
Les activités de mise à niveau et de réaménagement du secteur terrien progressent conformément au calendrier, deux grands contrats concernant respectivement la station sol de l'Odenwald et l'extension du réseau en bande S ayant été approuvés en novembre dernier par le Conseil directeur du programme.

Spacelab

Production ultérieure
Tous les équipements du niveau système fabriqués par le consortium Spacelab sous la maîtrise d'oeuvre de MBB-ERNO ayant été livrés en août dernier au Centre spatial Kennedy de la NASA, on est en train de se défaire du matériel électrique et mécanique de soutien au sol financé par cette dernière dans le cadre du contrat de production ultérieure du Spacelab. Des demandes de modification du contrat ont été émises par ERNO pour la livraison à la NASA de la majeure partie de ce matériel, dont le démontage et le conditionnement pour le transport sont en cours.

Les défaillances matérielles constatées sur le multiplexeur à grand débit ont été analysées et on procède actuellement aux réparations ou retouches nécessaires. Le mauvais fonctionnement d'un appareil d'entrée/sortie et d'un calculateur fait l'objet d'une enquête qui n'est pas encore terminée.

Les éléments manquants dans les précédentes livraisons ainsi que les rechanges commandées par la NASA sont fréquemment réceptionnés chez le client. Le contrat avec la NASA inclut dorénavant un service de réparation pour les équipements Spacelab du Centre spatial Kennedy à réparer aux frais de celle-ci par les soins du consortium Spacelab.

Des discussions approfondies ont eu lieu entre l'ESA, la NASA et ERNO en vue d'apporter des simplifications à la partie technique et à la partie financière du contrat de production ultérieure, adaptant ainsi de manière plus étroite les exigences contractuelles au genre d'équipements que l'on doit se procurer dans le futur. Il est prévu de négocier dans ces nouvelles conditions une première fourniture en février 1985.

L'assemblage du sous-système de pointage d'instruments chez Dornier se poursuit conformément au nouveau calendrier, la livraison étant attendue pour le 30 avril prochain (contractuellement, la date de livraison est fixée au 31 décembre 1984). Le gros des équipements relevant du contrat de production ultérieure se trouve dans les locaux du maître d'oeuvre.

IPS

Le système de pointage d'instruments a désormais achevé tous ses essais de qualification et de recette. Il reste à effectuer une série d'essais spécifiques sur les mécanismes et le logiciel. Une Revue d'aptitude au vol a eu lieu avec succès en octobre et début novembre.

Un ensemble d'équipements et de logiciels de vol et de soutien au sol destinés à la mission Spacelab-2 a été expédié en novembre au Centre spatial Kennedy pour intégration à l'unité de vol du laboratoire spatial. Les travaux d'intégration prendront fin à la mi-décembre et les essais dureront de la mi-décembre à la mi-janvier.

Une dernière série d'essais sera effectuée d'ici avril 1985 sur des équipements et logiciels dont on n'a pas besoin pour la mission Spacelab-2. Ceci viendra mettre un point final à la phase de réalisation principale du système de pointage d'instruments, mis à part le lancement et le soutien à apporter au cours de la mission.

Microgravité

Module de physique des fluides
L'exemplaire de vol du Module de physique des fluides a été réaménagé et perfectionné après son retour de la première mission Spacelab. Il a été livré depuis lors à MBB-ERNO pour prendre à nouveau place sur le Spacelab dans le cadre de la mission allemande D1. Deux séances d'entraînement ont eu lieu à l'intention des expérimentateurs et du membre d'équipage devant utiliser le modèle technologique du Module.

Les procédures à suivre pour les opérations en vol sont à un stade d'élaboration avancé. A titre préparatoire, deux vols ont été organisés à bord d'un KC 135 appartenant au Centre spatial Johnson de la NASA; l'avion fera décrire à ses occupants une quarantaine d'arcs de parabole équivalant chacun à quelque 20 secondes d'apesanteur.

Biorack
La revue précédant l'expédition du modèle de vol du Biorack s'est déroulée sans encombre et celui-ci a maintenant été livré pour intégration à la charge utile allemand D1 destinée à prendre place sur le Spacelab. L'équipe du projet Biorack a pris part à la revue d'intégration de ladite charge utile, qui s'est tenue chez ERNO du 27 au 29 novembre 1984.

La recette en bonne et due forme du Biorack en provenance de la firme Matra et sa remise en mains par l'Agence aux responsables du Spacelab auront lieu en décembre 1984.

Ainsi qu'on l'a déjà signalé en d'autres occasions, l'électronique de commande du réfrigérateur-congélateur demande encore un surcroît de travail avant de pouvoir être considérée comme entièrement achevée. Ce travail s'effectue en parallèle sur l'actuel modèle thermique, que l'on remplacera ensuite par le modèle définitif sur l'unité de vol du Biorack déjà livrée.

The flight-operations procedures are in an advanced state of completion. In preparation for the mission, two flights with the KC 135 aircraft belonging to NASA/Johnson Space Center have been organised. This aircraft will fly about 40 parabolic trajectories, providing about 20 s of weightlessness per trajectory.

Biorack

The Biorack pre-shipment review has been conducted successfully and the flight model has been delivered for integration into Germany's Spacelab-D1. The Biorack Project supported the Spacelab D1 Payload-Integration Review held at ERNO on 27 – 29 November 1984.

The acceptance review required to formalise the acceptance of Biorack by ESA from Matra and the handover from ESA to Spacelab-D1 took place in December 1984.

As already reported on previous occasions, the cooler-freezer control electronics still require further work before this unit can be considered fully complete. This work is being performed in parallel on the present thermal model, which will be substituted later for the unit in the Biorack flight model already delivered.

Preparation of the Biorack experiments and the ground-support equipment needed to support operations until the launch is proceeding in parallel.

Ariane

Preparatory Development Programme for the Large Cryogenic Engine (HM60)

Studies have shown that any future European launcher concept (for Ariane-5) dictates the use of a cryogenic engine with a thrust of about 1000 kN. An in-flight thrust duration of about 600 sec has been specified; the technology chosen involves the use of a bypass-flow cycle with separate turbopumps.

The development of this engine is the most critical element in the Ariane-5 programme in terms of schedule. A preparatory programme has, therefore, been set up in order that, pending a decision on the future launcher and on engine development itself, the most critical activities can be undertaken, i.e. technological activities concerning critical items, design and manufacture of the engine and its subsystems, and start of construction work on test stands.
These activities are planned to take place from end-1984 until end-1986. The budget allocated to the preparatory programme amounts to 138.3 MAU at mid-1983 price level (based on 1984 rates).

In October 1984, the Member States approved the conditions of execution of the preparatory programme; the subscribed level of contribution should allow this programme to be started in December 1984 or January 1985.

Space Station/Columbus

Space-Station-Related Columbus Preparatory Programme

Following the German-Italian initiative to propose the nationally studied space station 'Columbus' programme for Europeanisation, a Preparatory Programme covering a definition study (Phase B) and supporting technology has been approved by the Member States, and a Declaration detailing the content of the Preparatory Programme established on 23 November 1984. The preparation of a Request for Proposal (RFP) for Phase-B studies has been initiated by ESA and the RFP will be sent to European industry by late January 1985. It is expected that the corresponding contracts will be placed in April 1985. A major milestone will take place in late 1985 when the content of Europe's collaboration in the US Space Station Programme will be finalised, after detailed definition during 1985. The Preparatory Programme will be completed in late 1986.

Provisional Ariane Launch Calendar (per 1 December 1984)

Year	Month	Flight No./ Vehicle Type	Spacecraft	Launcher Orbit
1985	January	V12 (AR-3)	SBTS-1 + Arabsat	GTO
	April	V13 (AR-3)	G-Star 1B + Spacenet-3	GTO
	July	V14 (AR-1)	Giotto	GTO
	August	V15 (AR-3)	Telecom-1B + SBTS-2 or ECS-3	GTO
	September	V16 (AR-2)	Intelsat-V F13 or Spot-1/Viking	Heliosynchr. or GTO
	November	V17 (AR-1)	Intelsat-V F13 or Spot-1/Viking	Heliosynchr. or GTO
	Dec. '85–Jan '86	V18 (AR-3)	G-Star 1A + SBTS-2 or ECS-3	GTO
1986	Jan–Feb	V19 (AR-2)	Intelsat-V F14	GTO
	April	V20 (AR-2)	Intelsat-V F15 or TV-Sat	GTO
	May	V21 (AR-2)	Intelsat-V F15 or TV-Sat	GTO
	June	V22 (AR-3)	Aussat-3 + Flight Opportunity	GTO
	July	V23 (AR-4 or -2)	AR 4-01 (demonstration) or TDF-1	GTO
	Aug–Sept	V24 (AR-4 or -2)	AR 4-01 (demonstration) or TDF-1	GTO
	November	V25 (AR-3)	SBS-5 + Flight Opportunity	GTO
1987	February	V26 (AR-2)	Tele-X	GTO
	April	V27 (AR-4)	Flight Opportunity	GTO
	July	V28 (AR-3)	Olympus	GTO
	August	V29 (AR-4)	TDF-2 + Flight Opportunity	GTO
	September	V30 (AR-3 or -4)	Operational Meteosat + Flight Opportunity	GTO
	October	V31 (AR-4)	DFS-1 + Flight Opportunity	GTO
	December	V32 (AR-4)	Intelsat-VI F3	GTO

Simultanément on poursuit la préparation des expériences et du matériel de soutien au sol nécessaire au fonctionnement des appareils jusqu'au moment du lancement.

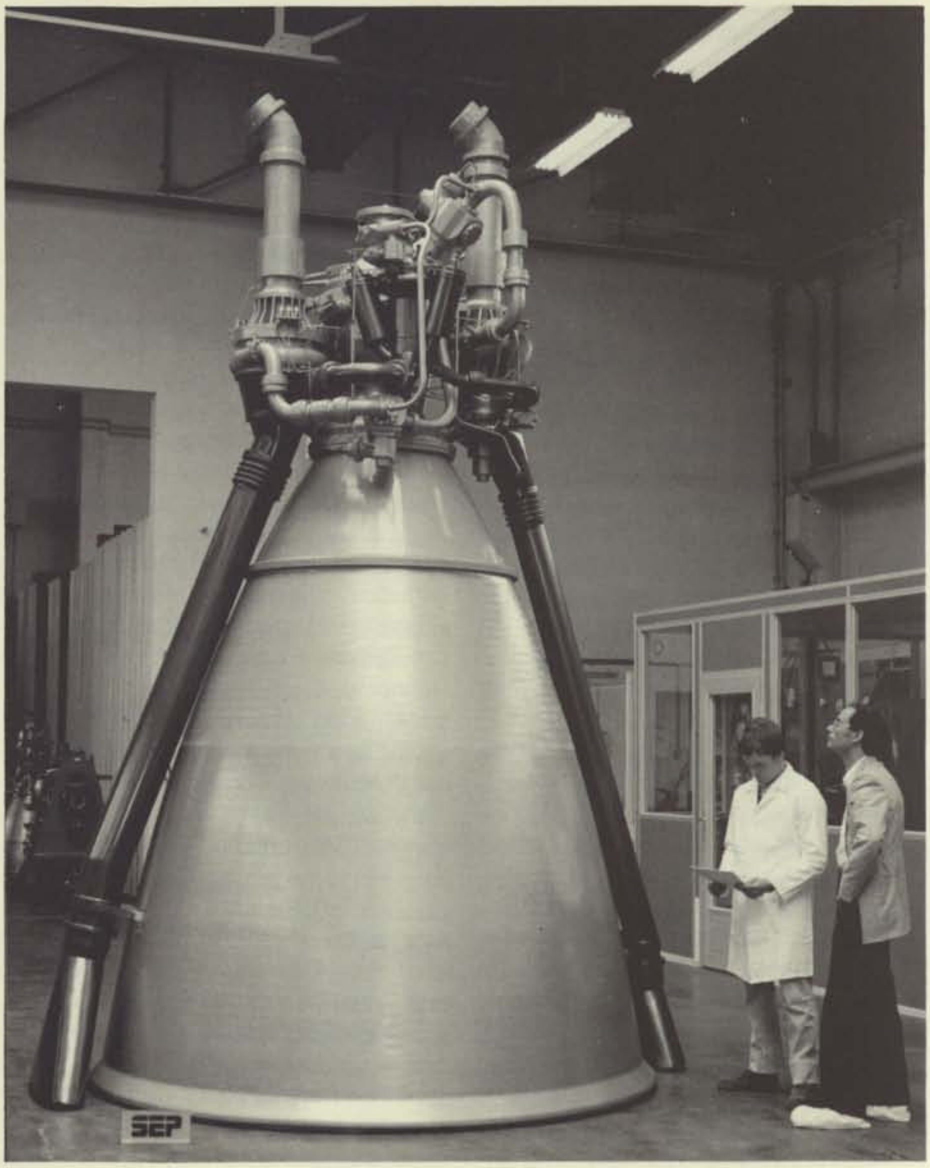
Ariane

Programme préparatoire de développement du grand moteur cryotechnique (HM60)
Les études ont démontré que tout concept de lanceur européen futur (Ariane-5) impose le recours à un moteur cryotechnique d'une poussée d'environ 1000 kN. La durée de son fonctionnement en vol a été fixée à environ 600 s; la technologie utilisée prévoit l'utilisation d'un cycle à flux dérivé et de turbo-pompes séparées.

Le développement de ce moteur est l'élément le plus critique du programme Ariane-5 du point de vue calendaire; c'est pourquoi il a été mis sur pied un programme préparatoire devant permettre, en attendant la décision sur le futur lanceur et sur le développement proprement dit du moteur, de lancer les opérations les plus critiques: activités de technologie sur des éléments critiques, définition et fabrication du moteur et de ses sous-systèmes et mise en chantier des bancs d'essais.

Ces travaux sont prévus dans la période fin 1984 — fin 1986. L'enveloppe financière du programme préparatoire s'élève à 138.3 MUC au niveau des prix de la mi-1983 (taux 1984).

En octobre 1984, les Etats membres ont approuvé les conditions d'exécution du programme préparatoire; il est prévu que le niveau souscrit de contribution permettra son démarrage en décembre 1984 ou janvier 1985.



The Large Cryogenic Engine (HM60) for Ariane-5

Le grand moteur cryotechnique (HM60) pour Ariane-5

Station spatiale/ Columbus

Suite à la proposition faite par l'Allemagne et l'Italie d'européaniser leur programme de station spatiale Columbus, déjà étudié au niveau national, les Etats membres ont approuvé un Programme préparatoire comprenant une étude de définition et des travaux de technologie de soutien et publié une Déclaration sur le contenu de ce programme le 23 novembre 1984. L'appel d'offres pour les études de phase B a été préparé au sein de l'Agence et sera envoyé aux industriels européens fin janvier 1985, avec l'espoir de pouvoir passer les contrats correspondants en avril. Une étape importante sera atteinte à la fin de l'année lorsque le contenu de la participation européenne au programme de la Station spatiale américaine aura été défini, après sa définition détaillée. Le programme préparatoire européen sera terminé fin 1986.

How Much Should Space Hardware Cost?

A. Franzke & J. Lex, Cost Analysis Division, ESA Directorate of Administration, ESTEC, Noordwijk, The Netherlands

In the twenty years since ESA began contracting space-hardware development to Industry, a total of twenty-eight satellites, plus Spacelab and Ariane, have either been launched or are presently under development. In addition, a large volume of advanced-technology equipment development has been contracted by the Agency. For every undertaking, at all stages from the feasibility (Phase-A) study through to evaluation of the main development phase (Phase-C/D) tender and subsequent contractual changes, the same question needs to be answered: namely, 'What is a fair and reasonable price for the product?'

A major contributor towards answering this question is the Cost Analysis Division, within the ESA Contracts Department and part of the Agency's Administrative Directorate. This Division is charged with two main tasks:

- The analysis of industrial economics: verification of rates, overheads, price-variation formulae and indices, as well as the auditing of direct expenditures. This task is handled by economists and chartered accountants.
- The estimating and analysis of prices: qualitative and quantitative analysis of a product and establishment of cost/price estimates at equipment, subsystem and system level, as well as the scrutiny of prices submitted by industry in Tenders and Proposals. This task is executed by engineers and systems analysts.

Only the second of these two tasks will be dealt with here.

To estimate cost or scrutinise industrial offers not only demands highly skilled personnel but also calls for a number of important prerequisites and tools if the job is to be properly completed. This holds true particularly for the innovative and sophisticated environment of the space industry, with its constant demand to advance technology, whether for scientific- or applications-type satellites and space vehicles.

The prerequisites include an extensive, formalised accumulation of factual data. This is needed to establish a baseline from which to build up a databank, to develop Cost-Estimating Relationships (CERs), and finally an overall cost model. Much of this data is obtained from tender documents, negotiated contracts, end-item data packages, cost-at-completion reports and, sometimes, data resulting from audits performed by the Agency. The various cost modules maintained in the ESA Cost Analysis databank are identified in Figure 1.

Since 1980, the Cost Analysis Division has logged the major technical design parameters of all the various items of mechanical and electronic equipment used in the various ESA satellite projects. To date, complete data on Cos-B, Exosat, ISEE-B, Meteosat, OTS, Marots, ECS/Marecs, and the Space Telescope (FOC) have been stored. Data on the Olympus satellite are presently being entered, to be followed by those for the Giotto and Hipparcos spacecraft in 1985.

Cost is an indicator of many things; in the space world it mirrors such factors as the complexity of a product, the technology used, the amount of new design work to be done, the reliabilities and lifetimes required, the number of units built, etc.

Figure 2 shows a typical cost curve, reflecting the impact of the above-mentioned factors on the design effort. As indicated, the cost of the product is largely controlled by the amount of design effort that is expended.

However, other, less technical considerations also find their way into the price of a product, such as a company's experience in a particular field, the type of

Figure 1 — The various modules in the ESA Cost-Analysis databank

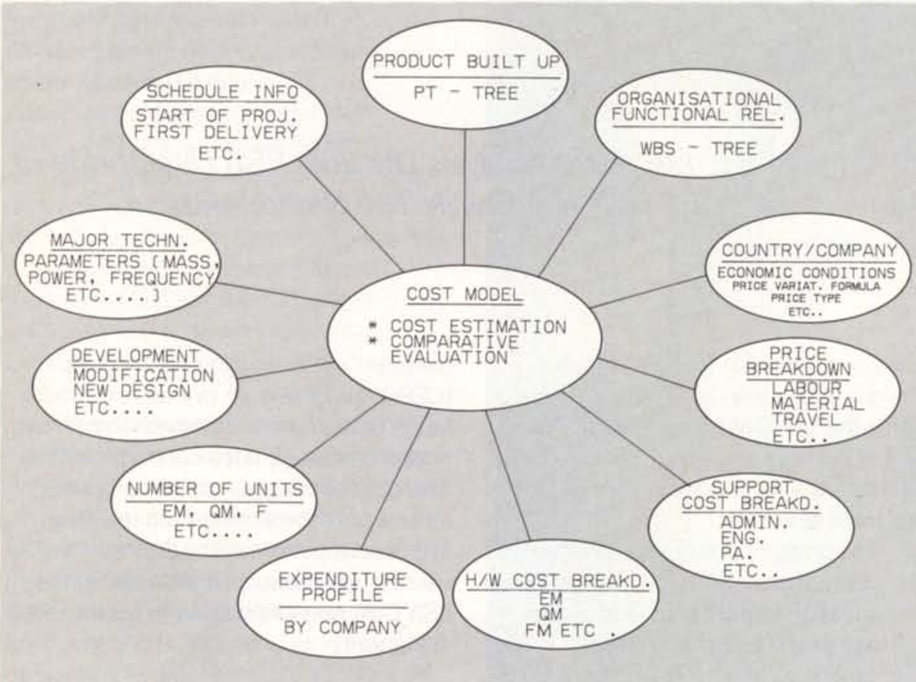
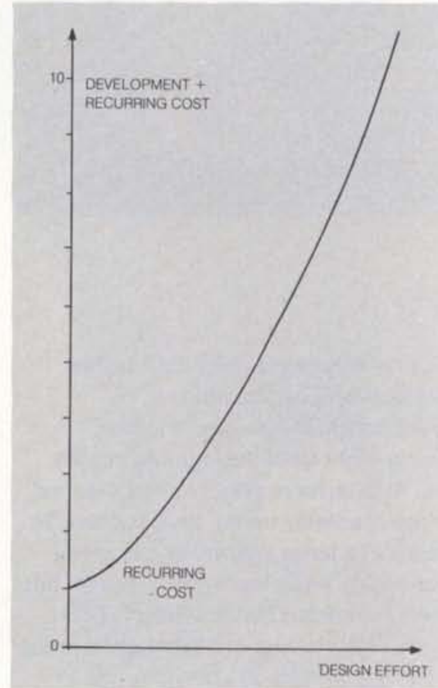


Figure 2 — Single-unit development and production costs



contract (fixed-price or cost-reimbursement) and competitive tendering versus direct negotiation, to mention but a few.

Current situation

In 1979, ESA rented a computerised parametric cost model which it subsequently used to establish cost estimates. However, it was soon realised that this cost model alone was inadequate, particularly in the project-management area, when dealing with complex project compositions and geographical distributions of work. The need to develop and implement ESA's own data bank became more and more apparent.

The result is the ESA Cost/Price Data Bank and Cost Model (ECOM) which is being developed to overcome all of the shortcomings highlighted by the use of the earlier model.

ECOM is strictly space-oriented and is geared particularly to cost-estimating on the basis of performance parameters, rather than weight/new design and technology content, which however are also considered. In the case of a solar array, for example, the output power and technology applied (e.g. flexible, rigid, etc.) need to be specified before the resulting data processing will provide the cost (and the mass as a resulting variable). This direct method of estimating the cost of a product is certainly preferable to that of first performing a mass estimate and then obtaining the price by applying certain mass/cost relations.

The ECOM approach is ideally suited for 'design-to-cost' type programmes, where a change in performance parameters, for example, may be necessary in order to stay within a fixed financial envelope.

The situation is different in the case of product-support functions, such as project management, project control, product assurance, etc. Their cost has to be a result of something else. But what? – total product cost, project duration, number of subcontractors, or perhaps type of contract?

To decide which of the above approaches (or combination of several) gives the most representative result in terms of cost, CER programs need to be run.

An example of how a Cost-Estimating Relationship is established is shown in Figure 3.

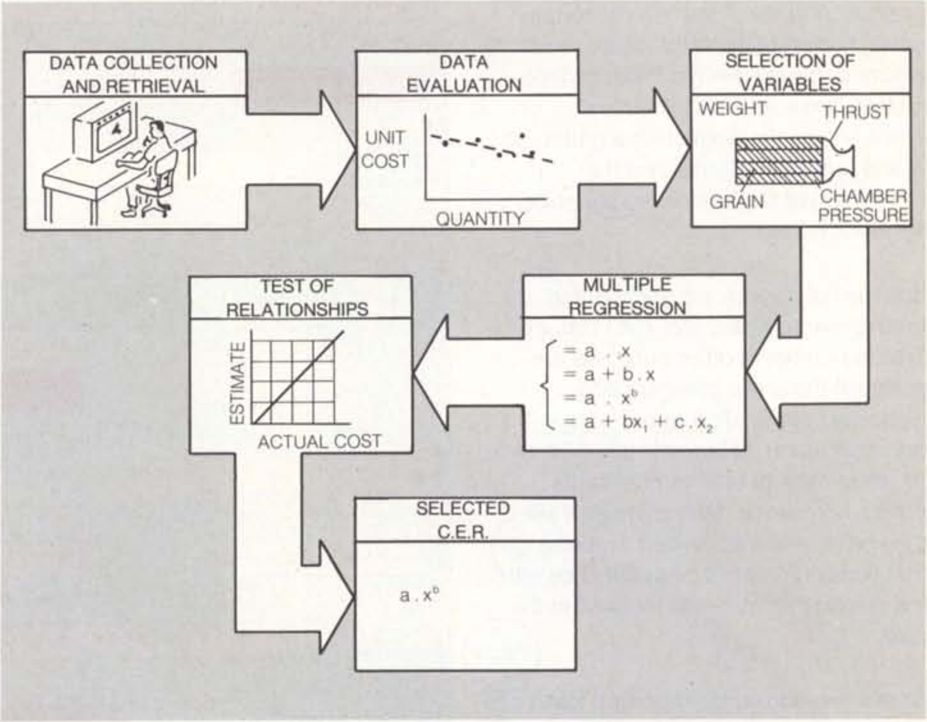
Neither of the above-mentioned hardware-cost models deals with the estimation of software costs, which for recent undertakings have reached an appreciable share of the project cost, as more and more onboard data processing is needed. ESA is presently conducting a pilot study with various on-going programmes with a view to including a number of CERs for software estimation.

Currently, data entry into the ECOM database is still done manually by industry and ESA, a tedious, time-consuming process with considerable scope for errors along the way.

Future plans

A programme initiated jointly with Eurospace as a consequence of the revised ESA Standard General Costing and Pricing Requirements, will result in

Figure 3 – Schematic of how a CER is established



standard ESA Cost Software (ECOS) that can be run on IBM-compatible personal computers*. The aim is to make it available to Industry by August 1985.

On the basis of this new software package, a number of major improvements in the industrial tender cycle are foreseen, as it will:
- provide for product-related cost identification and price build-up
- ensure compatibility of data input systems (interactive communication of cost data) and facilitate smooth compilation of the cost/price proposal
- considerably reduce the hardcopy content of tender documents
- provide flexibility when proposal data need to be changed at short notice
- facilitate updating of proposals to reflect final negotiated price
- improve data presentation and consistency
- provide flexibility in input level detail
- provide commercial security
- facilitate the organisation of cost data from various projects (contracts) for the derivation of cost-estimating relationships and parametric analysis.

By virtue of this software, industry will be in a position later this year to integrate its cost/price proposals at the various contractor/subcontractor levels electronically and to deliver the bulk of the data to ESA in machine-readable form (tape/floppy-disk or even via telecommunications link).

One of the guiding principles followed when setting-up the data bank and specifying the software was the need to ensure that the data would be entered in such a way that whenever a comparative analysis is to be performed or estimates are to be made, like is compared with like.

* The associated report (ref. EA/5692/JL) by the ESA/Eurospace Working Party has been submitted to all Participating Companies. Copies may be obtained from ESA Cost-Analysis Division at ESTEC.

One result of the ESA/Eurospace Working Party mentioned earlier is the creation of a strictly product-oriented breakdown, (Product Tree) to help to ensure that this homogeneity of approach will be achieved. The traditional Work Breakdown Structure, which is largely discipline and organisation-oriented, is not suited for this purpose.

If we take the design and building of a house as an example, two different approaches to the breakdown of the work are possible (Figs. 4 & 5):
- the product-oriented breakdown, or Product Tree (PT), which is a systematic division and subdivision of the product and/or services to be provided into discrete and related elements, such that every subtree contains all products/services related to the respective node; or
- the discipline- and industrial-organisation oriented breakdown, or Work Breakdown Structure (WBS), which is a systematic division of the product and/or services to be provided, designed to suit the project-specific industrial arrangement for the purpose of effective task management.

Neither approach is superior to the other; it is simply a question of the application determining which to select. Staying with the house-building example, a product-oriented cost breakdown is the most useful if one wants to know, for example, the cost involved in the inclusion or deletion of a fireplace. On the other hand, the discipline- and organisation-oriented breakdown is ideally suited if one wishes to obtain separate offers for the brickwork, heating system, doors/windows, etc.

Accepting, then, that both types of breakdowns have merits and shortcomings, the solution appears to be not to select one approach in lieu of the other, but to use both. The Product Tree is established during the early stages of project definition (e.g. during Phase A) and is expanded as knowledge and definition of the product progresses. Consequently, the Product Tree is the appropriate vehicle for any cost-analysis and estimating within and across

Figure 4 — Product-oriented breakdown, or 'Product Tree', approach

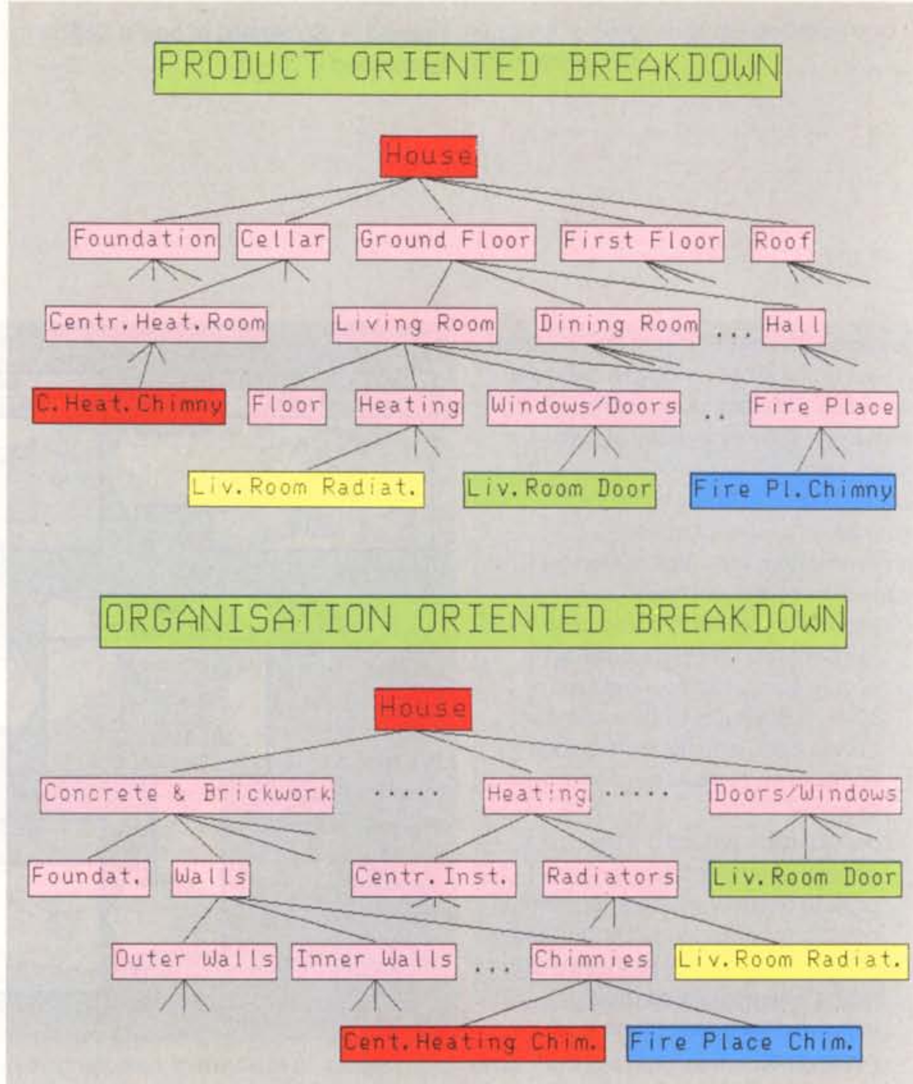
Figure 5 — Industrial-organisation/ discipline-oriented breakdown, or 'Work-Breakdown Structure', approach

Figure 6 — The support function/model breakdown

projects. Additions/deletions of certain parts (nodes) of the product are most efficiently handled in the Product-Tree system. Returning to the house's construction, the deletion of a bathroom would automatically result in the elimination of the associated plumbing installations, etc.

Because of the truly product-related breakdown provided with the Product Tree, a number of other purposes are served in the areas of scheduling, technical specification and documentation, deliverable items list, etc. All relate back to one and the same product or service description and will thus be consistently named, something that has certainly not been the case with many tender documents received in the past.

Finally one additional important feature to be mentioned with regard the Product Tree concept is the automatic



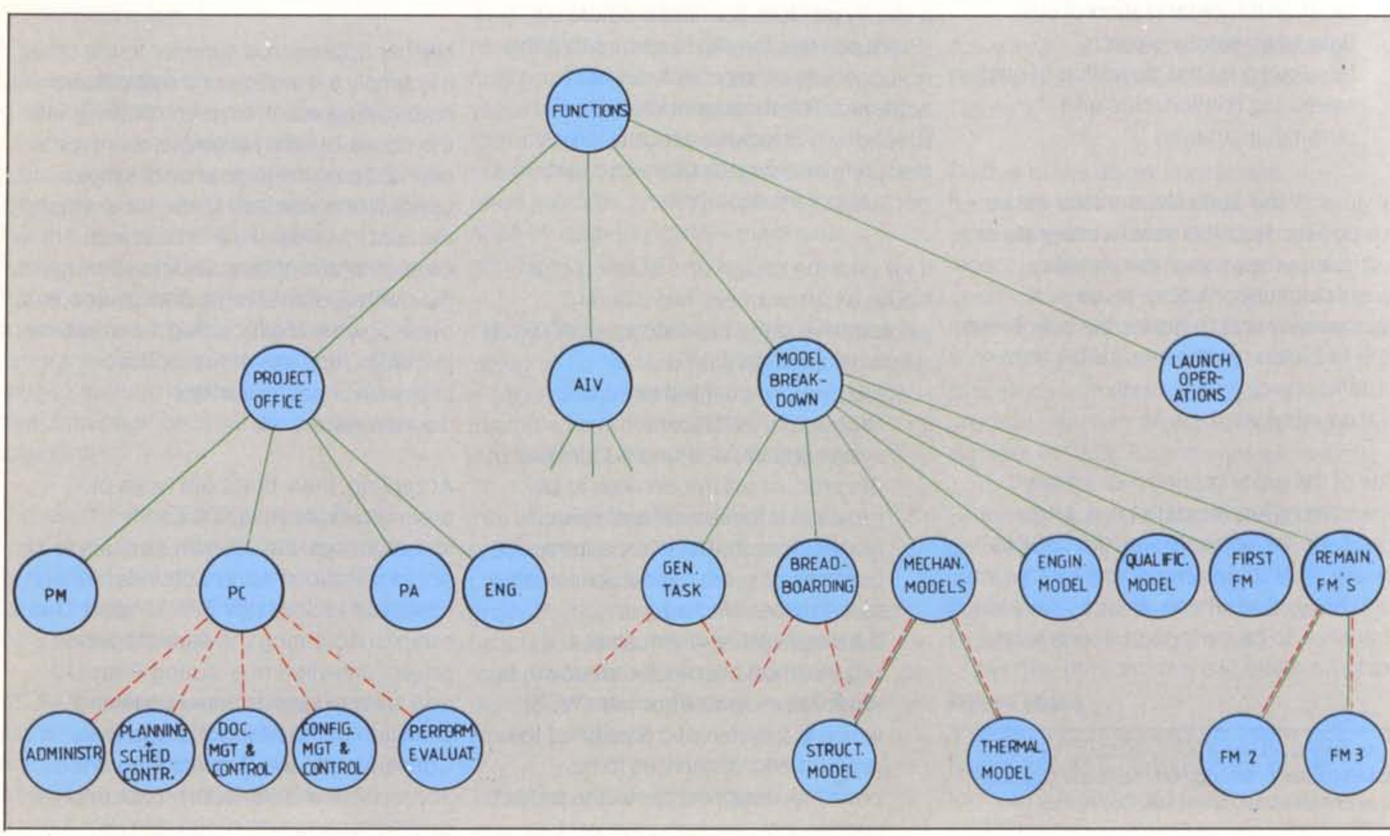
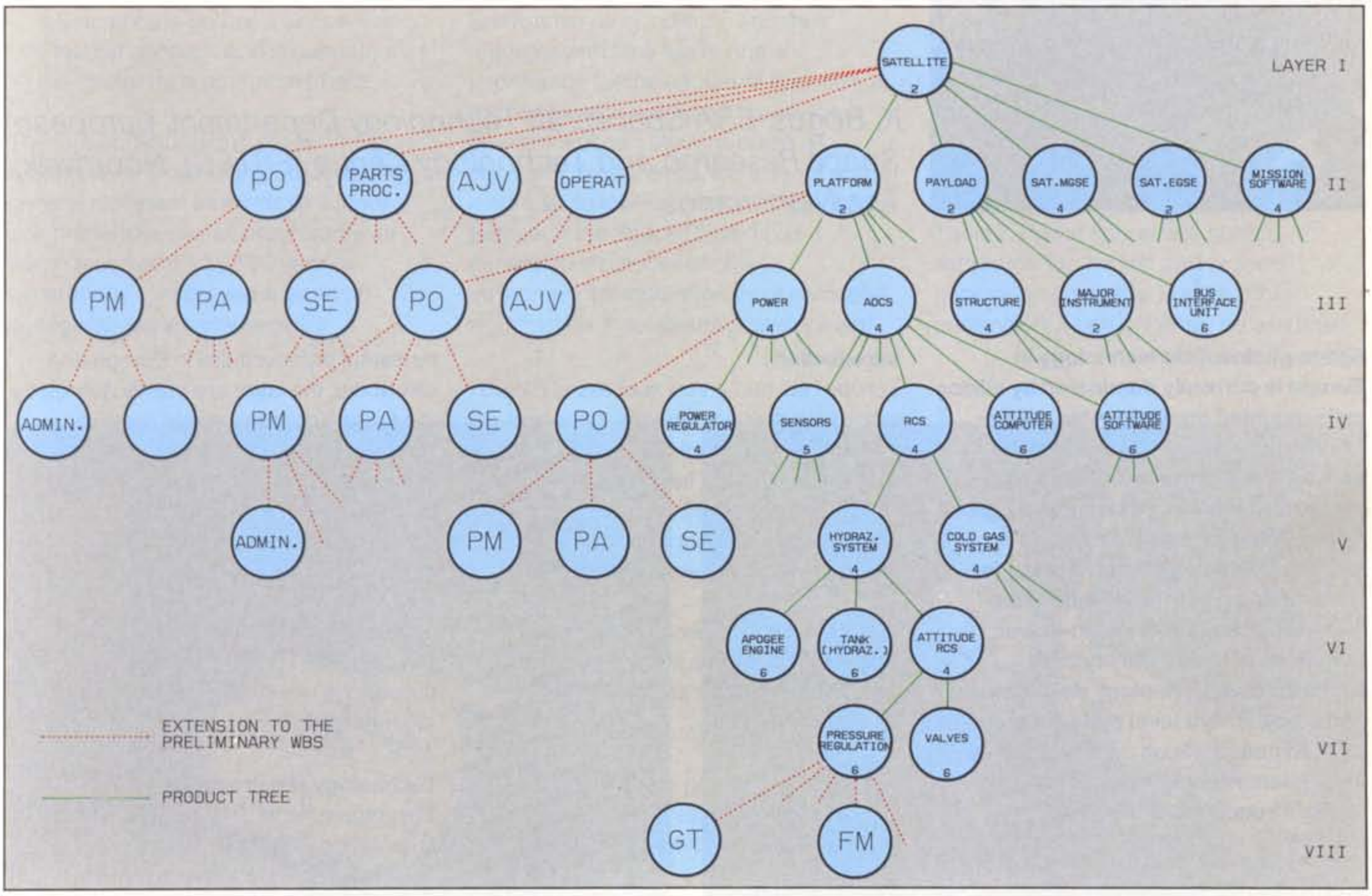


Figure 7 – Product Tree extended by the support function and model breakdown



identification of the support function and model breakdown (Fig. 6), which has been standardised and can be called-off at any product node level (Fig. 7). Appropriate Work Packages can therefore be derived for costing purposes by eliminative rather than creative effort.

The WBS approach is well-established and will not be further elaborated upon here. In the past, the approach generally used by industry has been to start with a product-oriented breakdown and then progress towards a discipline-oriented breakdown once the industrial organisation has matured sufficiently to provide an effective tool for managing the various disciplines involved.

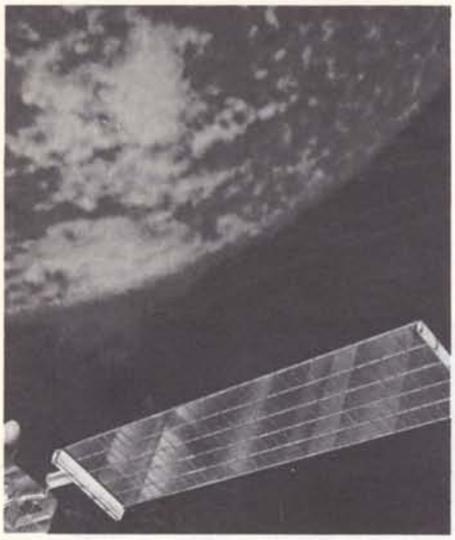
Conclusion
The standard cost software ECOS, to be used by industry as well as ESA, will avoid repetitive data entry at the various levels concerned, eliminate the need for manual arrangement and computation of cost/price estimates, and considerably increase the flexibility in establishing/modifying/reprocessing cost estimates.

The systematic accumulation of data that ECOS will allow and the subsequent ability to obtain reliable Cost-Estimating Relationships for inclusion in the ESA Cost Model (ECOM), will substantially increase the Agency's ability to analyse industrial proposals, as well as to develop its own estimates for future programmes.

As a consequence, both ESA and industry will have more time for the 'intelligent' tasks of cost-analysis work, including identifying sources of potential cost under- or over-estimation.

Though the means outlined above are new, the underlying spirit was formulated over 2000 years ago:

It is the mark of an instructed mind to rest satisfied with the degree of PRECISION which the nature of the subject admits, and not to seek EXACTNESS where only an approximation of the truth is possible. ARISTOTLE



Space Photovoltaics – Present and Future

K. Bogus, ESA Spacecraft Technology Department, European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands

Space photovoltaic technology in Europe is currently dominated by silicon cells mounted on deployable rigid or flexible panels. Europe leads in the application of large flexible blanket arrays for high-power missions (e.g. Space Telescope, Olympus) and is further developing the technology for retractable arrays. In the future, the increasing demand for high-power, minimum-area solar arrays will stimulate new technology development paths both at cell level (gallium arsenide and advanced silicon cells) and array level (planar blanket and advanced sunlight concentrator arrays).

Introduction

Europe has had a very successful record in the field of space photovoltaics and has achieved a competitive position in the world market. For a large variety of European spacecraft systems photovoltaic solar generators are the exclusive source of electrical power.

In considering the evolution of space photovoltaics from a system-theoretical viewpoint a number of specific features can be identified:

- selection among competing alternatives takes place within boundary conditions that can vary with time;
- long periods of continuous, predictable development are interrupted when unpredictable innovations emerge;
- a split into several development paths may be generated by different application needs;
- apparent blindness to long-term targets can lead to over-concentration on dead-end short-term-oriented developments.

This article first outlines the likely future of space photovoltaics based on currently identifiable capabilities and existing technology requirements, and then considers potential discontinuities and decision points in this development path.

In assessing the future all external and internal boundary conditions must be taken into account: the former being the interaction with non-European space programmes and with developments in terrestrial photovoltaics in Europe and elsewhere; the latter are mainly defined by the future European space mission scenario and its corresponding technology requirements. Within these boundaries the evolution of space photovoltaics is determined by the competition between those technology alternatives with a comparable degree of maturity and feasibility. These 'internal' stimuli are first defined in more detail and the various technology development lines are then described.

Technology requirements

The requirements and targets used in the formulation of a development programme have to respond to the needs of the future space projects. To illustrate these needs, four major projects driving European space photovoltaics technology have been selected (Fig. 1):

- *Eureca* (European Retrievable Carrier), currently entering its hardware phase, is the first European spacecraft designed to return to ground after operating for just under a year in low-earth-orbit (LEO). It relies on the US Shuttle for launch and retrieval and on its first mission will primarily be used for in-orbit materials processing.
- *Olympus* (formerly L-Sat) is a large telecommunications satellite designed for a planned ten-year lifetime in geostationary orbit (GEO).
- *AGORA* (Asteroid-Gravity Optical and Radar Analyser) a scientific mission currently in an early definition phase, aims to explore the asteroid belt at a distance of 2.5 AU from the Sun.

– *Columbus* is Europe's Space-Station-related concept, and is currently in preparatory programme phase.

The four configurations shown in Figure 1 are simply for illustration purposes and in general represent elements of a more comprehensive overall programme for which (excepting AGORA) various generations of improved spacecraft configurations are envisaged.

Environmental conditions and their changes with time are of prime importance for the course of evolution. In the photovoltaics context, the space environment can be considered as constant. Nevertheless, the current shift of emphasis to low-earth-orbit missions like Eureca or the Space Station has generated a number of new environmental requirements of particular significance in solar-array development.

Table 1 lists the main environmental conditions for LEO, together with their impact on solar arrays and the resulting technology-trend conflicts.

The solar-array-specific features of the four selected mission types are shown in Table 2. Power figures are quoted separately for the first and second generation concepts. For the other parameters it can generally be assumed

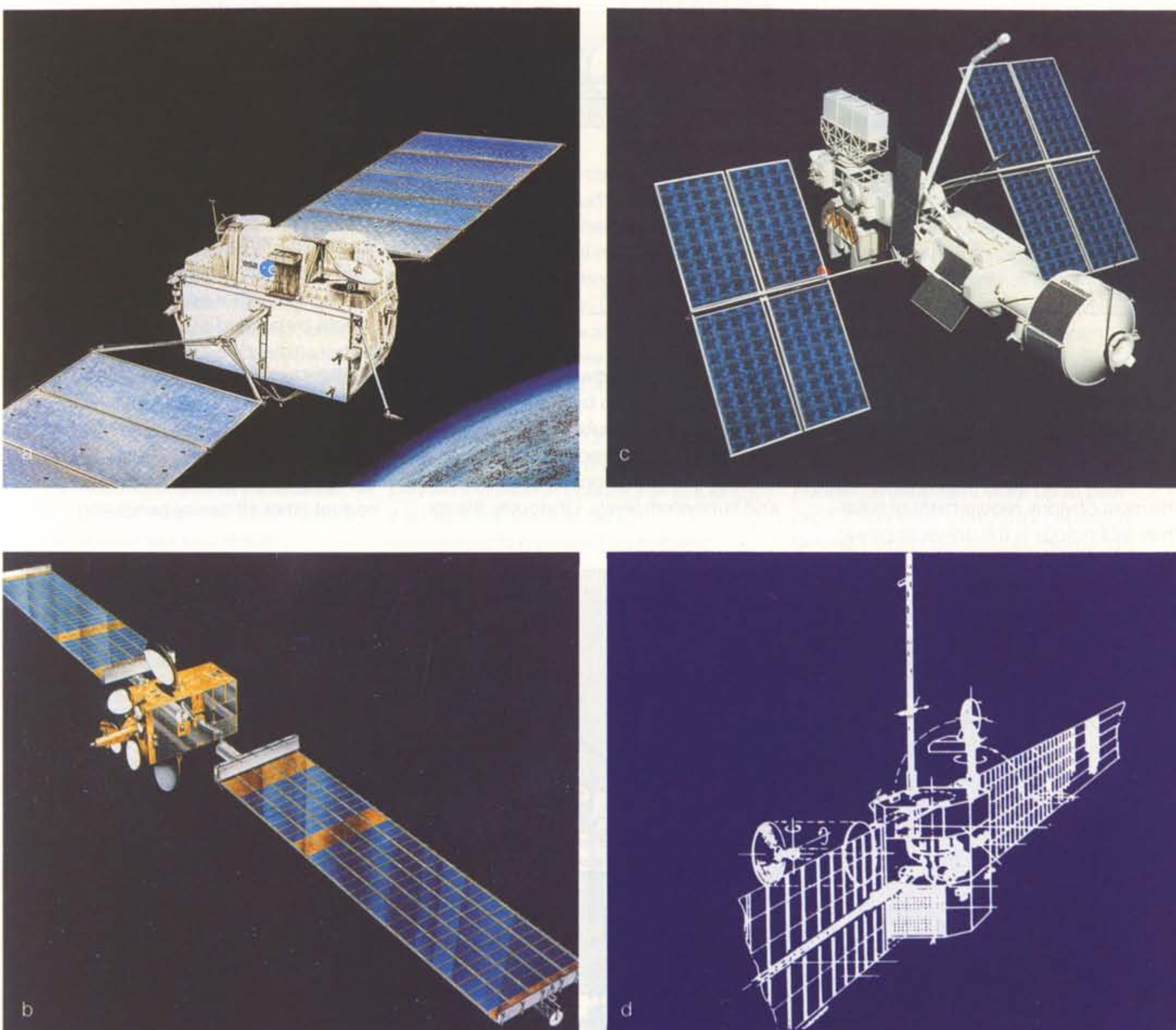


Figure 1 – European space projects acting as drivers for solar-array technology
a. Eureca
b. Olympus
c. Columbus
d. AGORA

Table 1 — Environmental effects on solar arrays in Low-Earth Orbit (LEO)

Environment	Effect on solar array	Technology conflict
Sun/eclipse thermal cycles	Fatigue of solar-cell interconnections	Long-life array
LEO plasma	Power loss due to plasma leakage electrical discharges	High-voltage arrays
Atomic oxygen	Erosion of exposed surfaces	Lightweight arrays
UV/particles	Performance degradation	High-efficiency arrays
Residual atmosphere	Air drag	High-power arrays

Table 2 — Spacecraft/solar array characteristics

	Eureca	Agora	Columbus	Olympus
1st Generation				
Array power (kW)	6	24	30	10
Lifetime (Yrs)	5 × 0.7	5		10
Bus voltage (V)	30	50	120	50
Partial deployment	–	–	+	+
Retraction	+	–	+	–
2nd Generation				
Array power (kW)	10–20	–	>100	10–30

that for the second generation the requirements become more demanding, i.e. lifetime will increase and operational versatility will become more important.

The most obvious requirement of solar-array technology is the absolute power level. Second is the power/mass ratio, reflecting the importance of lightweight design due to the very high launch costs per kilogram of spacecraft. These two key parameters are shown in Figure 2.

Future growth in power levels (left) shows a split representing the European situation with and without a large space station. The power/mass ratios of the four main solar-array types (right) assume silicon solar cells 200 microns thick, and that the stowed volume of the array is compatible with typical Ariane and Shuttle requirements. The application ranges of these four categories indicate general trends and are of course not absolute.

Solar-array evolution is dictated not only by the power and power-to-mass parameters but also by many other requirements. In Figure 3, six main technology-driving requirement trends are identified, at component, subassembly and subsystem levels. Obviously, the six requirements will each generate technology targets on all three levels. This article, however, concentrates on the three most important technology areas; the evolution of solar-cell technology, solar-cell-assembly technology, and solar arrays.

The description of these areas is largely based on the results of recent discussions within the European Space Photovoltaics community.

Solar-cell technology
In the past 20 years monocrystalline silicon solar cells have been used exclusively for space solar generators in Europe and it is almost certain that this will remain so for the near future. This does not mean, however, that no evolution has taken place. Compared to the early devices, advanced silicon cells like the BSFR (Back Surface electrical Field and optical Reflector) cells have about 50% higher operating efficiencies. It should be pointed out here that much higher efficiencies could already be reached with existing technology if this were the first priority. Generally, however, the priority requirement is the output power at end-of-life conditions and stable operational temperatures. Moreover, several other efficiency-penalising

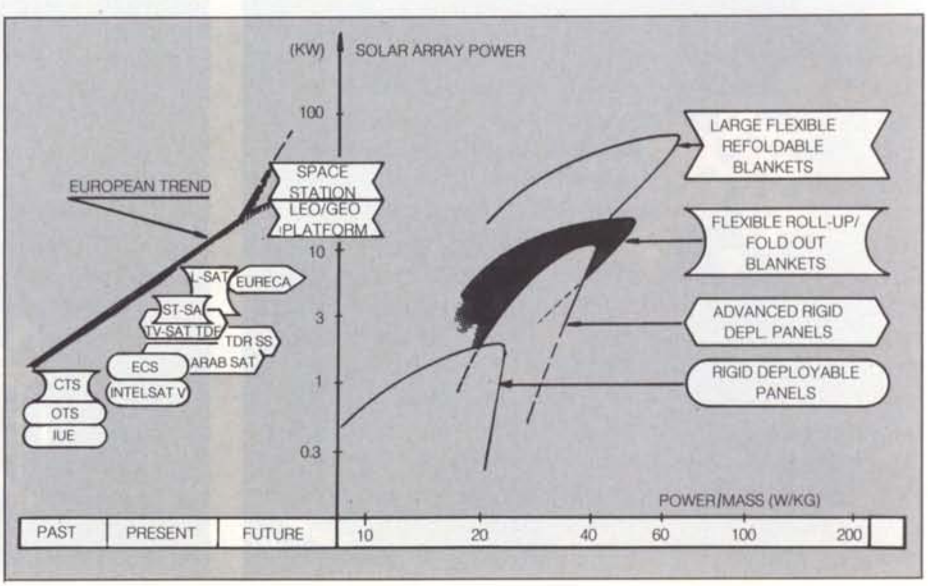
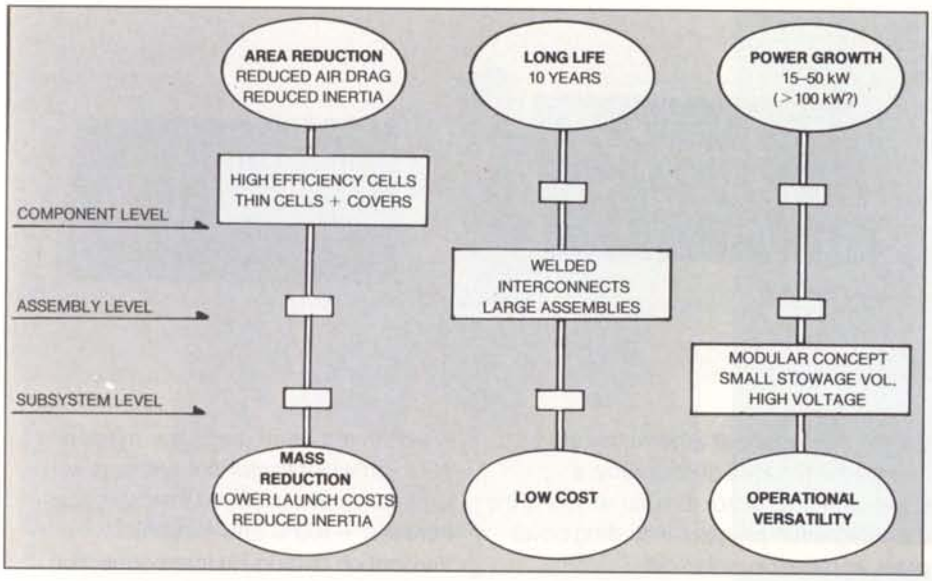


Figure 2 — Evolution of solar-array technology

Figure 3 — Derivation of technology requirements

Figure 4 — Operating principle of a bifacial silicon solar cell. On the right, a development sample of a solar panel constructed with bifacial cells



constraints originating from system-design (e.g. low mass) production, integration and reliability requirements do exist in practical applications. These constraints are often ignored in basic development programmes resulting in a gap between the promised efficiencies of early development and those achieved for state-of-the-art production devices.

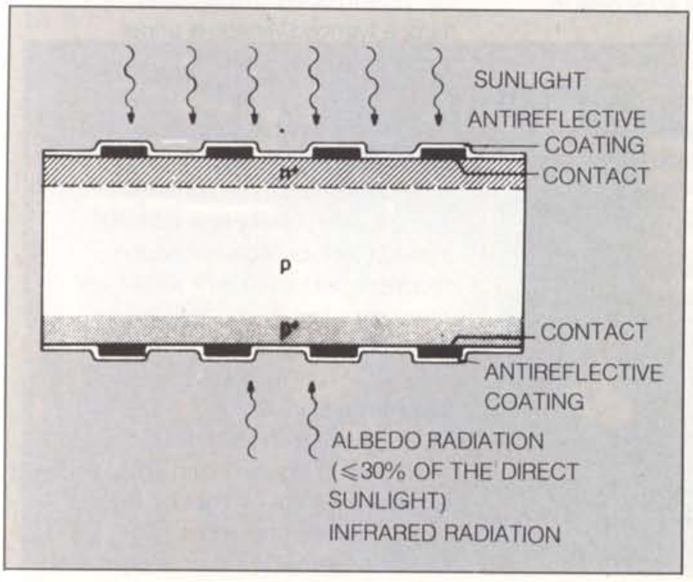
In addition to these near-term activities, other attractive development directions have been identified. One of these is the bifacial or albedo solar cell, which uses a transparent back-contact similar in geometry to the front-contact grid on a BSFR cell, the back surface field p+-layer providing adequate sheet conductivity to avoid excessive lateral resistive losses on the rear. This cell not only makes use of the albedo radiation in LEO, it also has the advantage of operating at a lower equilibrium temperature than any other cell configuration (Fig. 4).

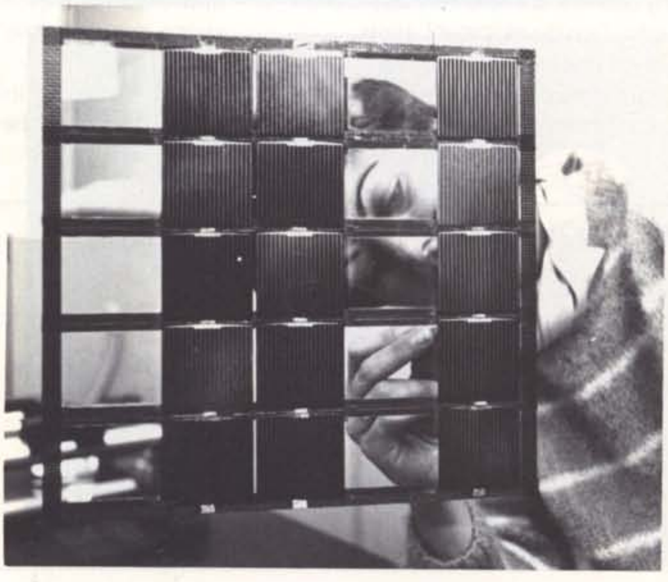
Considering that each 2° reduction in temperature provides more than one percent increase in operational efficiency, it is clear that thermal design improvements represent an efficient method of increasing performance. The bifacial cell has the potential to improve operational efficiency by 10 to 15 percent.

The future of silicon solar cells as outlined in Table 3 is derived from existing requirements and technological capabilities. The major potential challenge to this steady evolution lies in the development of GaAs (Gallium Arsenide) solar cells. Both solar-cell types may be produced in parallel, but, in view of the relatively small European space-solar-cell market, together with the high initial investment and running costs of a solar cell production line, it is probable that only one of these two competitors can survive.

The potential of GaAs solar cells for typical European space projects has been assessed recently under ESA Contract, using performance parameters and production characteristics obtained from European R&D laboratories actively engaged in GaAs-cell development. Results of environmental and performance tests conducted at ESTEC and DERTS (Toulouse) on GaAs solar cells were also taken into account.

Further development work up to pilot production level is definitely necessary before a clear comparative evaluation





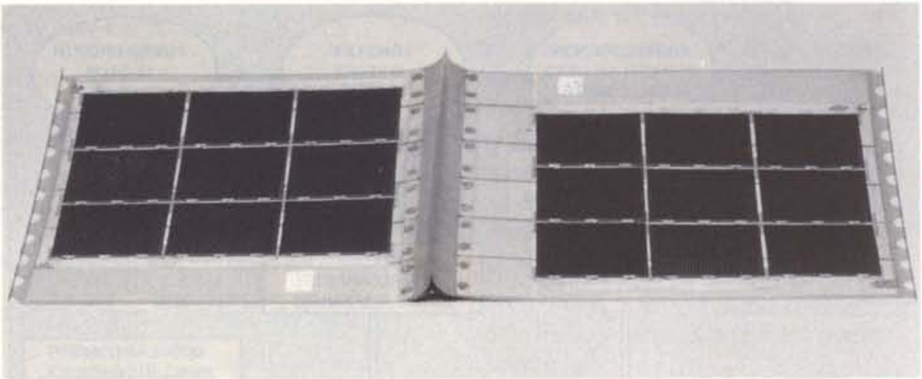


Figure 5 — Development sample of a 5 cm × 5 cm cell assembly on a fold-out flexible blanket substrate

can be made. The main areas of uncertainty in assessing GaAs-cell competitiveness are: selection of epitaxial layer production process, production process yields, production rates, production costs and assembly technologies.

Among the many advantages of GaAs one disadvantage is its high specific mass. This, with present cell thicknesses of more than 200 microns, presents a problem for mass-critical applications. Any potential breakthrough for GaAs cells must therefore be considered as having two steps: first, the production of GaAs cells of 200–300 microns thickness, at acceptable cost, for special applications where mass is not critical, but other parameters like minimum area or high-temperature operation are important. The second step is the development and production of very thin devices, less than 50 microns thick, for the many applications in telecommunications and other efficiency- and mass-critical projects.

Solar-cell assembly

Technological developments at the assembly level are often underestimated since they are less obvious and less spectacular than that at subsystem level. Many aspects are also very application-specific. Two development areas, however, merit special attention:

- large-area assemblies, and
- long-life solar-cell interconnections.

Large area solar-cell assemblies are of interest for reasons of economy; a significant cost factor in solar arrays is the cell-integration process, including cover-glass application, solar-cell interconnection and substrate bonding. The costs of these processes are proportional to the number of units to be integrated. In Europe initial steps in silicon solar-cell assembly development have been towards $5 \times 5\ cm^2$ cell assemblies (Fig. 5), but with new technology such as photolithography, laser-scribing and 4-inch-wafer processing, more emphasis is now being given to rectangular configurations with the same total area.

Other development activities centre on the introduction of low-cost technologies such as aluminium-contact systems, relaxed defect specifications and the application of terrestrial solar cells in space-qualified assemblies.

Long-life solar-cell interconnections must be able to survive the severe space environment. During a 5-year mission in LEO lightweight solar-cell blankets will experience about 30 000 thermal cycles between +100°C and −100°C. Verification of long-life interconnection concepts by thermal-cycling tests is therefore extremely important since analytical models cannot accurately predict the cycle lifetime for a given design.

Accelerated thermal-cycling test methods for the verification of long-life interconnectors have been studied and developed at ESTEC for many years. These methods provide test results on concepts with a 5-year lifetime in 1 or 2 months, compared to the 1 or 2 years necessary in conventional vacuum thermal cycling. Two Accelerated Thermal Cycling facilities (ATCI and ATCII) are currently in operation at ESTEC, and a third, advanced version is under development.

Results so far obtained indicate that lifetimes of 10 years in LEO and 15 years in GEO are likely to be achieved in this decade, with out-of-plane relief-loop interconnectors. More advanced concepts call for in-plane relief-loop interconnectors, which are still at an early stage of development.

Table 3 — Silicon solar cell evolution

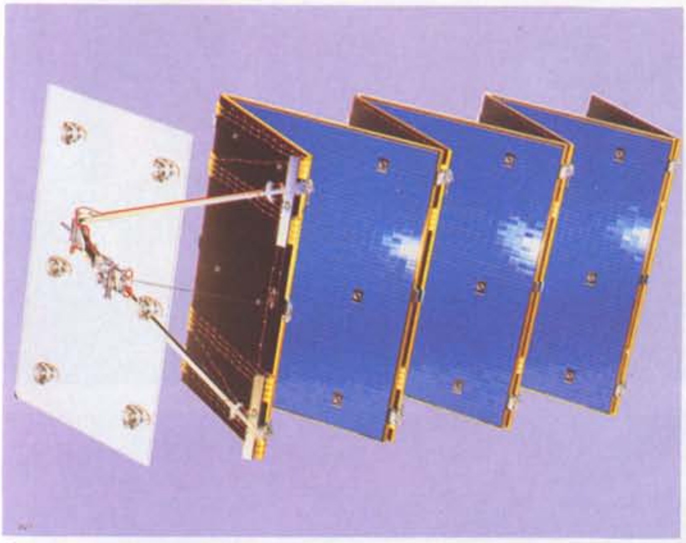
Development line	Present production	Goals for 1986	Long-term future
1. Large area	2×4; $2 \times 6\ cm^2$	$25\ cm^2$	
2. Thin cell	180 microns	110 and 140 microns	50 microns
3. Low temperature	BSR	Bifacial grid	
4. Long-life contacts	5 yrs (LEO)	10 yrs (LEO)	
5. Degradation		Improved silicon	Annealing
6. High efficiency	>14%	>15%	16%
7. Concentrator cell	–	–	Si <–> GaAs?
8. Processing	3-inch wafer Laser-scribe	4-inch wafer Photolithography	

Solar arrays

Current European solar-array concepts are shown in Figure 6, with advanced rigid or semi-rigid (left) and flexible blanket fold-out and roll-up arrays (right). Except for SOLA (a concept at an early

Figure 6 – Advanced solar arrays developed in Europe

a. ARA (Advanced Rigid Array)
b. GSR (Générateur Solaire Rigide)
c. ULP (Ultra-Lightweight Panel)
d. SOLA
e. Olympus (L-Sat)
f. Space Telescope



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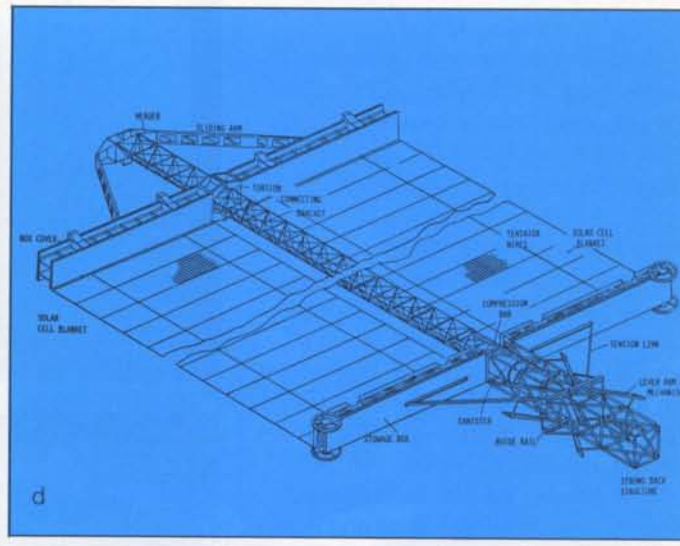

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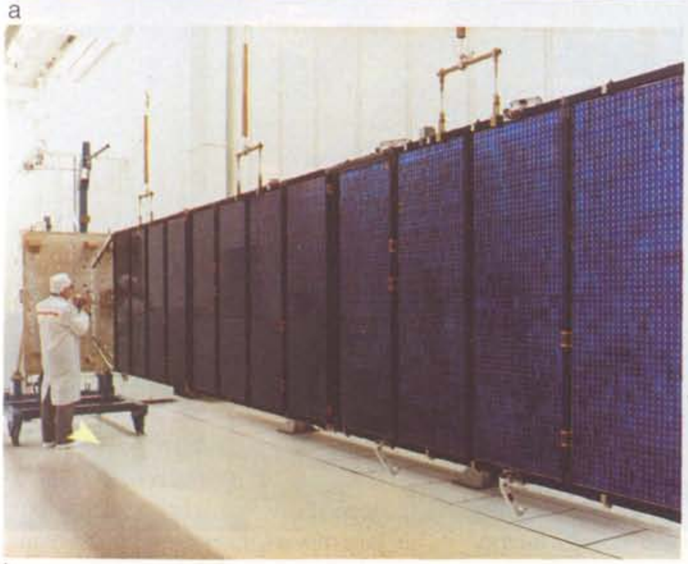

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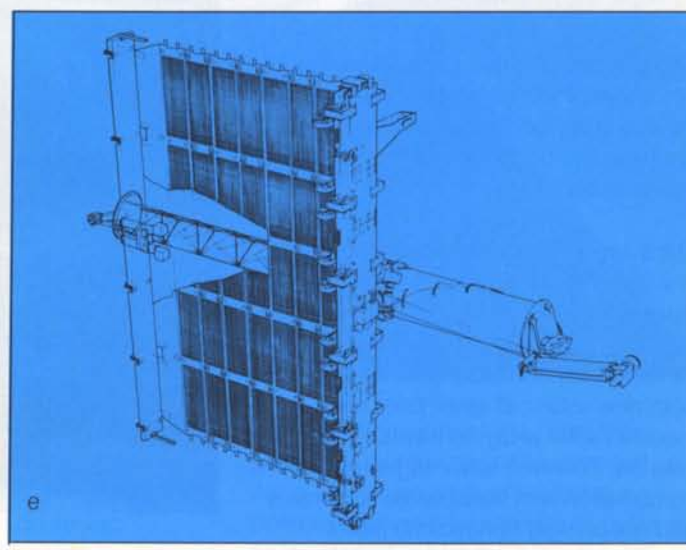

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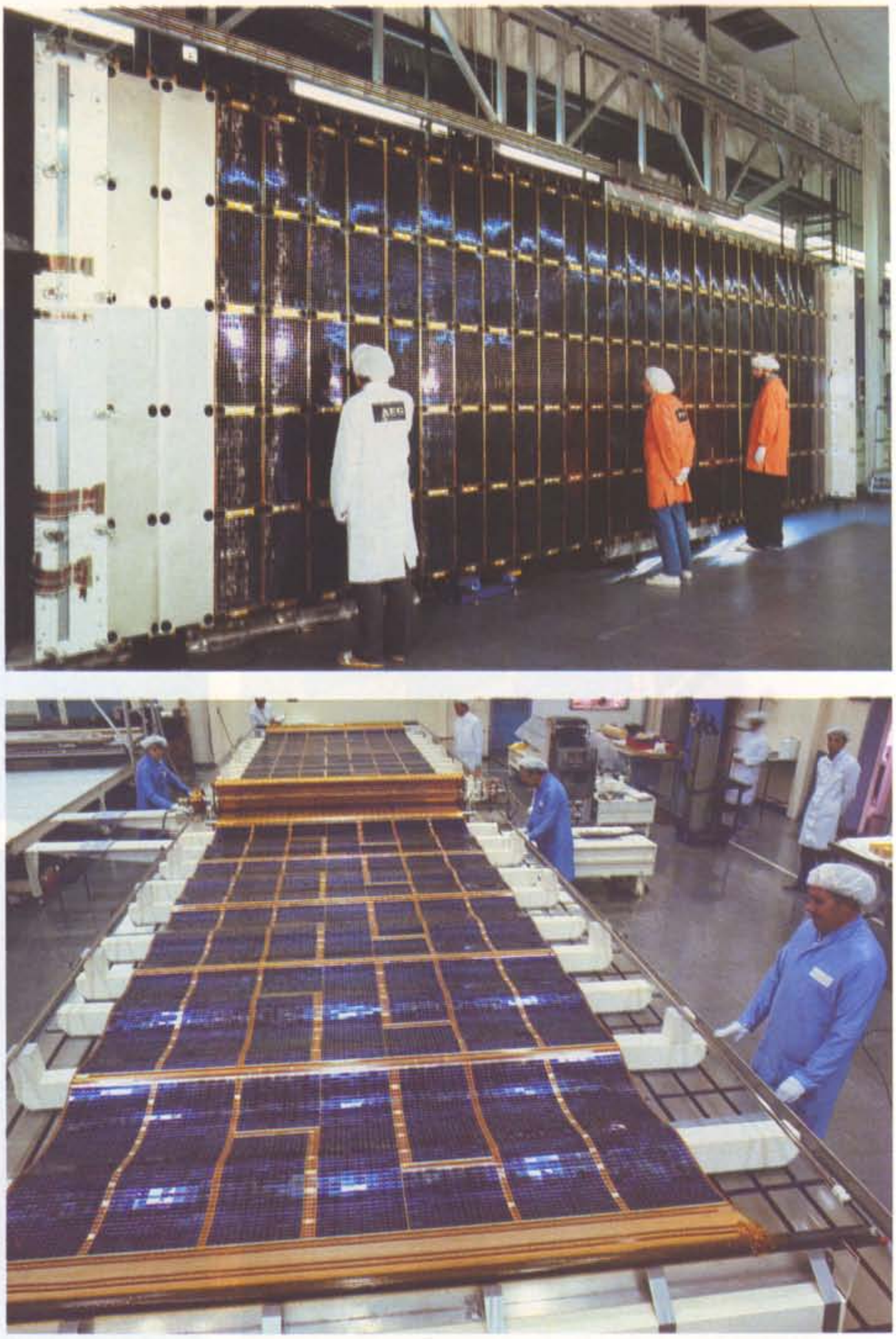
Figure 7 — Solar-array flight blankets for: (a) Olympus (formerly L-Sat); (b) Space Telescope



development stage aimed at LEO applications with a 15–50 kW power requirement), all concepts have reached a high degree of development maturity for applications in the 3–7 kW range (Fig. 7a, b).

The growth capability of these concepts to power levels of 9, 12 and 18 kW and above has recently been studied under ESA contract and results indicate that these higher power levels can be reached. The mass estimates given for the 18 kW case were between 300 and 650 kg. This wide range is due not only to concept-inherent differences, but also to different assumptions on dynamic load and EVA-interface (Extra Vehicular Activity) requirements. The results of this study also demonstrate that the applicability ranges identified earlier (Fig. 2) for the various array technology categories do not have firm boundaries at particular power levels.

The solar-array scenario described so far is supplemented by several other development activities.

Development of bifacial cells will lead to both new solar-cell assemblies and modified solar-array concepts. Bifacial cells are, however, advantageous only in combination with transparent substrates and not on rigid honeycomb panel structures.

Future large generators will need to operate at high voltages in order to handle multi-kilowatt power without excessive wiring mass and resistive losses. High-voltage solar-array technologies are under intensive study and several new development and test activities have recently been initiated.

The most major change in solar-array evolution is likely to come from the new requirements generated by the Space Station and its ancillary elements e.g. co-orbiting platforms. In addition to increased power levels, discussed earlier, two other new requirements are for a low profile (air-drag) and for modular growth capability.

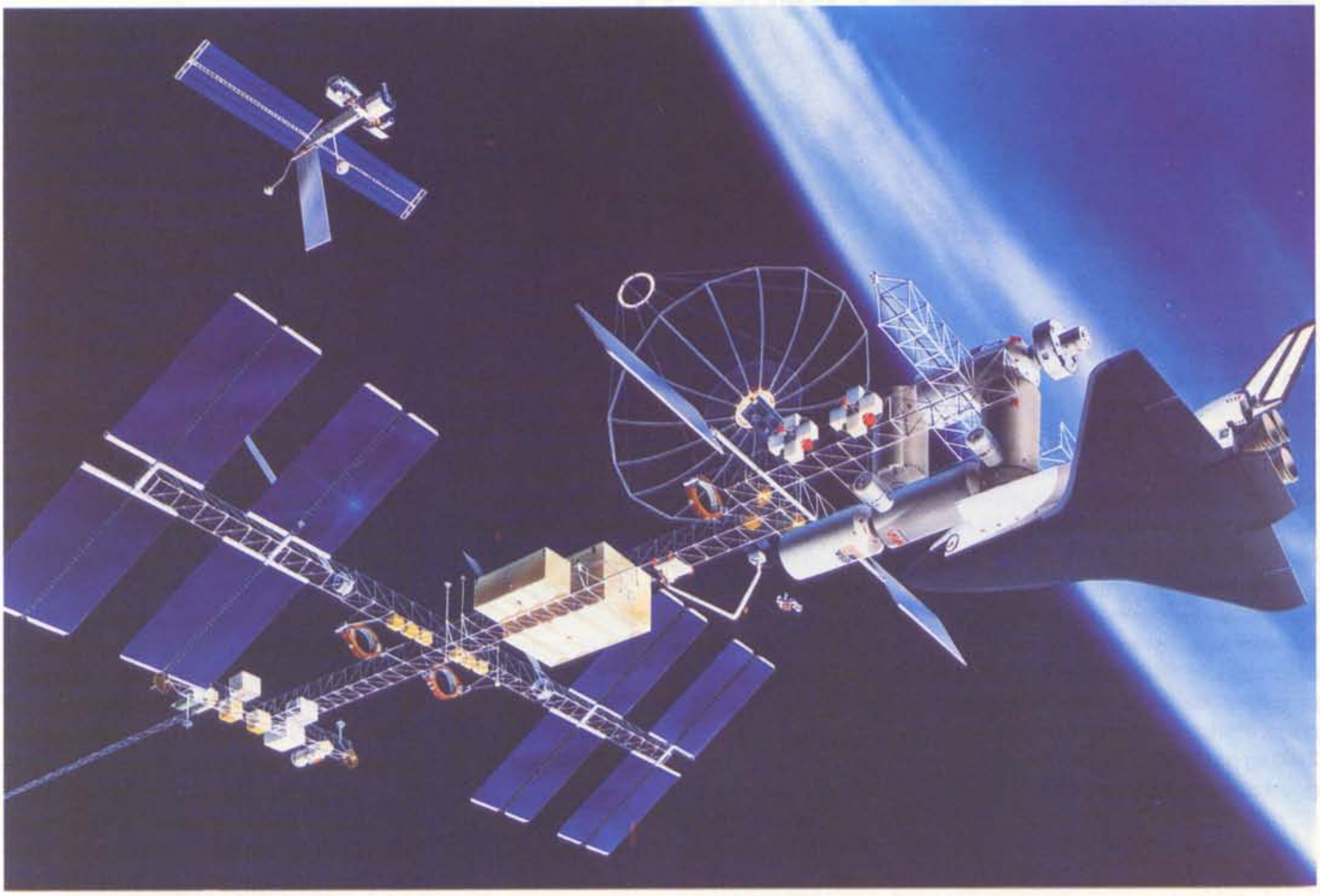
The technology options stimulated by these new requirements can be divided into planar array concepts on one hand and concentrator concepts on the other. This division is comparable with the branching in solar-cell technology (i.e. silicon v. GaAs cells).

In both cases deployment can be achieved either by an array-integrated deployment method or by the in-orbit erection of blankets and panels with the assistance of Space Station manipulator systems.

The new requirement for reduced airdrag seems to demand minimum array area, i.e. high efficiency 'concentrator' concepts. Another method, however, of reducing the air drag would be to optimise the aerodynamic profile in LEO.

The capabilities of various concentrator concepts for typical mission models, e.g. LEO platforms, telecommunications satellites and interplanetary missions, are under study. Early results seem to indicate that low concentration ratio (below 15) concepts like the linear trough, the truncated pyramid and the SARA are compatible with general spacecraft system requirements and that these are

Figure 8 – A possible Space Station ('Power-Tower') and platform solar-array configuration



prime candidates for development in view of their short-term viability. Moreover, these low-concentration ratio concepts could initially be developed with silicon solar cells and upgraded with GaAs solar cells when these become available.

Further development and study activities are needed for accurate assessment of the potential advantages and disadvantages of concentrator array concepts. One of the main questions remaining open is the performance and efficiency of the optical system in space environmental conditions i.e. susceptibility to atomic oxygen erosion, combined charged particle and UV degradation and thermal-cycle fatigue.

A prime candidate for initial Space Station applications is the advanced silicon-solar-cell flexible planar blanket, as shown in Figure 8. The solar-array requirements of the main Station and of the co-orbiting platforms, in terms of wing-size and orbital altitude, are not dissimilar; conceptual commonality and exchangeability of solar-array elements giving low cost and high versatility may thus become key features of the Space Station system.

Conclusions

The European space photovoltaic development programme is based on the one hand on existing capabilities in solar-cell technology, assembly technology and solar-array design and on the other on the identified requirements of technology-driving future missions.

Although the evolution of space photovoltaics can to a certain extent be forecast, several important areas where significant innovations may alter the predicted course have been identified. Although it is possible to predict the potential technology alternatives that may be developed in parallel, it is more difficult to specify when this branching will occur and which routes will be the most successful in the long-term.

The Latest Ariane Launch – Flight V11

A.S. Palmer, Ariane Department, Directorate of Space Transportation Systems, ESA, Paris

In the late evening of 9 November 1984, two spacecraft, the American Spacenet F2 and the European Marecs B2, were injected into near-perfect geostationary transfer orbit with the launch from the Guiana Space Centre of the eleventh Ariane vehicle. It was the second launch of Ariane-3, derived from the original Ariane-1 through a number of modifications, the most important being the addition of two solid strap-on boosters and an increase in third-stage propellant capacity. The augmented performance of Ariane-3 allows a 2580 kg payload to be placed in geostationary transfer orbit.

The V11 activities in Guiana started on 17 September, with the arrival by sea at the port of Cayenne of the launcher's first and second stages, the nose fairings, propellants for the first and second stages and one of the propellants, liquid hydrogen, for the cryogenic third stage (the other third-stage propellant, liquid oxygen, is manufactured in French Guiana). The first major event of the campaign proper was, however, the erection on the launch pad on the 6 and 7 October of the first and second stages. Check-out of these stages commenced immediately and the third stage, which had been flown in from Europe, was erected four days later. Erection of the vehicle equipment bay took place the next day.

Whilst check-out continued, an event occurred in Europe which was to upset the smooth running of the campaign. After a test on the second stage of a later launcher, the cold-gas pressurisation system was found to be contaminated. One could not be certain that the similar unit on V11 was not contaminated and it was therefore decided to replace it by one known to be uncontaminated. The work was extremely delicate due to accessibility problems inside the upper part of the stage. The operational team were to be congratulated on the efficient manner in which they carried out the work.

The change itself took three extra days, but also led to a number of verifications being repeated. However, as a result of further extra working, the original schedule was regained, and the boosters could be mounted on the first stage on 29 October as planned.

The two spacecraft were then ready for their mating with the launcher. Ariane double launches are carried out by placing one spacecraft inside an egg-shaped structure known as the SYLDA (Système de Lancement Double Ariane), with the second spacecraft riding on top of this structure, as shown in Figure 1. The spacecraft are held in place by clamp bands, which are released in flight at the appropriate moment, allowing the spacecraft to be ejected by means of springs. To allow the lower spacecraft to exit from the SYLDA, the two halves of the latter are also held together by a clamp band and parted by springs. In the V11 case, Marecs was mounted inside the SYLDA, and Spacenet on top.

The two spacecraft and the SYLDA were mounted on the launcher on 31 October and enclosed by the nose fairing one working day later. Spacecraft and launcher check-out and preparation continued according to plan and the launch rehearsal was held on 6 November. The next day, the Launch-Readiness Review gave the go-ahead for the start of the two-day countdown.

The first day of the countdown, during which the first and second stages were filled with propellants, was marred by the breakdown of one of the two controlling computers. This necessitated manual instead of automatic filling, but the breakdown was repaired before the countdown was re-started, as planned, the next day. The operations that included the filling of the cryogenic third stage went

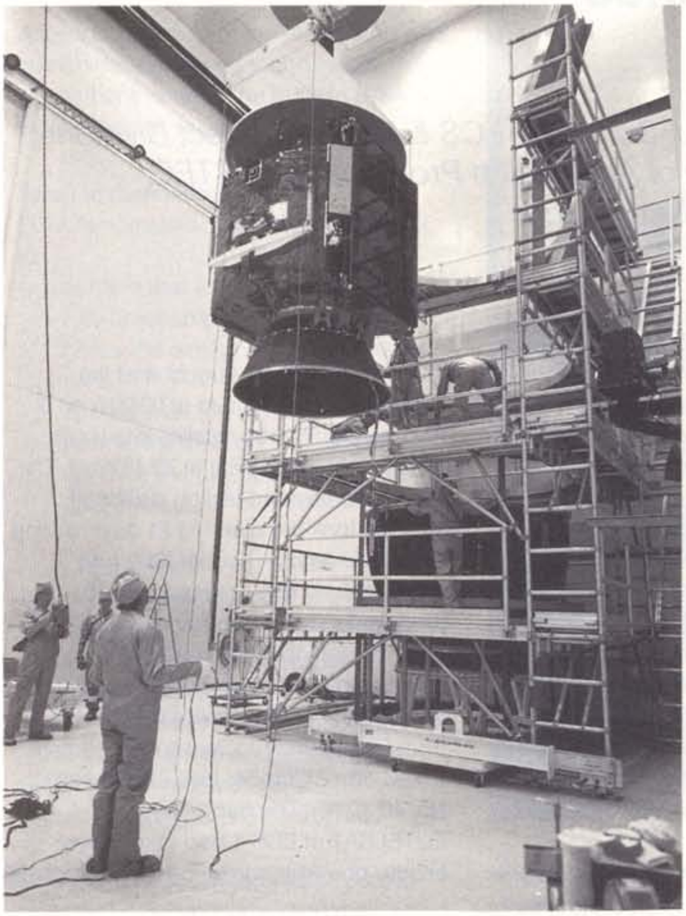


Figure 1 – Insertion of Marecs-B2 into the lower half of the SYLDA

Figure 2 – Upper half of the SYLDA carrying Spacenet-2

smoothly and would have led to first-stage engine ignition at the start of the 45 min launch window, had not most communications into and out of French Guiana been lost due an antenna losing track of a commercial communications satellite. Communications having been restored, the 8 min synchronised sequence was entered. This was completed without interruption and first-stage ignition took place at 22 h 14 min 15 sec local time (01 h 14 min 15 sec GMT on 10 November), 25 min later than originally planned, but still almost in the middle of the launch window.

With the almost cloudless night sky, one could observe with the naked eye not only the bright flames during booster thrusting, but also booster separation and fall, the continuing first-stage flight, stage separation and part of the second-stage flight. The trajectory was very close to nominal, as was the orbit attained. This can be seen from the following table, showing the orbit of the third stage at the time of thrust cut-off (i.e. just before spacecraft separation).

	Measured	Nominal
Inclination, deg	7.01	6.994
Apogee altitude, km	36022	35994
Perigee altitude, km	199.9	199.9
Argument of perigee, deg	177.97	177.99

The apogee altitude errors, measured more accurately later by spacecraft tracking, were 5 km for Spacenet and 2 km for Marecs, showing that the orbits were quasi-perfect and among the best yet achieved by any launcher. The orientation and spin-up manoeuvres carried out before the separation of each spacecraft were also close to nominal.

The launcher's mission was formally completed with the injection of the spacecraft into transfer orbit, but success continued with circularisation into geosynchronous orbit by the firings at third apogee of Marecs' European Mage-2 apogee motor and at ninth apogee of Spacenet's Thiokol STAR 30-B motor.

In summary, therefore, a difficult campaign for the operational team, and a schedule troubled by ground-equipment faults, was followed by a close-to-perfect launch.

(See also pages 80 – 85)

ECS-2 and Marecs-B2 – First Impressions of In-Orbit Performance

G.G. Fuller & J.-J. Dumesnil, ECS & Marecs Project Divisions, ESA Directorate of Application Programmes, ESTEC, Noordwijk, The Netherlands

The ECS-2 satellite was launched by the first Ariane-3 flight, on 4 August and Marecs-B2 on the second Ariane-3 launch on 9 November. Both launches took place on the days scheduled and placed the satellites into accurate transfer orbits. From there, their Mage-2 apogee boost motors placed both into final geostationary orbit with very high accuracy.

ECS-2 is already positioned at its final operating station of 7° East longitude and in operational use, having been fully commissioned and accepted by the customer, EUTELSAT, on 12 October.

Commissioning and acceptance of Marecs-B2 have also been carried out successfully and were completed on 9 December. The final orbital station at 177.5° East (over the Pacific Ocean) was reached on 20 December. Operational service for INMARSAT is due to start on 1 January 1985.

ECS-2

The ECS-2 launch took place in daylight (13.32 h GMT) on 4 August and the apogee motor was fired at 03.00 h on 6 August, placing the satellite into a near-synchronous drift orbit at 29.4° West. The drift to the payload testing station at 10° East took the planned 21 days, during which the service module (SM) and payload were fully commissioned in preparation for acceptance testing. The latter started on 28 August and was completed on 4 October, the formal acceptance of the satellite by EUTELSAT from ESA taking place at a ceremony at ESOC on 12 October (see ESA Bulletin No. 40, p. 76). The hand-over to EUTELSAT of ECS-1 had taken place exactly one year earlier, on 12 October 1983

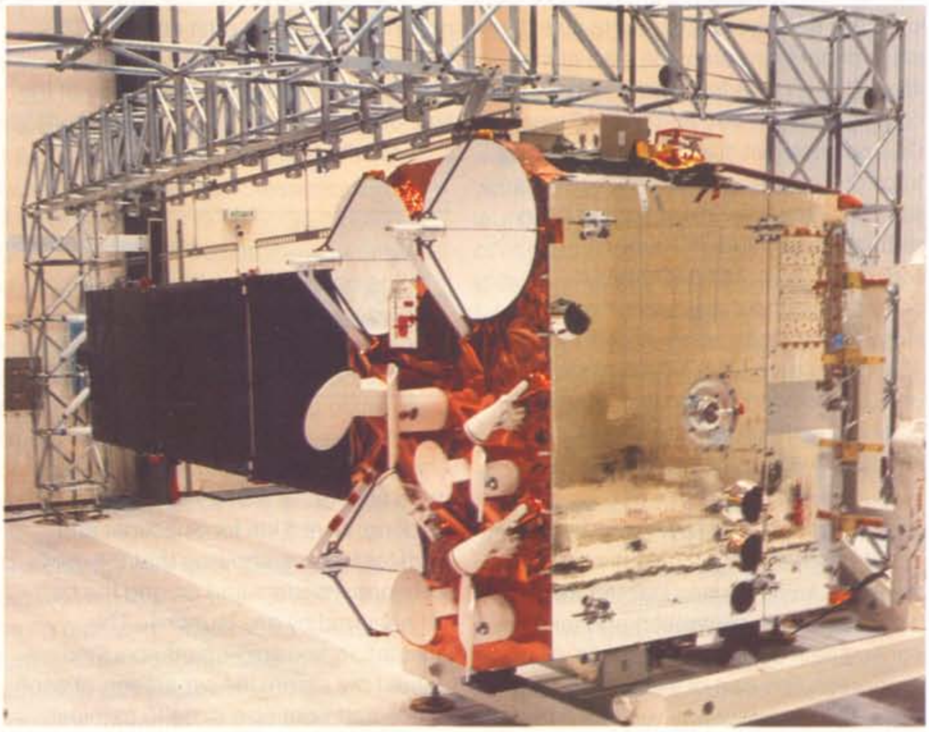
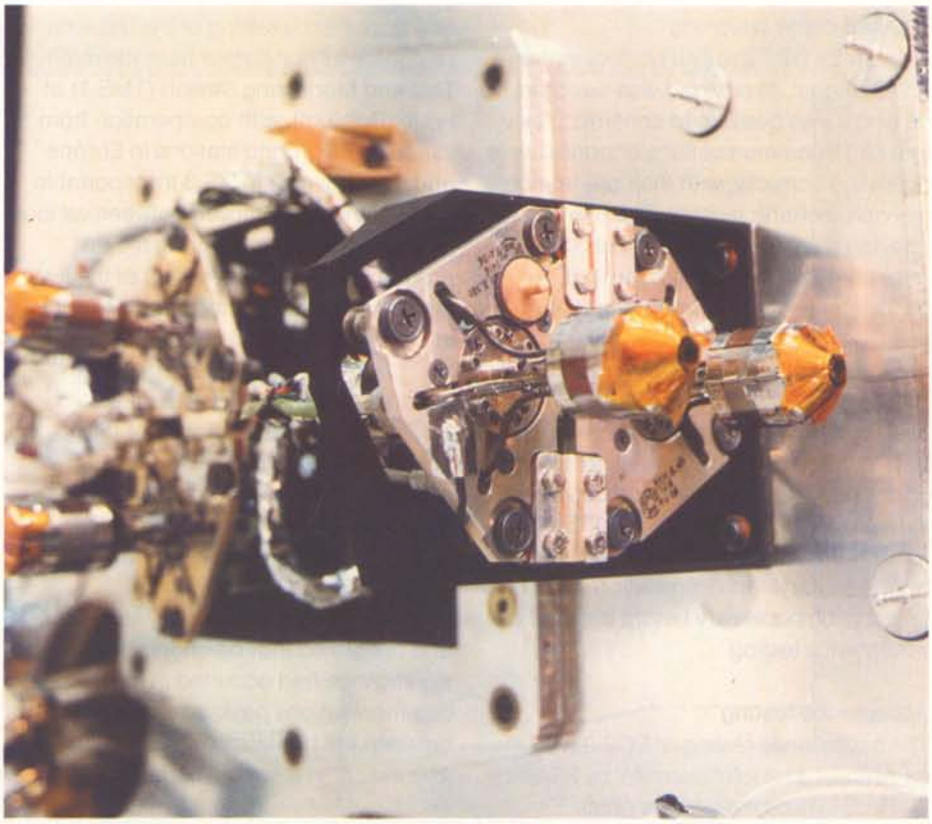


Figure 1 — Final deployment testing of ECS-2's solar arrays before launch

Figure 2 — The additional 0.5 Newton thrusters mounted on ECS-2



A fuller description of the pre-launch and launch details can be found in last November's issue of the Bulletin (ESA Bulletin No. 40, pp. 72–75).

Satellite commissioning
ECS-2's commissioning was carried out to:
- confirm that all the subsystems were fully functional
- check the availability of redundant units
- characterise the satellite's behaviour, prior to the start of operations
- optimise the payload prior to start of acceptance.

Power subsystem
The power subsystem of ECS-2 differs from that on ECS-1 in that it has larger batteries to provide a full eclipse capability; i.e. the satellite maintains full communications throughout eclipses, unlike ECS-1, where it is necessary to switch off some communications channels under eclipse conditions.

It was quickly confirmed that the solar array on ECS-2 was providing the expected power of 1210 Watts, and that all subsystem units were functioning correctly.

Thermal subsystem
A number of minor improvements have been made to the ECS-2 thermal design, benefiting from the observed in-orbit behaviour of ECS-1. The expected behaviour of the thermal subsystem and the correctness of the improvements was confirmed. In particular, the perennial problem of thermal 'soakback' from the apogee motor after its firing has been almost completely eliminated, and the thermal subsystem is maintaining the new, larger batteries at almost ideal operating temperatures.

Reaction-control subsystem (RCS)
Prior to launch, it was possible to load an extra 10 kg of hydrazine fuel onboard the spacecraft (nominal load 108 kg), equivalent to an extension of ECS-2's in-orbit lifetime by several months. Also, since there is no clear explanation to date of a loss of thruster performance observed on OTS, ECS-2 is equipped with additional redundancy for those thrusters used for long station-keeping burns; these extra thrusters will only be operated if there is evidence of a loss of performance later in the satellite's lifetime.

The RCS subsystem has behaved correctly, except for a thruster used for easterly station manoeuvres, which consistently provides only half of its expected performance. This has been attributed to a partial fuel blockage.

Attitude and orbit control subsystem (AOCS)
ECS-1 was the first European commercial satellite to incorporate a micro-processor in its AOCS system, which is used for attitude control during station-keeping manoeuvres. On ECS-2, the use of micro-processors has been extended to provide automatic control over other manoeuvres (spin down, Sun acquisition, and emergency loops); these functions it has accomplished in an exemplary fashion.

During commissioning, and just before the onset of the eclipse season, an unexpected Sun 'blinding' of one of the Earth-pointing sensors (IRES 'A') was experienced. This effect, which disturbed the sensor's operation for about 2 h per day, continued until just after the end of the eclipse season. The precise origin of the spurious Sun interference is not yet clear, and in the meantime the satellite is being controlled by the onboard redundant Earth sensor (IRES 'B').

All other tests on the AOCS subsystem have confirmed nominal performance and proper operation of safety loops and redundant units.

Telemetry tracking and command subsystem (TT&C)
This subsystem is performing faultlessly.

Figure 3 – A TMS-3 test station on location in Cyprus

Figure 4 – The controls, data logger and telephone links for a TMS-3 station (antenna can be seen outside the window)

Payload commissioning

After the satellite's arrival on final station on 25 August, its payload was switched on and it was possible to confirm quickly that all 12 communications channels were operating correctly, with their pre-launch measured characteristics. The two additional multi-service channels (SMS) were confirmed as functioning, but performance checks were not possible because ESA is not equipped for in-orbit measurements at the SMS frequencies.

Tests confirmed the need for a small pitch bias to trim the satellite's pointing, to compensate for the difference between the nominal design station at 11° East and the actual station longitude of 10° East. No further payload optimisation was found to be necessary before the start of acceptance testing.

Acceptance testing

The acceptance testing of ECS-2 was carried out as a joint exercise, by ESA, EUTELSAT and the satellite prime contractor (British Aerospace), following a previously agreed schedule of tests.

The acceptance testing of the baseline payload was conducted from the main Test and Monitoring Station (TMS-1) at Redu (Belgium), with co-operation from various PTT ground stations in Europe and from the small TMS-3 transportable stations that were moved between various beam-edge locations during the test programme. A full description of the test stations and test methods can be found in ESA Bulletin No. 36 (pp. 12–20).

In addition to the baseline payload, EUTELSAT was responsible for the acceptance testing of the two SMS channels, these tests being carried out from the PTT stations at Berçenay (France) and Darmstadt (Germany).

The test programme ran very smoothly and confirmed that no changes of any significance had occurred in the communications payload's characteristics between the pre-launch measurements and the same measurements repeated in-orbit.

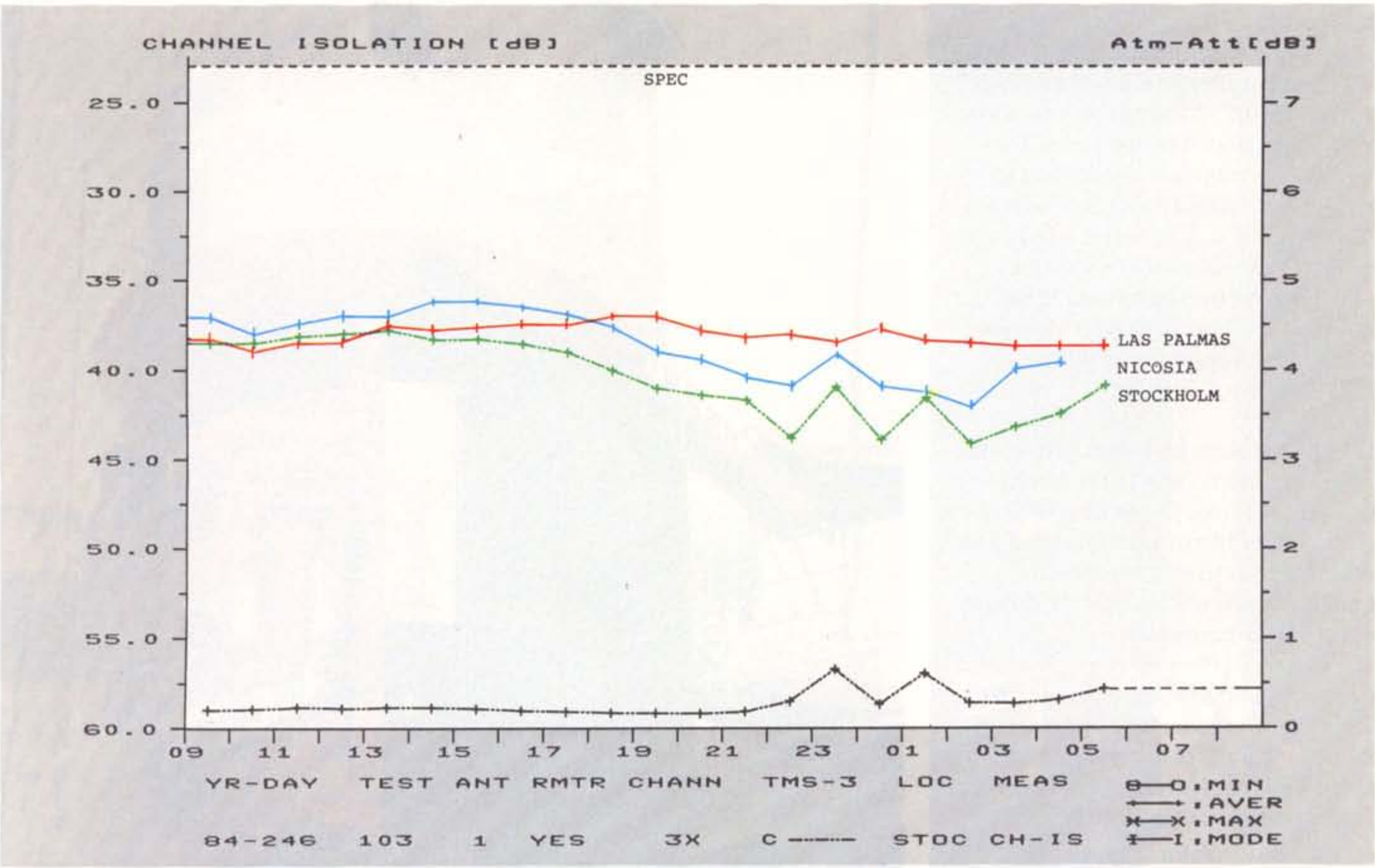
It is difficult in pre-launch tests to measure high values of discrimination between the cross-polar channels (XPD). In orbit it is possible to make this measurement more accurately. The values so measured exceeded expectations and fully justified the decision to use the new offset Eurobeam antennas with which ECS-2 is equipped.

Also of particular note was the influence on communications performances of the excellent attitude stability provided by the AOCS subsystem and the stable temperature environment provided by the thermal subsystem. These characteristics combine to result in isotropic radiated powers and input-power flux densities which remain very stable with time and well within the specified and expected limits.

It is evident from the excellent correlation between in-orbit and pre-launch performance measurements, not only on ECS-2 but also on ECS-1, that it should be possible in future to streamline the in-orbit test programme even further, allowing the satellites to be brought to full operational status even more quickly following launch.

Figure 5 – Cross-polar plot showing 10 dB margins for stations at the edges of ECS-2's beams

Figure 6 – Routine monitor display of ECS-2 attitude and orbit control parameters, photographed on 27 November



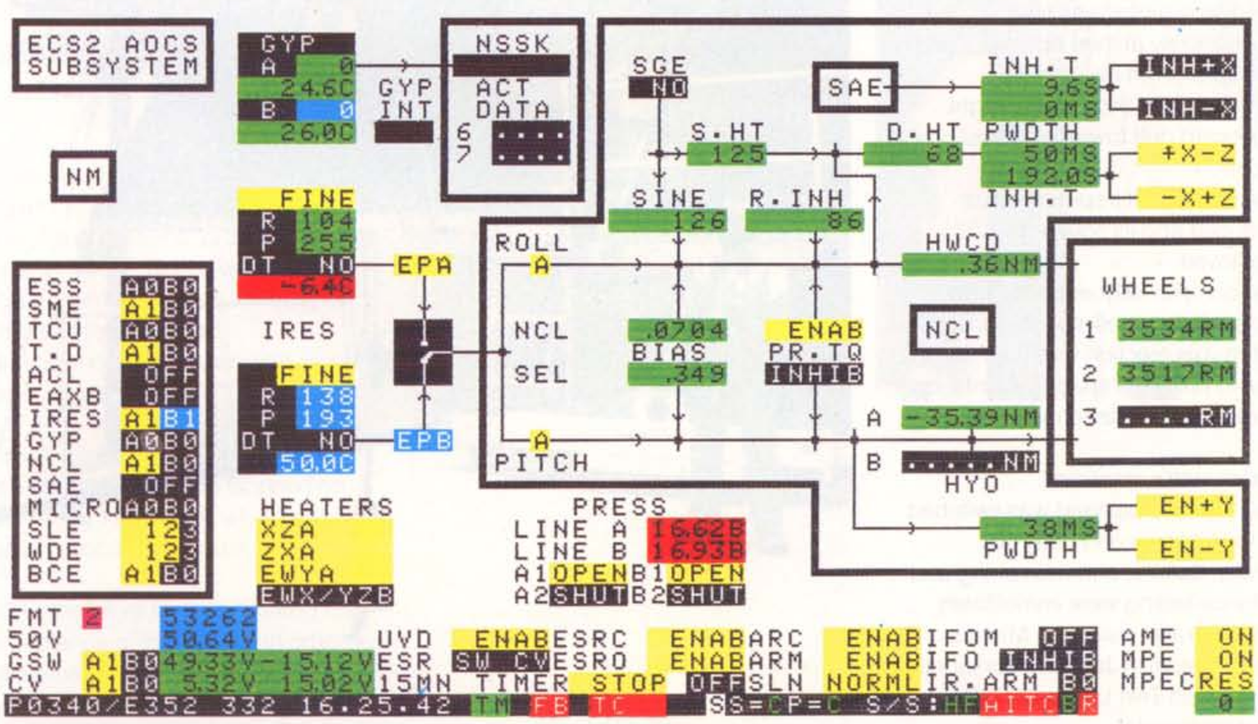
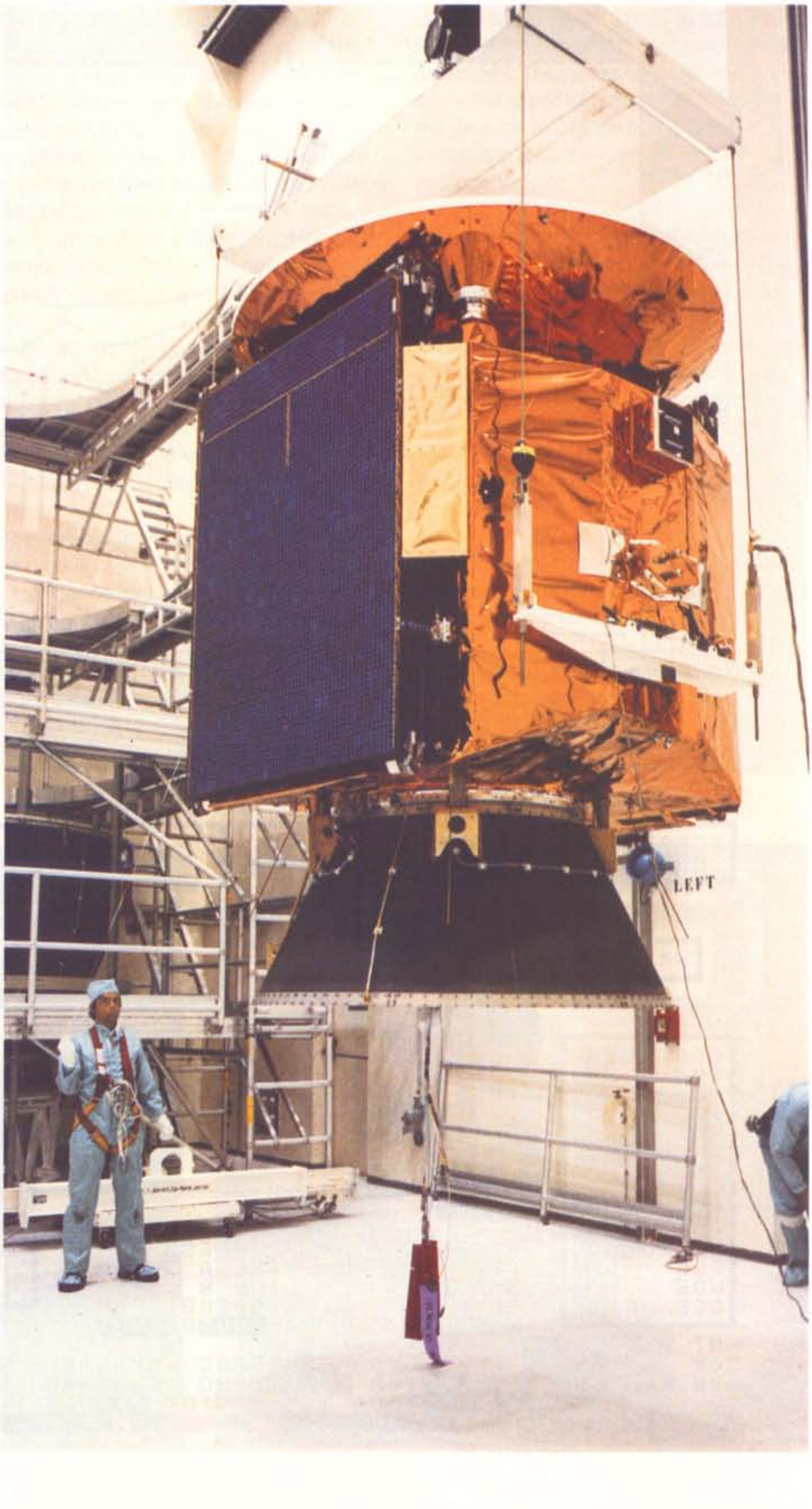


Figure 7 – Marecs-B2 ready for installation in the SYLDA double-launch structure



Marecs-B2

Following a successful Preship Review on 4 September 1984, at BAe in Stevenage, the Marecs-B2 spacecraft was shipped to Kourou for launch preparations. The launch campaign went according to schedule, although it was quite eventful. A faulty thruster was replaced, a solar-array wing was dismantled to replace the dummy panel by a live one, and, last but not least, the Thiokol STAR 30 apogee boost motor was replaced with a European Mage-2 motor.

Lift-off took place on Friday 9 November, at 22.14 h Kourou time (10 November 01.14 h GMT) (see pages 78 and 79 of this issue). Some 18 min later, Spacenet-2 was separated, and 3 min thereafter Marecs-B2 was ejected from the SYLDA double-launch structure.

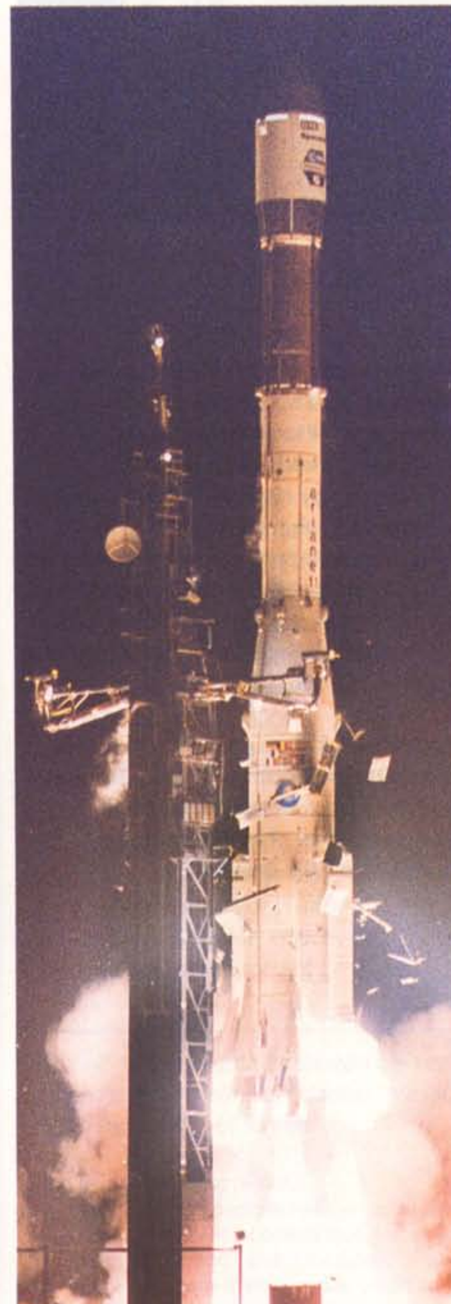
Injection parameters were perfect and within a few minutes ESOC was able to take over control of Marecs-B2 via the Malindi station. The early orbit phase progressed without problem:

- the spacecraft's spin axis was reoriented during the second orbit
- the Mage motor was fired successfully at third apogee, injecting the spacecraft into a near-synchronous orbit, with a slight eastward drift towards its final orbital position
- the spacecraft's spin rate was reduced and its solar arrays deployed
- the complex sequence of Earth-acquisition, wheel speed-up, and pitch-axis erection was then carried out to bring the spacecraft into its three-axis-stabilised mode.

The spacecraft's maritime communications payload was switched on for the first time on Friday 16 November. Satellite commissioning and acceptance testing were immediately started in parallel, using the Marecs station at Ibaraki in Japan in conjunction with a Payload Test Laboratory (PTL) installed on the site.

Figure 8 – Mating of Marecs-B2 and its apogee boost motor (Mage-2)

Figure 9 – Lift-off of the Ariane-3 vehicle carrying Marecs-B2 and Spacenet-2

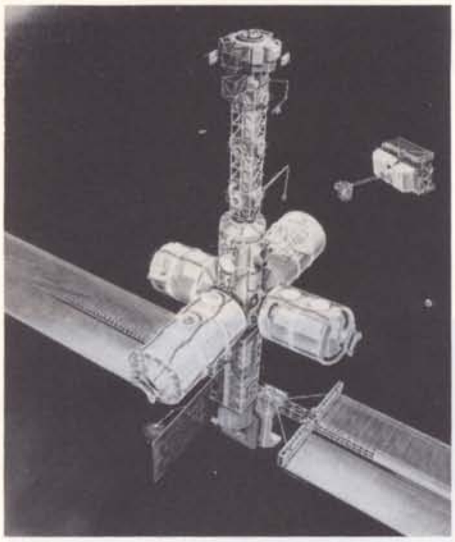


The commissioning phase was aimed at verifying all the satellite's operating modes as well as the operational procedures. The acceptance test phase was more specifically oriented towards verifying compliance of the maritime communications payload parameters with the specifications.

All went well and according to plan. The satellite's eastward drift was stopped on 20 December at 177.5° East, which is the duty station allocated to Marecs-B2.

INMARSAT therefore formally notified ESA of its acceptance of the satellite in orbit and requested that operational service over the Pacific Ocean Region be started on 1 January 1985.

The baseline lease period is 10 satellite-years, to be jointly accumulated by Marecs-A and Marecs-B2. An option for additional satellite-years may also by taken by INMARSAT, to maintain continuous service until launch of the second generation of INMARSAT satellites presently foreseen for 1989 onwards.



The ESA/Industry Workshop on Space-Station Technology

H. Stoewer, Head of the Systems Engineering Department, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

The objectives of the Workshop, held in Noordwijk on 23-25 October 1984, were:

- **to present to participants the present status of European technology applicable to the Space Station/Columbus, and**
- **to obtain inputs from participants on new elements, re-orientations, or confirmations of planned work for updating ESA's technology planning for 1985-1987.**

External Workshop participants (more than 200) came primarily from European space industry, but included some representatives of national space centres and ESA Delegations.

The Workshop agenda included a plenary opening session during which the status of the Space-Station Programme was reported and reviews of ESA's technology relevant to the Space Station and the corresponding NASA technology were given. The eight specialised sessions that followed had the following topics as their themes:

- Data Management and Information Systems
- Thermal Control and Environmental Control and Life-Support Systems
- Attitude and Orbit Control
- Low-Gravity Science Facilities
- Crew Work Stations and Communications
- Electrical Power Systems
- Structures and Materials
- Operations Technology.

In addition there were two special-emphasis sessions on:

- Computer-Aided Engineering (CAE), Electronic Design Tools and Engineering Databases
- In-Orbit Technology Demonstration.

These were included in order to highlight two 'non-Space Station' issues deemed to be important and relevant to the proposed Space-Station Programme. The objective of the CAE session was to review the present status of electronic engineering tools in Europe, and to outline the necessary steps towards an approach that would both ensure compatibility and allow the use of these tools in the European Space-Station Programme. The objective of the Technology Demonstration session was to provide industry with an update on preparations for the Programme, particularly the accommodation studies and the priority technology experiments that have been identified so far for possible flight opportunities in the coming years.

The eight technology sessions were structured around a number of key issues for each discipline, which were reviewed in detail and formed the basis for the final conclusions and recommendations (Table 1).

Programme status/ESA and NASA technology planning*

Studies relevant to European participation in the International Space-Station Programme, as proposed by the United States, have already been conducted by ESA and by some of its Member States, notably Germany and Italy, who have established the concept and associated scenario called 'Columbus'. The latter forms the major input to the definition studies, planned for 1985/86, candidate elements for which are shown in Table 2.

The Columbus pressurised module and platform concepts, as presently perceived, are shown in Figures 1 and 2. The module layout has been conceived for microgravity missions and is based (externally) on a three-segment growth

* Based largely on the three opening presentations:
- Status of Activities Related to the Preparatory Space-Station Programme 'Columbus', by G. Altmann & J. Collet
- ESA Space-Station Technology Overview, by H. Stoewer & R. Barbera
- NASA Space-Station Technology Overview, by R.F. Carlisle

Table 1 – The Workshop's scope and themes

DATA MANAGEMENT AND INFORMATION SYSTEMS
- Columbus Information Management System
- Aspects of Multiprocessing
- Data Management System (DMS) Architecture and Related Technologies
- The Space Station DMS as an Evolution of Present ESA Data-Handling and Management Systems
- Telecommunications and Data-Handling Aspects of Space Platforms
- Spacelab Lessons Learned and Space Station Prospects
- Software as a Subsystem
- Software Engineering for Distributed Processing Systems
- Software Technology
- VLSI Technology for the Space-Station Data Systems
- Technology Options for Space-Station Data Management
- Mass Memories for On-board Computer Systems
- Fault-Tolerant Design Principles

THERMAL CONTROL, RADIATION AND ECLSS
- Thermal Control for Space Station
- Two-Phase Heat-Transport Systems for Future Space Stations
- Advanced Two-Phase Systems
- Space-Platform Thermal Control
- Radiation Dosimetric Studies and Evaluation Problems
- European ECLSS Technology for Space Station

ATTITUDE AND ORBIT CONTROL
- Available Concepts (US Trends)
- Pointing Systems
- Attitude Control Systems Technology
- AOCS for Space Platforms
- AOCS for Columbus Elements
- AOCS Systems, Software and Hardware Elements
- Control of Space Stations
- Large Wheel Actuations
- Control of Large Flexible Spacecraft
- In-Orbit Performance Demonstration on Structural Elements
- Control of Flexible Structures

LOW-GRAVITY SCIENCE FACILITIES
- Space-Station Aspects of Low-Gravity Payloads
- Heating-Facility Evolution for Use on Space Station
- Materials Science on Space Station, a Quality in Modular Concept
- Fluid-Science Facilities for Space Station and Advanced Two-Phase Systems
- Life-Sciences Facilities for Space Station
- Life-Support Systems for Biological Facilities on Space Station
- Instrument-Development Requirements for Human Space Physiology
- Facilities for Man-Performance Optimisation
- Image Compression for Microgravity Payloads

CREW WORK STATIONS AND COMMUNICATION
- Cockpit Instrument Systems
- Aspects of the Man/Machine Interface
- Crew Communications for Columbus
- Technology Pointers Derived from Satellite System Experience
- Avionics Technologies
- Advanced Man/Machine Interface Options
- Information Archiving and Retrieval Technology

ELECTRICAL POWER SYSTEMS
- Main Issues at System Level
- Options and Development Effort
- Kinetic Storage by Flywheels
- Energy-Storage Wheels
- Power System for Space Station
- Space-Station Technology – Electrical Power
- System-Related Interference Simulation
- Advanced Power Distribution System
- Space-Station Power System
- Technology Requirements for Electrical Power System
- Design Considerations for Space-Station System
- Space – Therm. Dynamics – Power-System
- Large Solar Arrays
- Power Generation Using Storable Propellant
- Concentrator Arrays
- High-Power Arrays

STRUCTURES AND MATERIALS
- Key Structural Issues
- Structural Aspects of the Space Platform
- Pressurised-Structure Issues
- Impact Problems on Modules/Carbon-Fibre Reinforced Plastics Structures
- Spacelab Module Improvements
- Airlocks for Space Stations
- Key Material Issues

OPERATIONS TECHNOLOGIES
- General Operations-Technology Requirements of the Space Station
- In-Orbit Propulsion
  - ESA Propulsion Developments
  - Standardised Propulsion Module for Space Station
  - In-Orbit Propellant Management
  - Integrated Space-Station Propulsion Concepts
  - Space-Station Propulsion – The Magneto-Plasma-Dynamic Option

RENDEZVOUS AND DOCKING (RVD)
- RVD Techniques/Technologies/In-Orbit Demonstration
- Some Questions on RVD in Space-Station Context
- Optical Sensors for RVD and Docking. Technology Status and Requirements

ROBOTICS, TELE-MANIPULATION AND SERVICING
- Robotics, Tele-manipulation and Servicing
- Technology for Spacecraft Servicing
- Maintenance and Assembly Operations
- Aspects of Efficient Payload (incl. Technology Development) Operations
- In-Orbit Servicing, Operations, Technologies, In-Orbit Demonstration of RTS
- Human Operator Aspects in Rendezvous and Docking and Tele-manipulation
- Orbital-Systems Simulator

version of the Spacelab module. The platform concept (Fig. 2) also shows the resources module, containing the housekeeping functions, and a 'backbone' structure to which different payload carriers (Spacelab-derived pallets, Eureca, etc.) can be docked. The platform is expected to be serviced/resupplied by a servicing vehicle.

Table 3 highlights the high degree of dialogue in progress with potential users in the process of establishing the key input to the further definition study phase.

Figure 3 shows the NASA Reference Configuration for the Initial Operating Capability (IOC) in 1992, as contained in the NASA Request for Proposal for the US preliminary design and definition studies. The schedule for these studies, with emphasis on milestones pertaining to the international cooperation, is shown in Figure 4.

ESA's technology preparations for participation in a Space-Station programme go back several years, to when advanced space platform technologies were first selectively investigated and important

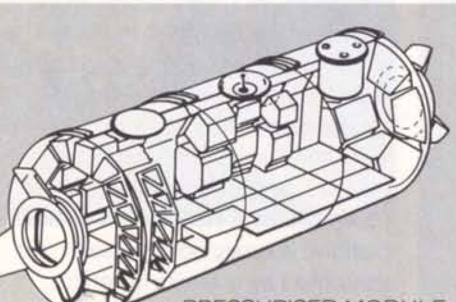
Table 2 – Candidate European elements for competitive definition studies (subject to the availability of funds)

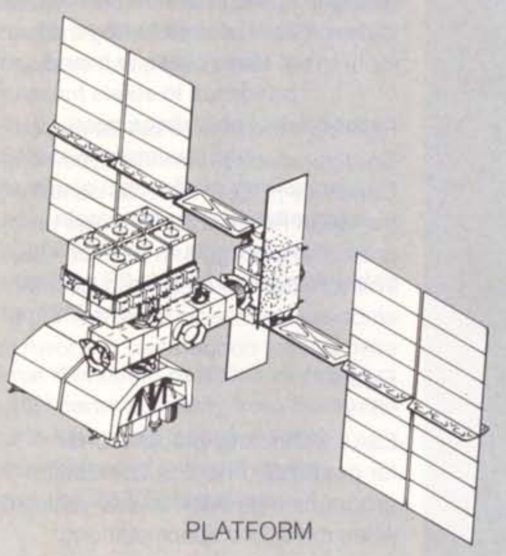
- Spacelab-derived modules
- Eureca-derived platform/free-flyer applications
- Spacelab-derived laboratory modules
- Spacelab-derived logistics modules
- Common Space-Station module based on Spacelab (thus also applicable as habitation module)
- Spacelab pallets and/or Eureca/SPAS carrier attached to Space Station
- Co-orbiting platforms derived from Eureca (possibility of use of platform resource module in support of resources supply for attached unmanned or manned element)
- Elements of the Space-Station infrastructure, e.g. a Tele-operated Service Vehicle (TSV)
- Other potential concepts, e.g. for a hangar/shelter for in-orbit maintenance
- Solar arrays, heat radiators and other Space-Station subelements

Figure 1 — Space-Station/Columbus pressurised-module concept

Figure 2 — Space-Station/Columbus platform concept

Figure 3 — NASA Reference Configuration for the Initial Operating Capability (IOC) for the preliminary design and definition phase. This Space Station 'Power Tower' concept is about 400 feet long and the solar arrays would generate about 75 kW of electrical power


1 PRESSURISED MODULE


2 PLATFORM

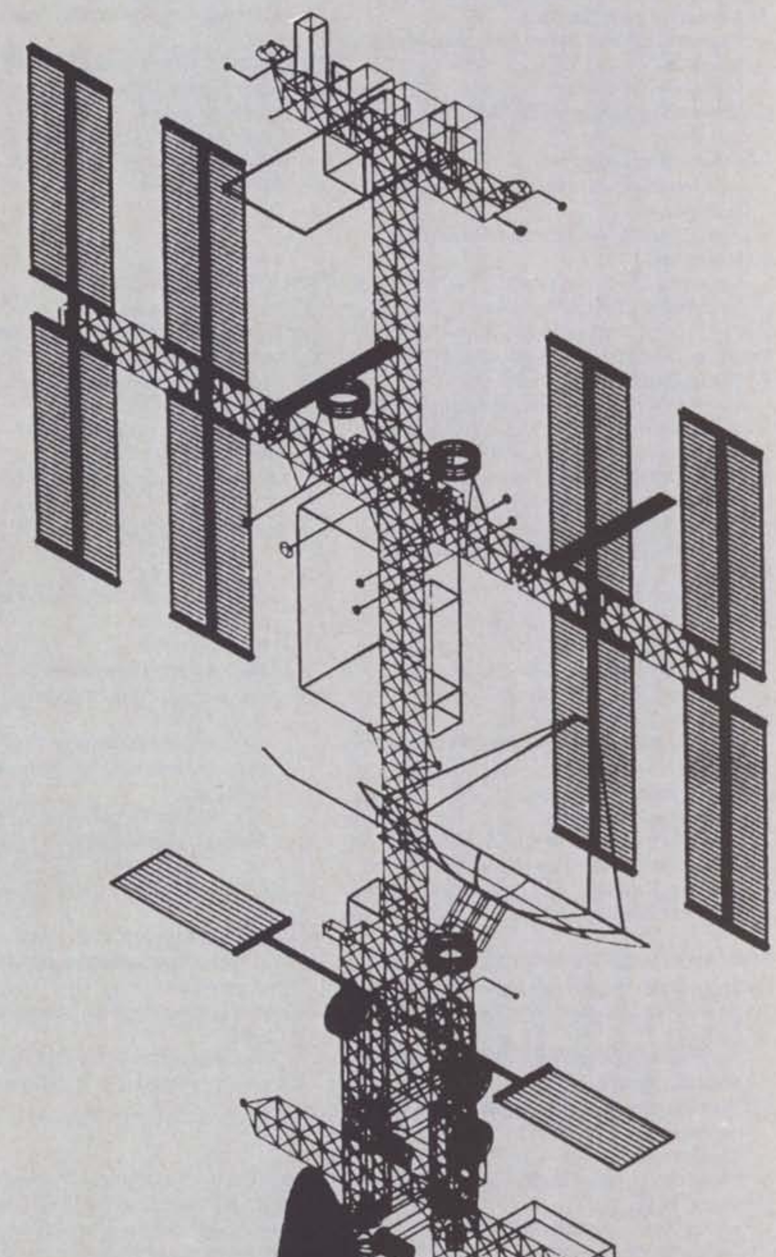

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Table 3 — Interactions with expected and potential users

- ESA has created a Space-Station User Panel (SSUP) to advise different user disciplines on the use of the Space Station infrastructure. Panel members report back regularly to ESA's user advisory groups
- Forum of contacted users enlarged within ESA's Space-Station Utilisation Study, conducted by DFVLR plus European industry. Workshops held regularly
- ESA participated in the NASA Mission Requirement Workshop (Woodshole, 24 September — 4 October 1984)
- Further Space-Station Utilisation Study to be initiated in the coming weeks (contract value: 500 kAU)
- Greatest interest so far shown by microgravity user community (life sciences, space processing), space sciences and earth observation. Efforts underway to promote interest on the part of non-aerospace industry in commercial applications

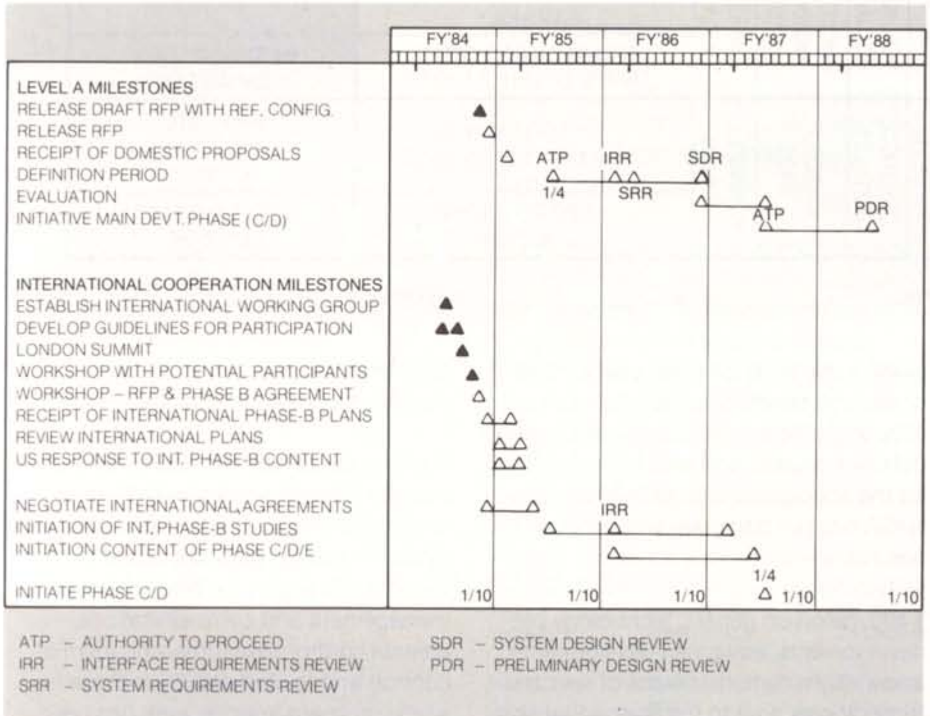
Figure 4 — Schedule for the Space-Station design and definition studies, highlighting the relevant milestones for international co-operation

Figure 5 — Rationale for ESA's technology development programme

Figure 6 — Scope of the present NASA Initial Operating Capability (IOC) concept

pre-developments were initiated. Emphasis presently centres around the development of the most critical technologies through a Preparatory Support Technology Programme (PSTP) and, should this new initiative be approved by ESA Member States, the later in-orbit demonstration/verification of some elements (Fig. 5).

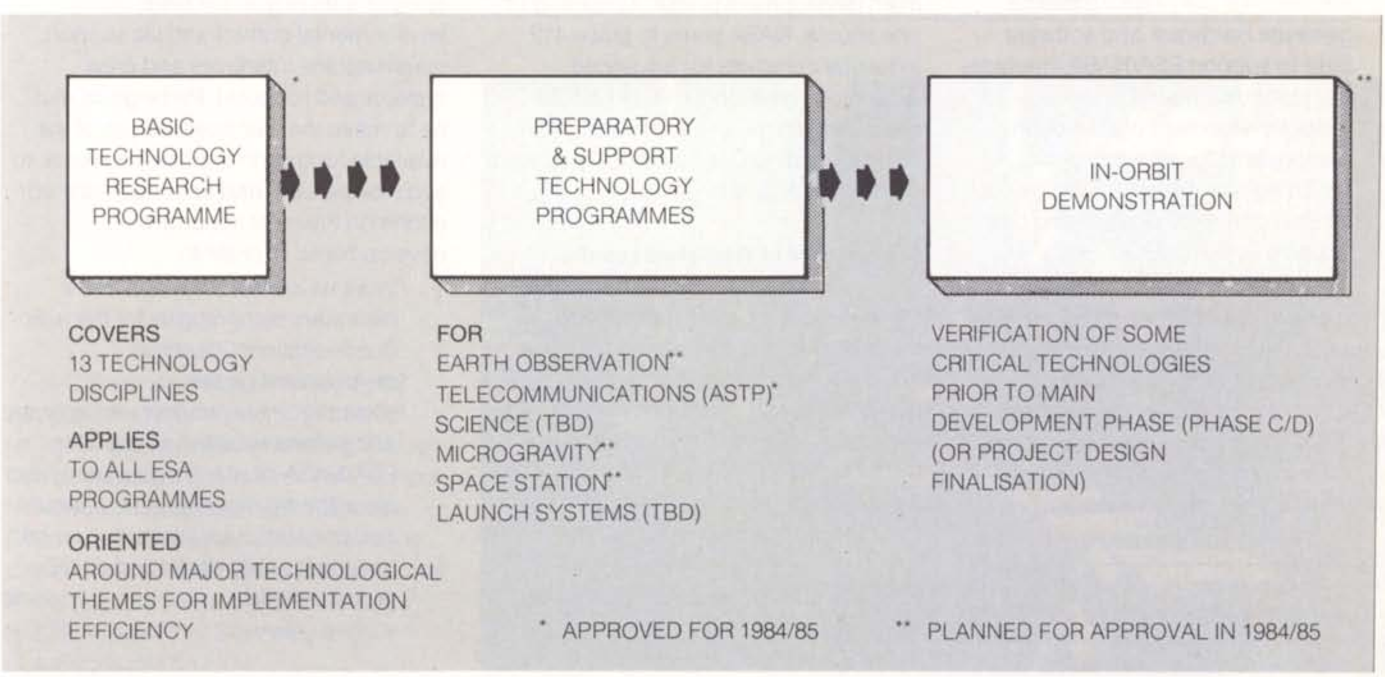
The twelve technology disciplines that have a bearing on the potential European Space-Station Programme elements, as defined in the draft declaration, are listed in Table 4. They address areas in which ESA or its Member States have developed a certain technological competence already, as well as some that are new for Europe, or for which Europe has relied in the past on procurements from the USA.

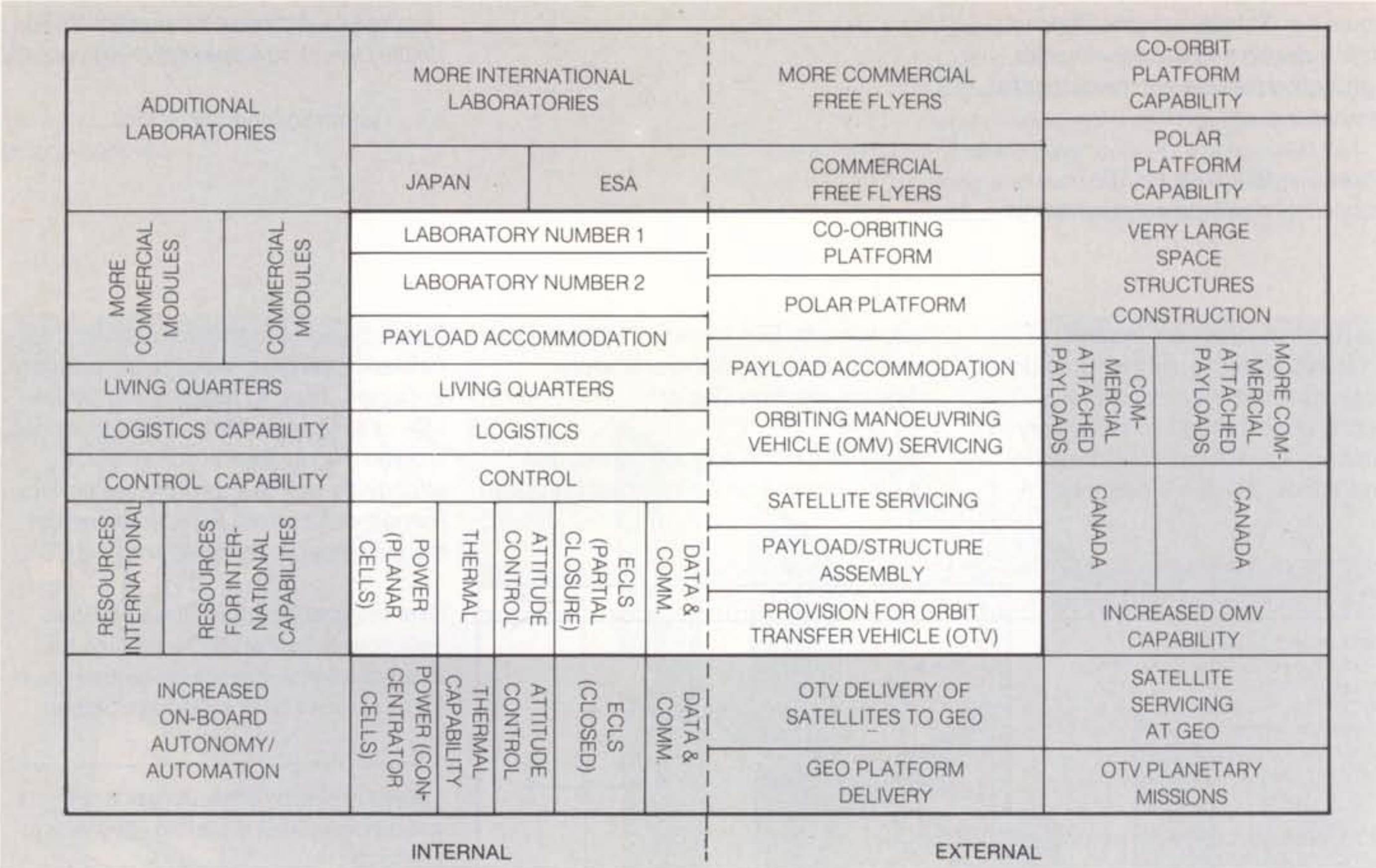


Over the past few years, the ESA Basic Technology Research Programme has initiated studies and pre-developments in many areas of Space Platform/Station

Table 4 — Technology domains relevant to European Space Station Programme elements

- Data Management and Information System
- Structures and Materials
- Thermal Control
- Environmental Control and Life-Support System
- Electrical Power Generation, Distribution and Storage
- Attitude and Orbit Control Systems
- Communications
- Crew Systems
- Robotics and Servicing
- In-Orbit Manoeuvring and Propulsion
- Rendezvous and Docking
- Payload Facilities





technology. The advanced development of critical Space-Station hardware and software items and the setting-up of simulators and test beds to verify complex functional relationships are principal aims of the PSTP, which will be closely phased with the corresponding system-definition effort.

Specific objectives of the PSTP are to:
- advance relevant technologies to allow selection of (identified) low-risk solutions for the project baseline
- generate hardware and software data to support ESA/NASA interface-standard discussions
- foster development of European components for all subsystems, including new areas for Europe such as Environmental Control and Life-Support Systems (ECLSS).

The scope of the PSTP as presently defined would involve the investment of 24 million Accounting Units at 1983/4 prices (1 AU = ±1 US $) in the period 1985/86, and would be implemented by the placing of between 40 and 50 contracts with European industry.

NASA's planning foresees a very active phase of technological development in support of the Space-Station design and definition studies and also in preparation for the anticipated later growth phase. NASA has put particular emphasis on the need to advance many areas of technology and could spend well over $400 million on generic technology pre-developments, advanced developments, and in-flight demonstrations of selected technologies prior to the Space-Station's main development phase. According to one source, NASA plans to place 412 industrial contracts for advanced technology developments in 1985/86 alone. The scope of the present NASA Initial Operating Capability (IOC) concept is shown in Figure 6.

Assessment of Workshop results*

The Workshop featured many detailed presentations on all of the relevant technologies and provided a forum for extensive discussions. It provided external participants with important insights into the status of Space Station/Columbus technology, the context in which it will be used, and the preparations under way for the developments in the 1985/1986 period.

In return, ESA received valuable inputs from the participants, which formed an important basis for the updating of the 1985 technology activities and the medium-term planning for 1986/1987.

The Workshop was considered by the majority to be very timely, with Europe needing to improve certain technologies for which there are already some foundations (e.g. in the fields of data management and communications, attitude control, structures, and thermal control) and to start actively in those in which no space specific work has been done to date (e.g. in the fields of environmental control and life support, man/machine interfaces and crew systems and robotics). Prime goals must be to make the best possible use of the available funding in the next two years, to avoid dispersion, and to concentrate our efforts on the most important developments, in order to:
- facilitate low-risk selection of the necessary technologies for the main Space-Station/Columbus development phase
- allow the timely provision of hardware and software data to support the ESA/NASA interface discussions, and
- allow the development of European components in areas where Europe has traditionally depended on US procurements.

* A copy of the Summary Report, including the conclusions from each of the working-group sessions, can be obtained from the author by written request or by telephone: (31) 1719-83656

In Brief

Four Space Agencies Meet on Halley's Comet Cooperation

Representatives of the space agencies of Europe, the Soviet Union, Japan and the United States met in Tallinn, USSR on 13-16 November 1984, to continue discussions on a broad range of cooperative activities being planned to investigate Halley's comet during its present apparition. This fourth annual meeting of the 'Inter-Agency Consultative Group (IACG)', held at the invitation of the Intercosmos Council of the USSR Academy of Sciences, was preceded by meetings of scientists and technical specialists. The prime goal of this cooperative effort is to maximise the overall scientific return from the studies being undertaken during this once-in-a-lifetime apparition of the famous comet (Halley reappears only once every 76 years).

Heading the delegations at the meeting were Prof. R.M. Bonnet of the European Space Agency (ESA), Academician R.Z. Sagdeev, of the Space Research Institute of Moscow, Prof. K. Hirao of the Institute of Space and Astronautical Science (ISAS) in Tokyo, and Dr. G.A. Briggs of the US National Aeronautics and Space Administration (NASA).

The most significant aspect of this year's IACG meeting was the signing by all four space agencies of a formal document specifying the technical details of the 'Pathfinder Concept'. This joint navigational effort takes advantage of the fact that the Russian Vega Spacecraft will encounter Halley about a week before the Giotto spacecraft. ESA intends to target its Giotto spacecraft nearer the comet nucleus than any of the other spacecraft, which will require high-precision targeting. Positional data on the comet nucleus from the Vega cameras will therefore be used to reduce greatly Giotto's targeting error. This will also allow Giotto to avoid the dust jets, those regions in the cometary atmosphere in which the Giotto spacecraft would be quickly destroyed. NASA will assist in the Pathfinder activity by providing tracking support for the Vega spacecraft from its 64 m Deep-Space Network antennas located in California, Australia and Spain.

No spacecraft has ever been sent to a comet before; now a total of five will encounter Halley's comet in March 1986; in order of launch date, they are:

Mission	Responsible agency	Launch date	Flyby date	Flyby distance
Vega-1	Intercosmos	15 December 1984	6 March 1986	10 000 km
Vega-2	Intercosmos	21 December 1984	9 March 1986	10 000 km or closer
MS-T5	ISAS	8 January 1985	11 March 1986	7 million km
Giotto	ESA	2 July 1985	13 March 1986	500 km
Planet-A	ISAS	14 August 1985	8 March 1986	200 000 km

The IACG meeting was attended by 38 delegation members and a number of technical experts. Shown from right to left Dr. R.L. Newburn (IHW), Prof. R.M. Bonnet (ESA HQ), Academician R.Z. Sagdeev (IKI), Mr. I. Toome (Vice Chairman of the Council of Ministers of the Estonian Soviet Republic), Academician V.A. Kotelnikov (USSR Academy of Sciences) and Dr. G.A. Briggs (NASA HQ).

In addition, NASA's ICE (International Cometary Explorer) spacecraft, formerly known as ISEE-3, was redirected in December 1983 to encounter comet Giacobini-Zinner on 11 September 1985 and to fly close to Halley's comet in March 1986. Moreover, in March 1986 NASA will put the Astro payload, consisting of three highly sensitive ultraviolet telescopes complemented by two wide-field telescopes, into low Earth orbit aboard the Space Shuttle.

A large variety of in-situ measurements will be carried out by the scientific instruments onboard the various spacecraft. They include mass-spectrometers to measure the composition of the cometary atmosphere and cameras to detect and image the comet nucleus (the small body in the centre of a comet from which all activity emanates). The various missions to Halley's comet complement each other in instrumentation and flyby distances, they extend the total time of in-situ observations in the cometary environment, and they allow simultaneous observations from several spacecraft.

The International Halley Watch (IHW), an international network involving over 900 professional astronomers from 50 countries and several thousand amateur observers, will coordinate and standardise all ground-based observations and archive all Halley data (spacecraft and ground-based) for present and future generations of scientists. The IHW was represented at the Tallinn meeting by its two leaders, Dr. R.L. Newburn of NASA's Jet Propulsion Laboratory, Pasadena, California and Prof. J. Rahe of the Dr.-Remeis Sternwarte, Bamberg, Germany, and several Discipline Specialists.

The Pathfinder Technical Steering Committee after the signing of the Pathfinder Technical Project Document. From right to left, Mr. D. Dale (ESA/ESTEC), Dr. C.T. Force (NASA HQ), Dr. J.F. Jordan (NASA/JPL), Mr. J. Jensen (ESA/ESOC), Academician R.Z. Sagdeev (IKI), and Dr. G.S. Balayan (Intercosmos).

Turkey to Participate in Meteosat Operational Programme

The accompanying photograph shows the signature in Paris of an Arrangement between the Government of the Republic of Turkey and ESA covering Turkey's participation in the Meteosat Operational Programme. This Programme is being carried out within the framework of the ESA Convention, pending the entry into force of the EUMETSAT Convention, scheduled for early 1986.

The photograph shows, from left to right, Dr. W. Brado, Head of ESA's Cabinet, Prof. R. Lüst, ESA's Director General, Mr. Ahyan, Second Secretary at the Turkish Embassy in Paris, His Excellency E. Bulak, Ambassador of the Republic of Turkey in Paris, and W. Thiebalt of ESA's Legal Affairs Department.

ESA's Former Director General Receives Légion d'Honneur

On 23 October 1984, Mr. Erik Quistgaard, Director General of the European Space Agency from May 1980 until August 1984, was made an Officer of the 'Légion d'Honneur' by Prof. Hubert Curien, French Minister for Research and Technology and former Chairman of the ESA Council, in recognition of services rendered in promoting European space research and technology during his term of office.

The accompanying photograph taken at the ceremony shows (from left to right), Prof. Reimar Lüst, ESA's new Director General, Prof. Hubert Curien, and Mr. and Mrs. Quistgaard.

Giotto Press Conference in Toulouse

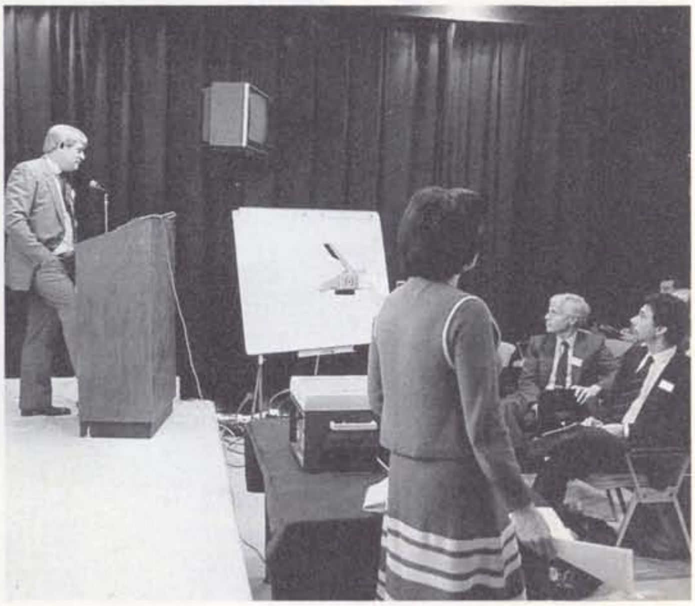
In preparation for the forthcoming Giotto mission, ESA and the Star Consortium, with British Aerospace (BAe) as Prime Contractor, jointly invited the press to view the Giotto flight spacecraft in Toulouse on 22 November 1984, after successful completion of the solar-simulation and thermal-vacuum tests. The Press Conference was attended by some forty journalists from eight countries.

Presentations were made by Prof. R.M. Bonnet, Director of ESA's Scientific Programme, Dr. R. Reinhard, Giotto Project Scientist, and Mr. D. Dale, Giotto Project Manager. The first of the accompanying photographs shows Prof. Bonnet during his introductory talk. The second shows D. Dale responding to questions from the press, with Prof. Bonnet (left) and J.M. Lenorovits (Aviation Week and Space Technology) seated and, with her back to the camera, Mme J. Gomerieux (ESA Press and Publication Section), who arranged the event.

The Press Conference was followed by a detailed presentation on the Giotto spacecraft by Mr. D. Link, BAe's Giotto Project Manager.

The remainder of the environmental test programme (acoustic, vibration) has been completed in the meantime, and the spacecraft is now (January 1985) in the final phases of the test programme. Delivery to ESA is scheduled for 1 March and preparations for shipment to Kourou in French Guiana will start in mid-April.

After Giotto's arrival in Kourou on 25 April, there will be an eight-week launch campaign. Mission constraints result in the Ariane-1 launch having to take place between 2 July and 12 August 1985. Given the uniqueness of this window (due to the comet's 76-year periodicity), every effort will be made to launch immediately the window opens on 2 July.



Europe's First Retrievable Carrier Given Go-Ahead

After a three-year study effort carried out in industry and in-house in ESA, the Participating States in the Eureca Programme – Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland and the United Kingdom – have now given ESA the green light to proceed with the development of Europe's first retrievable carrier.

Eureca is not only a logical follow-on to ESA's Spacelab Programme, it is also an important step in the direction of a future European long-term programme of Space Transportation Systems, providing, as it does, the required experience in the development, utilisation and operation of unmanned, automated platforms in low Earth orbit.

Eureca is scheduled to be launched from the Space Shuttle in March 1988. After deployment by the Shuttle at an altitude of 296 km and initial activation of the subsystems, which includes deployment of the large solar arrays, the platform's own propulsion system will take it into its operational orbit (inclination 28.5°) some 500 kilometres above the Earth. Once it has reached this orbit, subsystem activation and checkout will be completed and the payload will be switched on. Eureca operations will be under the responsibility of the European Space Operations Centre (ESOC).

Eureca will stay in orbit for a nominal period of six to nine months, depending on the exact timing of its retrieval by the Shuttle. On completion of its mission, the platform will return under its own power to an orbit 315 km above the Earth for retrieval by the Shuttle. The Shuttle's remote manipulator arm will collect the platform and place it in the cargo bay, ready for its return to Earth. It will then be transported from the United States back to its home base, Europe, for refurbishment prior to its next mission.

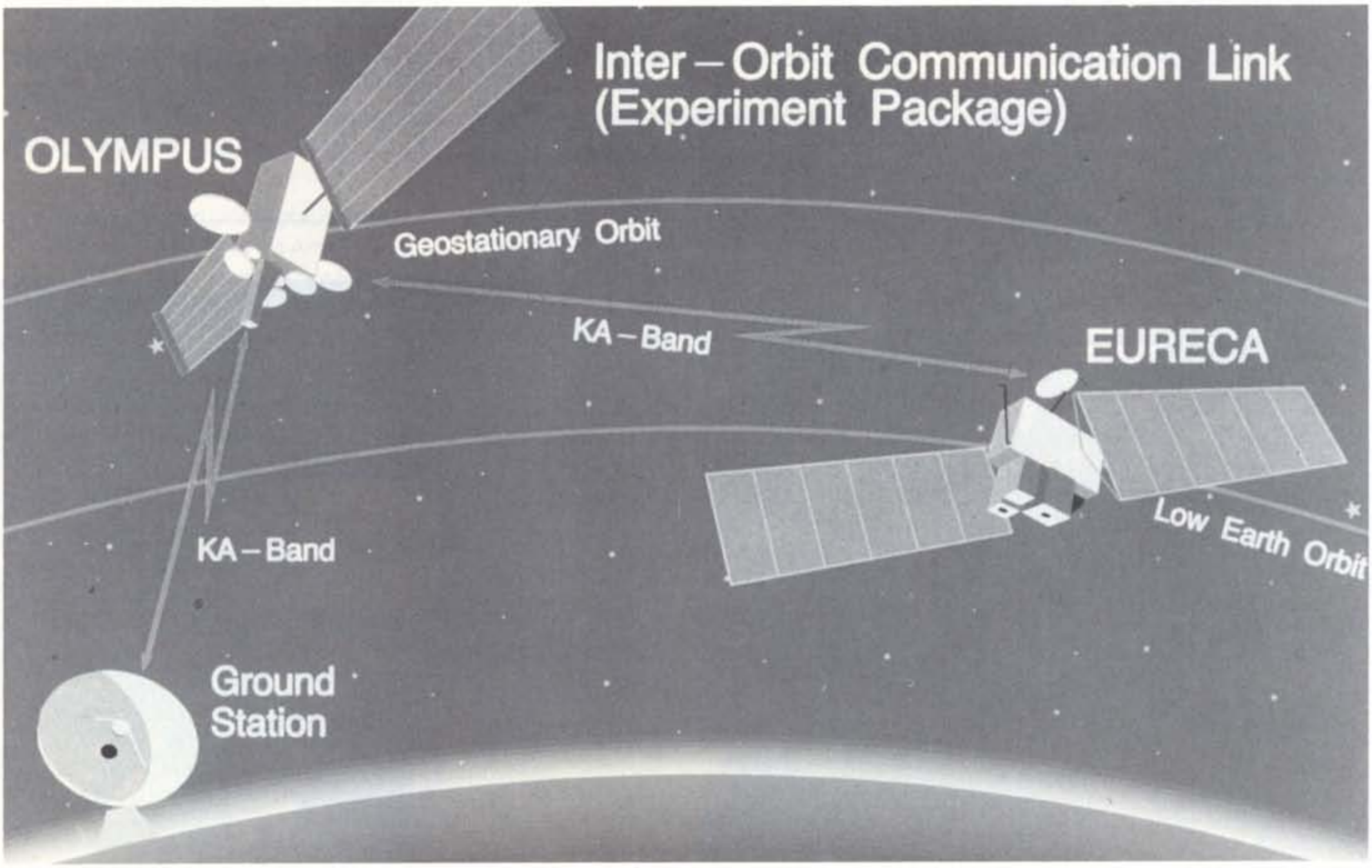
The first Eureca payload consists largely of a so-called 'core payload', which constitutes about two thirds of the total 1000 kg payload mass available for the first mission. This core payload, developed and funded by ESA, consists of five facilities designed specifically for materials and life-sciences experiments in the microgravity environment.

Another important aspect of the first mission is the inclusion of an Inter-Orbit Communications (IOC) package for a data-transmission experiment, the forerunner of a future European Data Relay System. This experiment will establish a data link between Eureca and the ground via the 20/30 GHz payload on-board ESA's geostationary Olympus communications spacecraft.

IOC definition studies have been executed as part of ESA's future Telecommunications Preparatory Programme, and should be completed by the end of April 1985. The development work proper will be carried out within the framework of an optional communications programme, which is expected to be approved during the coming months.

The other Eureca experiments are being provided and funded by States participating in the Eureca Programme. They include two additional microgravity facilities – one German and one Italian – and a number of scientific and technological experiments.

The cost envelope for the Eureca Programme is 206 Million Accounting Units [1 AU = $ US 0.8 (1985 rate)] at mid-1983 price levels. 116.5 MAU of this has been earmarked for the industrial development phase (Phase-C/D). An additional 25.5 MAU has been reserved for the development of the core payload.



20-Year Service Awards for ESA Staff Members

At the end of ESA's celebratory 20th year, the Director General, Prof. R. Lüst, invited all those staff members, who, at 31 December 1984, would have served with the Agency for 20 years or longer, to attend a ceremony at ESA Headquarters in Paris on 14 December 1984.

At the ceremony, presided over by Prof. P. Auger, the first Director General of ESRO, Prof. Lüst presented each of these staff members with a long-service award, 'in recognition of their valuable contribution and in special appreciation of professional dedication'. ESA's Director of Administration, Mr. G. van Reeth, then announced that they would receive an additional five days annual leave. Prof. Lüst then invited the long-serving staff and their spouses to join him for cocktails, followed by a dinner aboard the boat/restaurant Iena Tour Eiffel.

The accompanying photograph shows Prof. Lüst presenting the long-service award to Miss E. Haug, ESA's longest-serving staff member.

ESA Staff Member Receives NASA Award

On 31 October, during a visit to ESTEC in Noordwijk, Dr. Milton M. Silveira, NASA Chief Engineer, presented Mr. Heinz Stoewer with the 'NASA Public Service Award'.

The Award, signed by Mr. James M. Beggs, the NASA Administrator, was presented:

'In recognition of his leadership skills in assembling an outstanding European Spacelab Team, guiding Spacelab through the early, difficult, formative years, and building the management base which helped make the success of the first Spacelab flight possible'.

The accompanying photograph shows, from left to right, Mr. Heinz Stoewer, Dr. Milton Silveira and Prof. Massimo Trella, ESA's Technical Director and Director of ESTEC.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 8, No. 4:

DEVELOPMENT AND APPLICATION OF NEW TECHNOLOGIES IN ESA'S OLYMPUS PROGRAMME
BONHOMME R & STEELS R

SPACECRAFT SYSTEMS ENGINEERING AND GEOMETRY MODELLING: THE ESABASE – MATVIEW APPROACH
FERRANTE J G ET AL

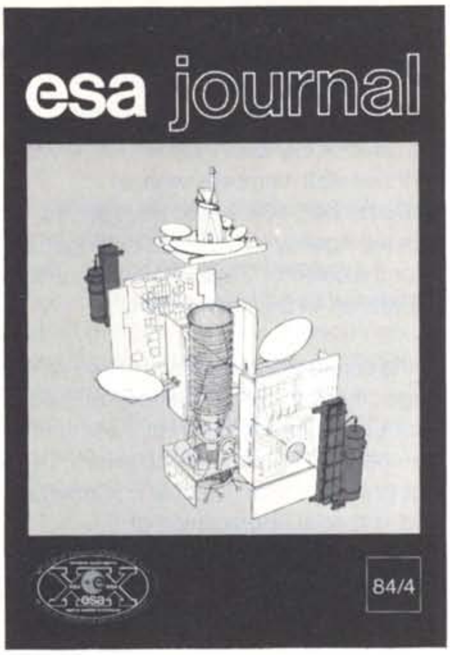
APPLICATION OF COMPONENT-MODE SYNTHESIS TO THE STRUCTURE OF THE INDIAN REMOTE-SENSING SATELLITE
PRAKASH B G & PRABHU M S S

FINITE-THRUST TRANSFERS
FLURY W

AN AUTOMATIC HIGH-RESOLUTION PICTURE TRANSMISSION RECEIVING STATION
BRUSH R J H & BAYLIS P E

LOW-COST STANDARDISED CURRENT-CONTROL MODULATOR FOR HIGH-POWER SWITCHING CONVERTERS
CAPEL A ET AL

ANALYTICAL INVESTIGATION OF EDGE-DELAMINATED COMPOSITES
DIEKER S, PAUL W H & LO H K



Special Publications

ESA SP-203 // 100 PAGES
THE GRAVITY RELEVANCE IN BONE MINERALISATION PROCESSES, PROC WORKSHOP HELD IN BRUSSELS, BELGIUM, 18-20 JANUARY 1984 (JULY 1984)
LONGDON N & MELITA O (EDS)

ESA SP-207 // 340 PAGES
PLASMA ASTROPHYSICS, PROC INTERNATIONAL SCHOOL & WORKSHOP, HELD IN VARENNA, ITALY, 28 AUGUST - 7 SEPTEMBER 1984 (NOVEMBER 1984)
GUYENNE T D & HUNT J J (EDS)

ESA SP-212 // 300 PAGES
LIFE SCIENCES IN SPACE, PROC 2ND EUROPEAN SYMPOSIUM HELD AT PORZ WAHN, GERMANY, 4-7 JUNE 1984 (AUGUST 1984)
LONGDON N & MELITA O (EDS)

ESA SP-214 // 375 PAGES
INTEGRATIVE APPROACHES IN REMOTE SENSING, PROC EARSEL/ESA SYMPOSIUM HELD IN GUILDFORD, SURREY, 8-11 APRIL 1984 (AUGUST 1984)
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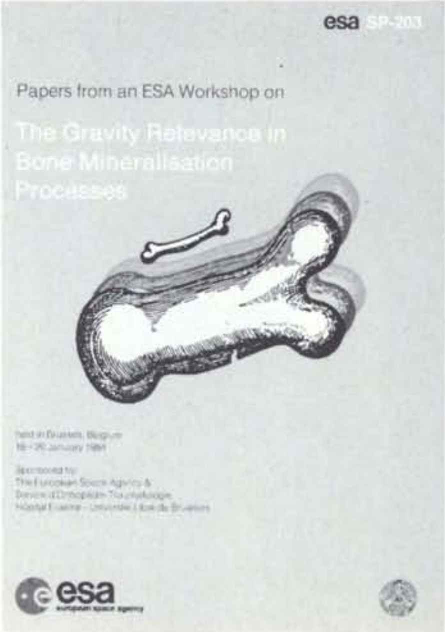

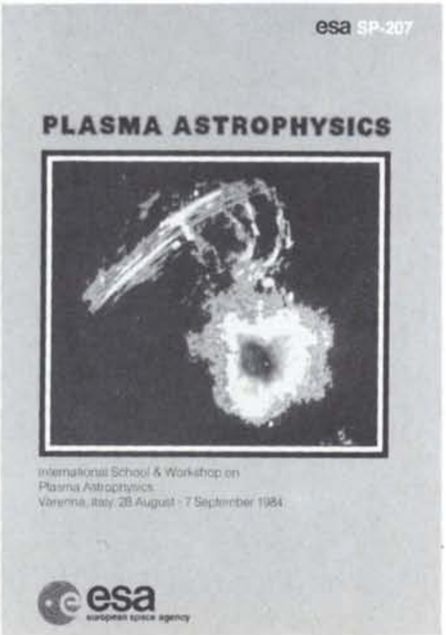

ESA SP-215 // 2 VOLS, 902 PAGES
REMOTE SENSING – FROM RESEARCH TO OPERATIONAL USE (IGARSS '84), PROC 1984 INTERNATIONAL GEOSCIENCE & REMOTE SENSING SYMPOSIUM, STRASBOURG, FRANCE, 27-30 AUGUST 1984 (AUGUST 1984)
GUYENNE T D & HUNT J J (EDS)

ESA SP-217 // 760 PAGES
ACHIEVEMENTS OF THE INTERNATIONAL MAGNETOSPHERIC STUDY (IMS), PROC INTERNATIONAL SYMPOSIUM HELD IN GRAZ, AUSTRIA, 26-28 JUNE 1984 (SEPTEMBER 1984)
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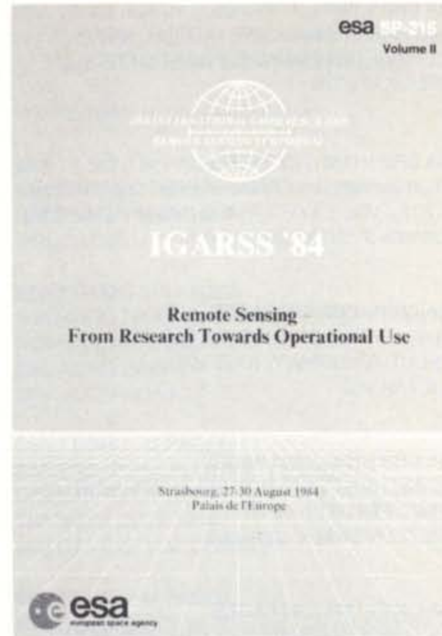

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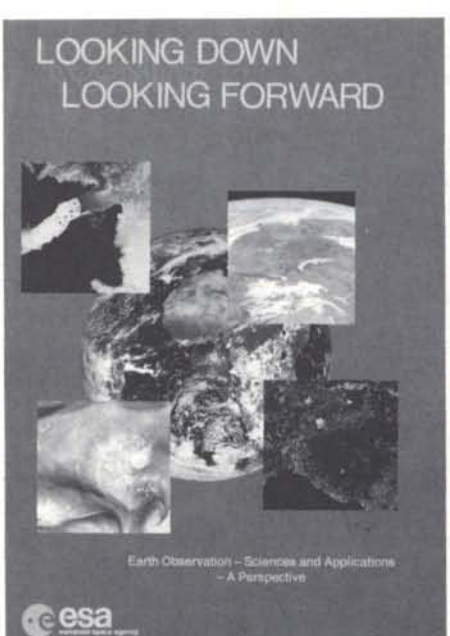

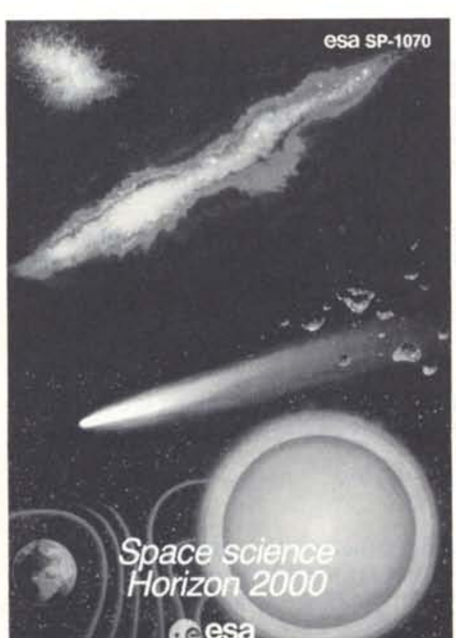

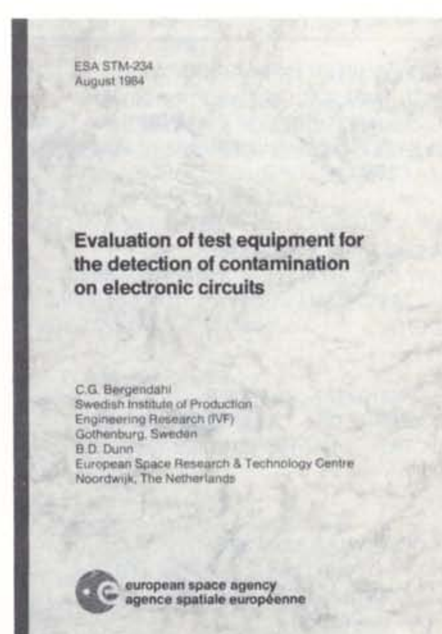

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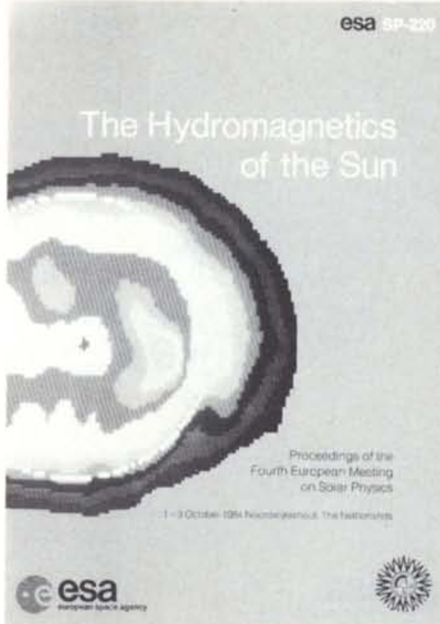

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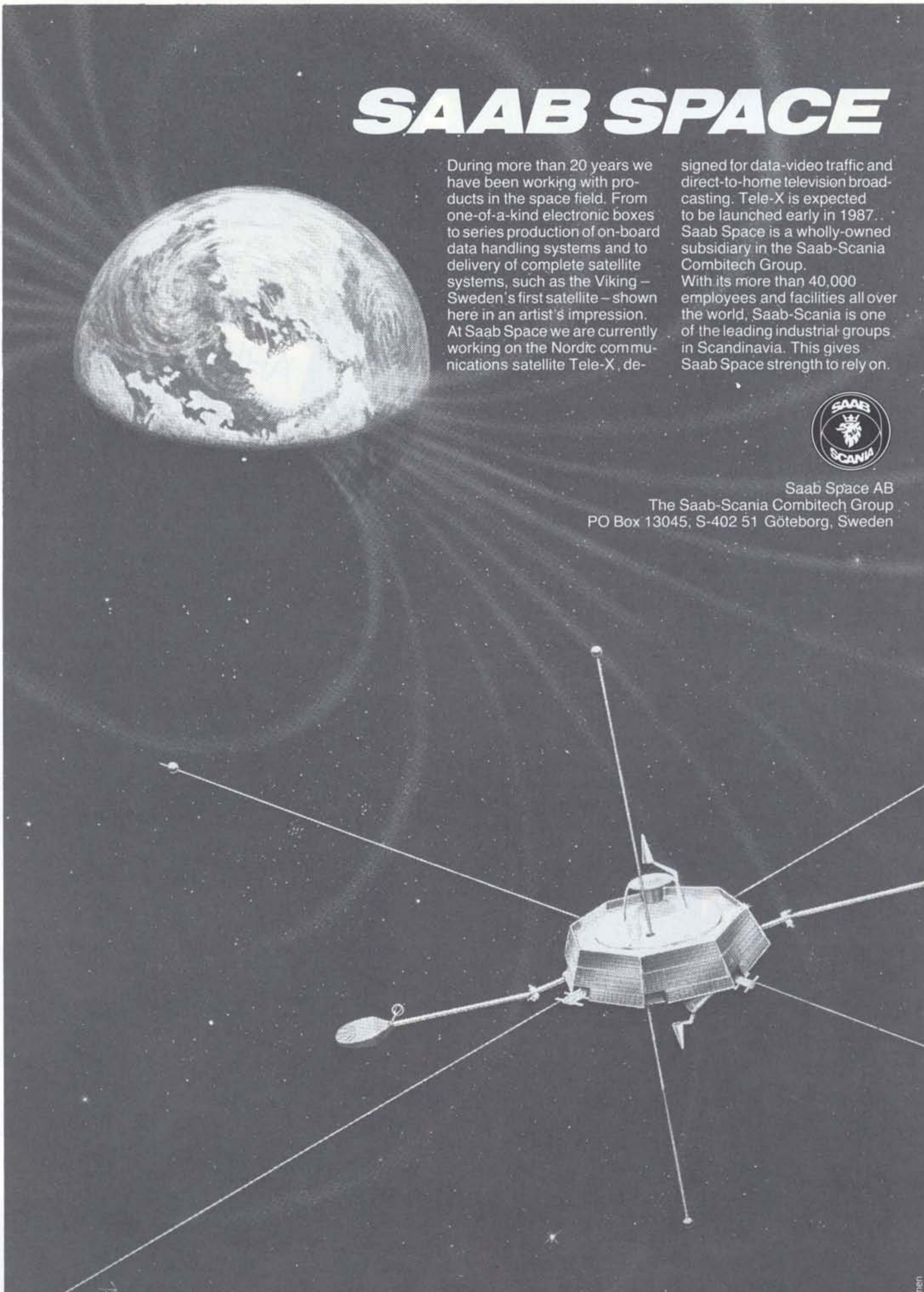
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At Saab Space we are currently working on the Nordic communications satellite Tele-X, designed for data-video traffic and direct-to-home television broadcasting. Tele-X is expected to be launched early in 1987.
Saab Space is a wholly-owned subsidiary in the Saab-Scania Combitech Group.
With its more than 40,000 employees and facilities all over the world, Saab-Scania is one of the leading industrial groups in Scandinavia. This gives Saab Space strength to rely on.
SAAB
SCANIA
Saab Space AB
The Saab-Scania Combitech Group
PO Box 13045, S-402 51 Göteborg, Sweden
Artmen

M.A.N. IN SPACE

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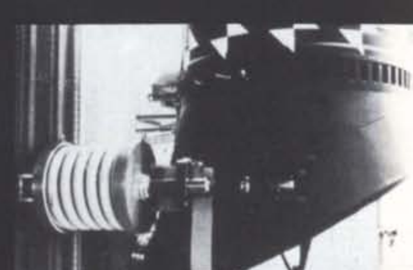

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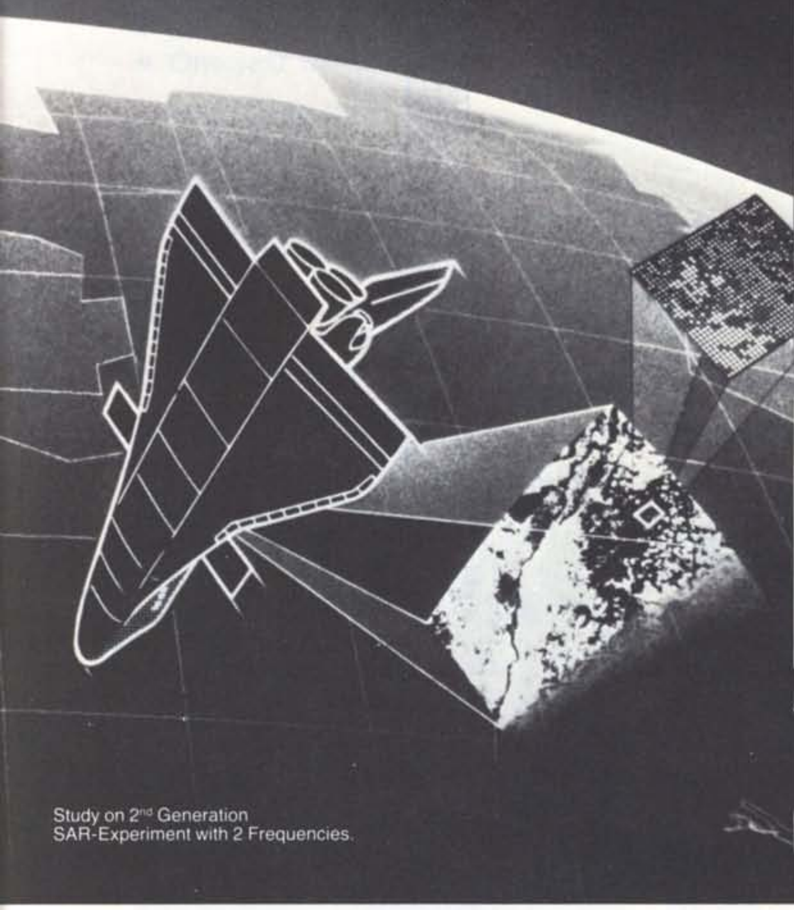

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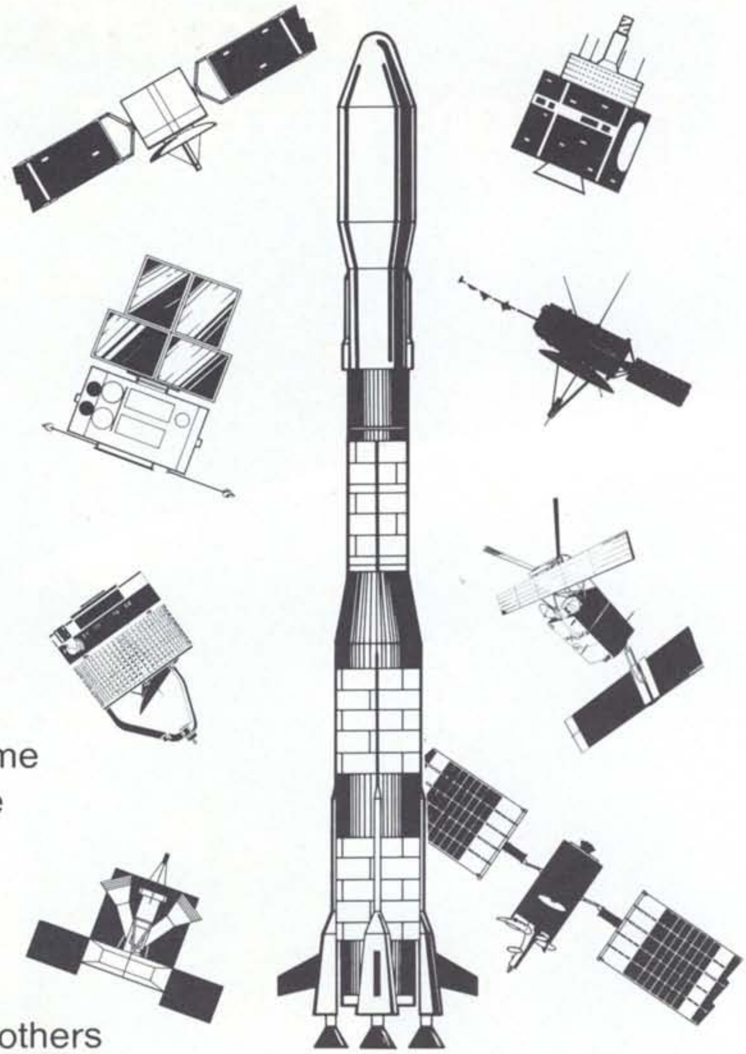

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- Low noise
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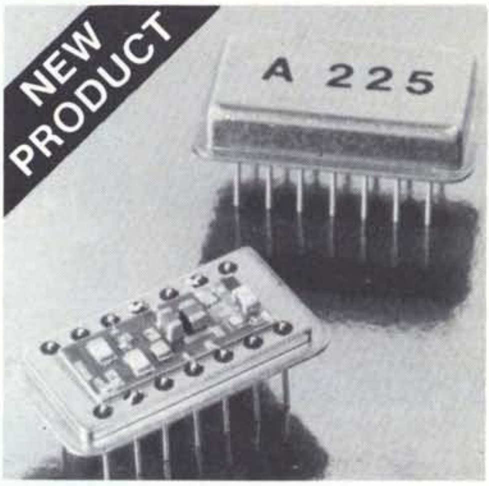

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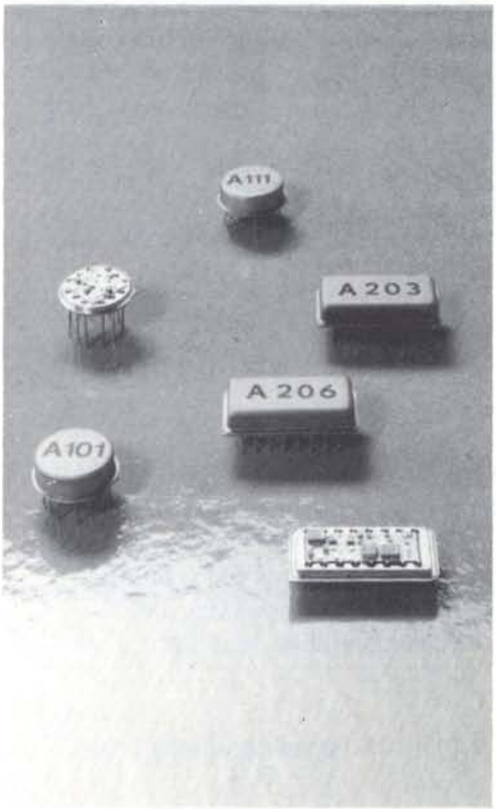

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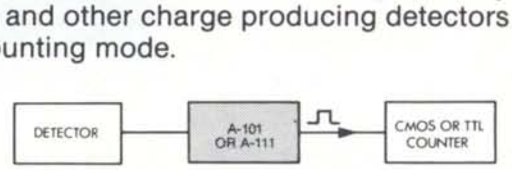

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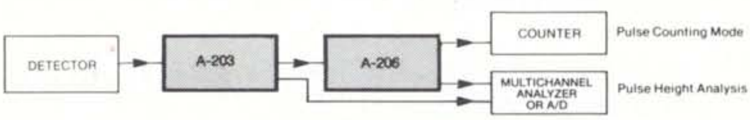

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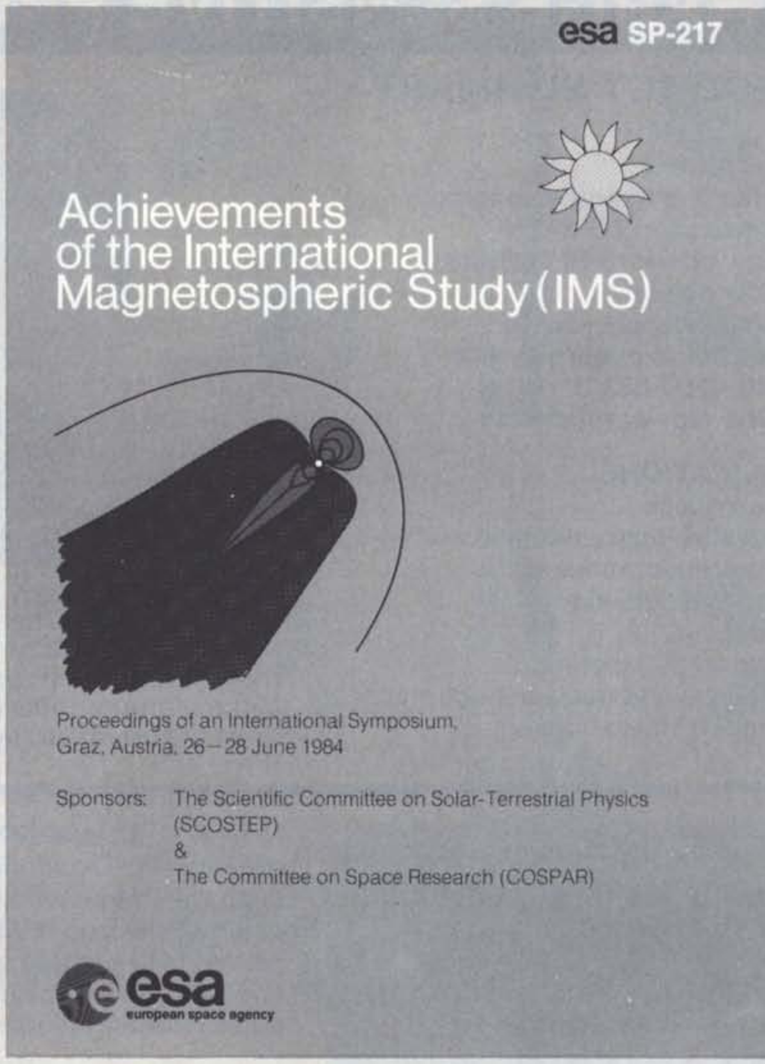

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