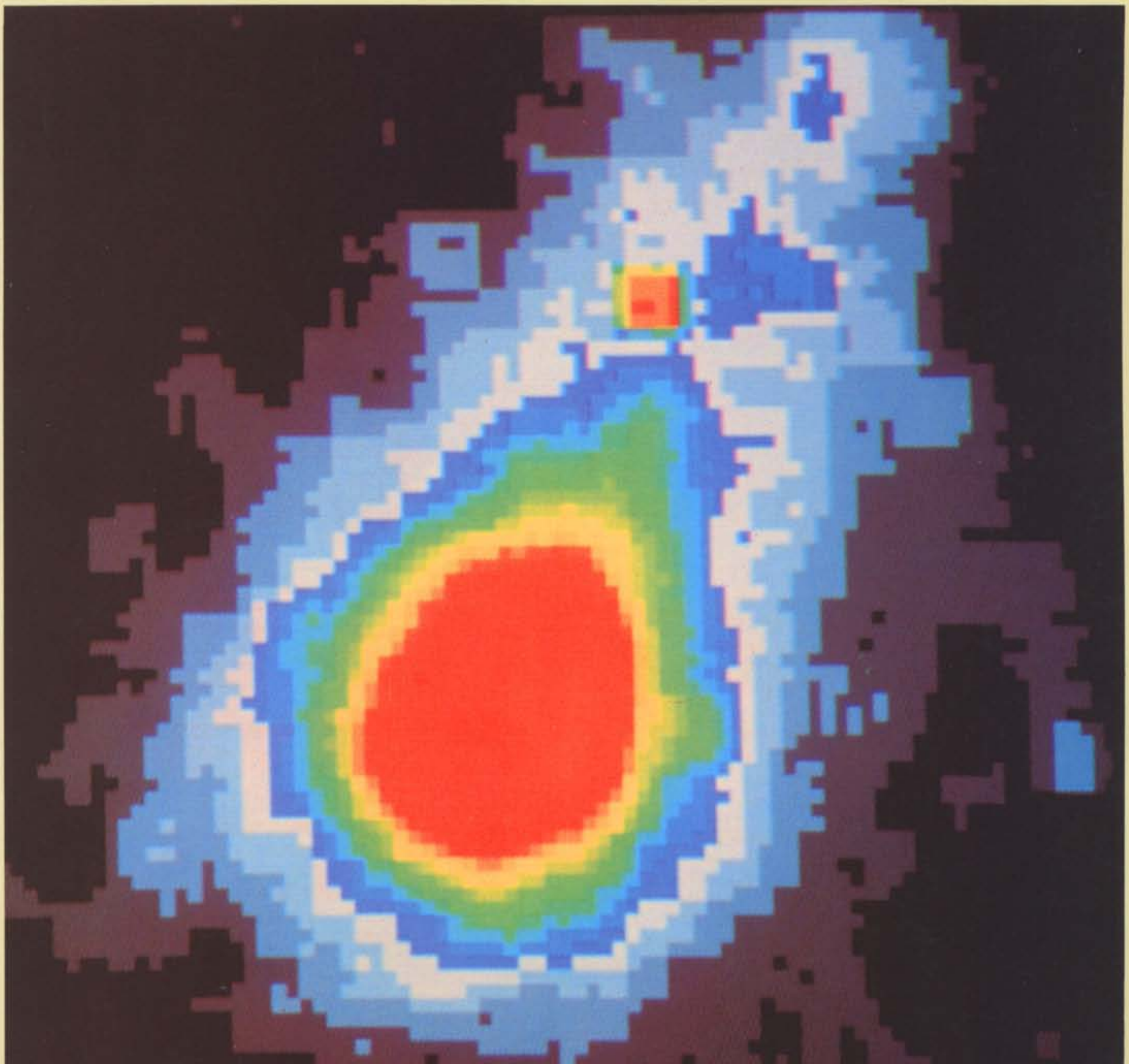
esa bulletin

number 23 august 1980



science programme issue

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, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Ireland has signed the ESA Convention and will become a Member State upon its ratification. Austria, Canada and Norway have been granted Observer status.

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of the Spacelab Programme; the Technical Director and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

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

Director General: Mr E. Quistgaard.

agence spatiale européenne

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

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

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

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

Le Directoire de l'Agence est composé du Directeur général, du Directeur des Programmes futurs et des Plans, du Directeur de l'Administration, du Directeur des Programmes scientifiques, du Directeur des Programmes d'Applications, du Directeur du Programme Spacelab, du Directeur technique et du Directeur de l'ESOC.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

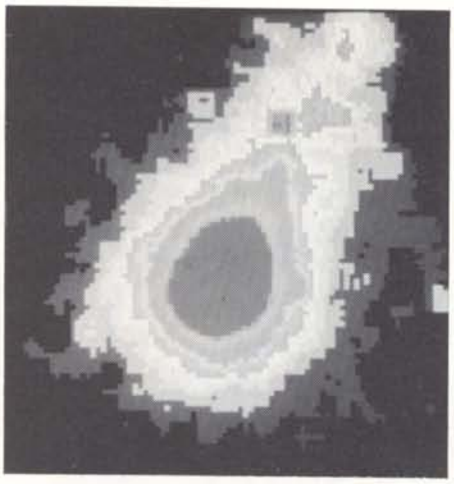
Président du Conseil: M.J. Stiernstedt (Suède).

Directeur général: M. E. Quistgaard.

esa bulletin

no. 23, august 1980

contents/sommaire



Front cover: IUE field-camera image (discrete sampling) of Comet Bradfield, with the cometary tail extending to the top right (field of view 15 arc minutes square).

Back cover: Final fitting of the thermal blankets to the engineering-model of the Exosat scientific satellite, at MBB, Munich.

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

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Editorial Assistants
Jacqui Mort, Gabrielle Lévy

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

Printed in The Netherlands, by ESTEC Reproduction Services 801040
ISSN 0376-4265

european space agency
agence spatiale européenne

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


ariane
and
aerospatiale
we put all the
pieces together
ARIANE is built in Europe by some fifty firms in 10 countries*. One industrial company puts it all together. One firm checks out all the interfaces between the numerous subsystems and components.
It's AEROSPATIALE, France.
Studies, Technical management, Production, Integration, Testing.
* ESA sponsored program, Prime contractor, CNES.
Société Nationale Industrielle
aerospatiale
DIVISION SYSTEMES BALISTIQUES ET SPATIAUX
B.P. 96 - 78130 Les Mureaux - France


ACo - TT135 - 172227 E

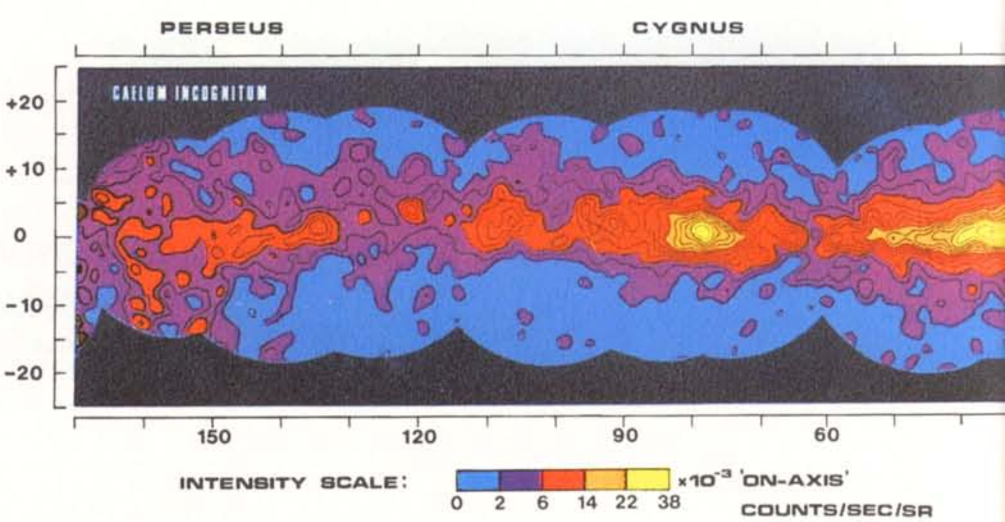
Foreword

E.A. Trendelenburg, Director of Scientific Programmes, ESA, Paris

The ESA scientific programme is one of the essential pillars of the Agency. Although in terms of current expenditure the scientific programme accounts for only about 15% of the Agency's budget, participation in this so-called 'mandatory' programme is one of the basic obligations of membership which Member States have formally included in the ESA Convention. Apart from this formal acknowledgment of the importance of the Science Programme, it is widely recognised that the pioneering success of the early scientific ventures (then under the aegis of ESRO) contributed greatly to the establishment of technical competence in space engineering in Europe, which in turn gave Europe the necessary confidence to start up the 'applications' and 'transportation-system' programmes that now account for the bulk of the Agency's expenditure.

I have been closely associated with the scientific programme since its early days, and I have shared with the scientific community the moments of triumph and the times of frustration. Above all, however, I have been aware of the sheer hard work that has gone into making a success of the various projects. This effort has come not only from scientific institutes throughout Europe, but also from industry and from within ESA. The resulting pride in what ESA has achieved with its very limited resources is evidenced in the articles that follow.

For those readers who are not already familiar with the scientific programme, let me put these articles into perspective. There is a certain current of opinion that space science represents an extravagant waste of tax-payers' money, and we have therefore included an article by Prof. Elliot



Presentation in galactic coordinates of the structure of the galactic gamma-ray emission as measured by Cos-B. The map indicates the numbers of gamma-ray events that would have been recorded from any direction if the experiment had been pointed there (so-called 'on- axis counts') entitled 'Why Bother with Basic Research?' Taking recent developments in space astronomy as a concrete example, he argues convincingly that basic research is an important human activity and that the wealthy nations of the world – which certainly include ESA Member States – ought to pursue a vigorous programme of pure research, including those areas, such as space science, which are relatively expensive.

Recent ESA missions (some in collaboration with other agencies) have been devoted to space astronomy in the gamma-ray and ultraviolet portions of the spectrum (Cos-B and IUE) and also to the sun-earth relationships (Geos and ISEE). Dr. Page's first article 'Recent Scientific Achievements of ESA Spacecraft' summarises the advances in scientific knowledge that have been made possible by means of these satellites. This article draws on results obtained and interpretations made by all the scientists involved in the missions. Dr. Page's second article is narrower in scope: it describes recent scientific work performed in ESA's Space Science Department (SSD). This Department is effectively a small scientific institute co-located with the Agency's technical establishment, ESTEC in Noordwijk (Netherlands). The article published here deals only with the purely scientific activities of SSD although the Department also plays an important role in coordinating the work of the experimenters during the development and exploitation of the satellite projects, and in representing the interests of the experimenters on a day-to-day basis vis-à-vis the Project Managers.

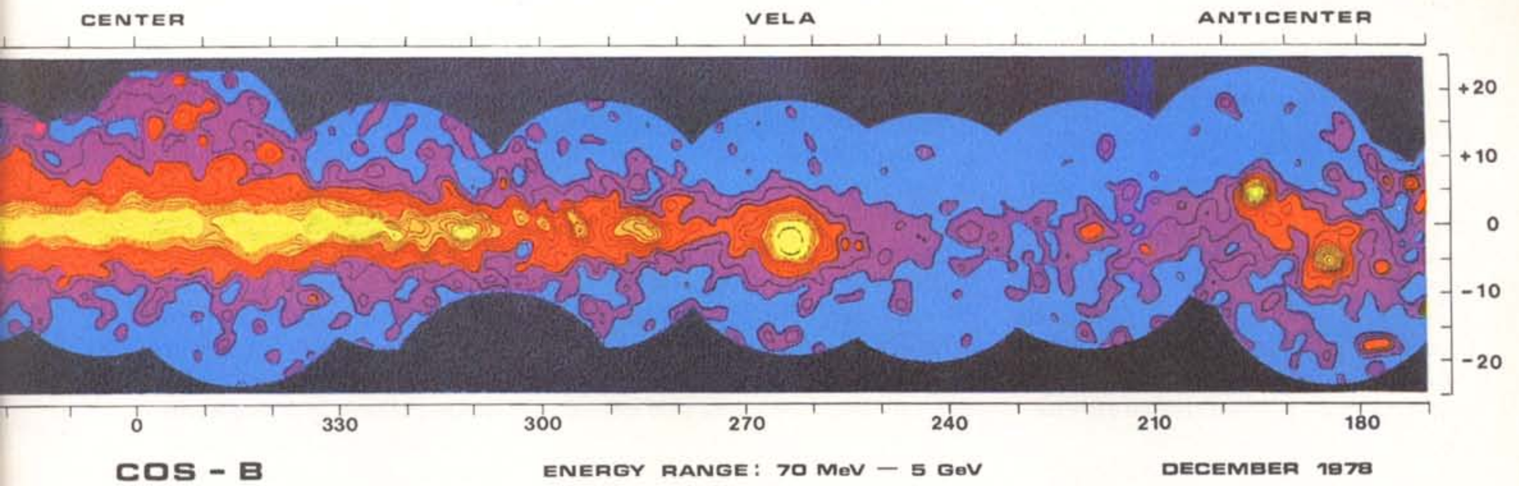
Mr. Delahais' article 'Scientific Projects under Development' outlines the scientific aims of the five scientific missions currently under development; namely the Exosat satellite, the Space Sled, the International Solar-Polar Mission (ISPM), the Space Telescope, and the Hipparcos satellite.

The article by Dr. Manno titled 'ESA's Science Programme: The Present Situation and Future Perspectives' strikes a note of alarm. We know that a number of space-science disciplines have not been served by ESA in the past and that the corresponding scientific communities are, quite naturally, clambering at the door. We know also that, as a result of progress made through two decades of space research, significant progress in the future will tend to require frequently large and complex missions that will be more expensive than the Agency is currently able to undertake. It is difficult to imagine how, with the present small and fixed budget, ESA can hope to keep European scientists at the forefront in their fields.

A pessimist would look at the political framework within which ESA operates – namely as an intergovernmental agency governed by eleven sovereign states – and would predict that it can move only at the speed of the slowest. However, the past achievements of the ESA Science Programme make me optimistic that we can combine the dedication of the scientist, the skill of the engineer and the motivation of the politician to maintain and improve the standing of the European space-science community in a worldwide context. Furthermore, recent discussions in the ESA Council have shown that the Member States are becoming increasingly aware of the insufficient size of the Agency's scientific programme. This encourages me to believe that, within the next few years, more resources for European space science will be made available, which will allow our scientific community to become as competitive as our scientific colleagues working in other modern 'big-science' fields in Europe, such as particle physics or radio astronomy where Europe has been in the forefront for many years.

FRENCH TRANSLATION OVERLEAF

FRENCH TRANSLATION OVERLEAF



Avant-propos

Le programme scientifique est l'un des piliers centraux sur lesquels repose l'Agence spatiale européenne. Bien qu'en termes de dépenses courantes il ne représente qu'environ 15% du budget de l'Agence, la participation à ce programme dit 'obligatoire' est l'une des conditions essentielles que les Etats membres ont formellement inscrite dans la Convention. Outre cette reconnaissance officielle de l'importance du programme scientifique, il est largement admis que les succès remportés dans des domaines de pointe par les premiers projets scientifiques (alors sous l'égide de l'ESRO) ont grandement contribué à la mise sur pied d'un potentiel technologique européen en matière spatiale qui, à son tour, a permis à l'Europe de prendre l'assurance nécessaire pour se lancer dans les programmes d'applications et dans le système de transport spatial qui absorbent aujourd'hui l'essentiel des dépenses de l'Agence.

Etroitement associé au programme scientifique dès le début, j'ai partagé les heures de triomphe et les moments de découragement de la communauté scientifique, mais j'ai surtout été le témoin du travail colossal qui a permis le succès des différents projets. Cet effort n'a pas été seulement le fait d'instituts scientifiques dans l'Europe entière mais également celui de l'industrie et de l'Agence elle-même. La légitime fierté inspirée par la réussite obtenue par l'Agence avec des ressources limitées ressort des articles qui suivent.

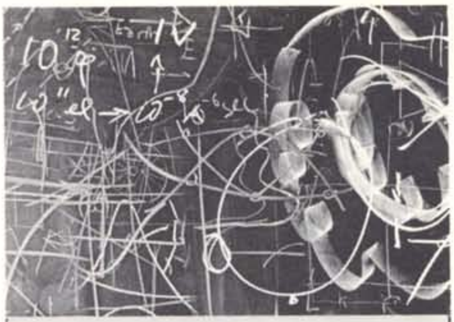
Que les lecteurs qui ne sont pas encore familiarisés avec le programme scientifique me permettent de situer ces articles dans un contexte global. Pour un certain courant d'opinion, la science spatiale représente un gaspillage exorbitant de l'argent des contribuables, c'est pourquoi nous avons inséré dans ce numéro un article du Pr. Elliot qui s'intitule 'Pourquoi se préoccuper de recherche fondamentale?; prenant comme exemple concret l'évolution récente de l'astronomie spatiale, il affirme de façon convaincante que la recherche fondamentale est une activité importante de l'homme et que les nations les plus riches du monde – dont les Etats membres de l'ESA font de toute évidence partie – doivent poursuivre un solide programme de recherche pure, englobant des secteurs relativement coûteux comme celui de la science spatiale.

L'ESA a consacré certaines de ses missions récentes (parfois exécutées en collaboration avec d'autres organismes) à l'astronomie spatiale dans les parties du spectre correspondant aux rayonnements gamma et ultraviolet (Cos-B et IUE) ainsi qu'aux relations entre le Soleil et la Terre (Geos et ISEE). Le premier article du Dr Page 'Résultats scientifiques récents des véhicules spatiaux de l'ESA', fondé sur les résultats de ces missions et sur les interprétations qu'en ont tirées tous les scientifiques intéressés, résume les progrès que ces satellites ont permis en matière de connaissances scientifiques. Le deuxième article du Dr Page est plus limité dans sa portée: il décrit les travaux scientifiques récemment accomplis par le Département 'Science spatiale' (SSD) de l'Agence. Ce Département constitue en soi un petit institut scientifique installé dans l'Etablissement technique de l'Agence, l'ESTEC, à Noordwijk (Pays-Bas). L'article ne traite que des activités purement scientifiques du SSD alors que ce Département joue également un rôle important, d'une part, en coordonnant les travaux des expérimentateurs pendant les phases de développement et d'exploitation des projets de satellites et, d'autre part, en se faisant le représentant des intérêts des expérimentateurs vis-à-vis des chefs de projet.

L'article de M. Delahais 'Projets scientifiques en cours de développement' décrit les objectifs des cinq projets scientifiques en cours: le satellite Exosat, le Traîneau spatial, la Mission internationale d'étude des pôles du Soleil (ISPM), le Télescope spatial et le satellite Hipparcos.

Dans son article intitulé 'Le programme scientifique de l'ESA: situation actuelle et perspectives d'avenir', le Dr Manno tire une sonnette d'alarme. Nous savons qu'un certain nombre de disciplines scientifiques spatiales n'ont pas été abordées jusqu'ici par l'Agence et que, tout naturellement, les chercheurs qui s'y intéressent essaient de se faire entendre. Nous savons également qu'en raison des progrès réalisés en vingt années de recherche spatiale, il faudra le plus souvent désormais, pour progresser de façon marquante, des missions importantes et complexes beaucoup plus coûteuses que celles que l'Agence est actuellement en mesure d'entreprendre. On a du mal à se représenter comment, avec le modique budget fixe qui lui est actuellement alloué pour la science, l'Agence sera capable d'aider les scientifiques européens à se maintenir au premier rang dans leurs spécialités.

Considérant le cadre politique dans lequel l'Agence fonctionne – une agence intergouvernementale dirigée par onze Etats souverains – un esprit chagrin prédirait qu'elle ne peut avancer qu'à la vitesse du plus lent. Mais les réalisations passées du programme scientifique de l'ESA me rendent optimiste et me font espérer que nous pourrons combiner l'obstination du scientifique, le talent de l'ingénieur et la motivation du politique pour maintenir et même renforcer la position de la communauté européenne spécialiste de la science spatiale vis-à-vis du reste du monde. Mieux encore, les récents débats au Conseil de l'ESA ont montré que les Etats membres sont de plus en plus conscients de l'excessive limitation du programme scientifique de l'Agence. Ceci me porte à croire que dans les prochaines années la science spatiale disposera de ressources plus importantes, qui permettront à notre communauté scientifique de devenir aussi compétitive que celle que constituent nos collègues européens engagés dans d'autres secteurs de la recherche scientifique 'lourde', comme la physique des particules ou la radioastronomie, domaines dans lesquels l'Europe se tient en tête depuis plusieurs années.



The highest wisdom has but one science – the science of the whole – the science explaining the whole creation and man's place in it.

Leo Tolstoy

Why Bother with Basic Research?

Professor H. Elliot, Professor of Physics, Imperial College of Science & Technology, London

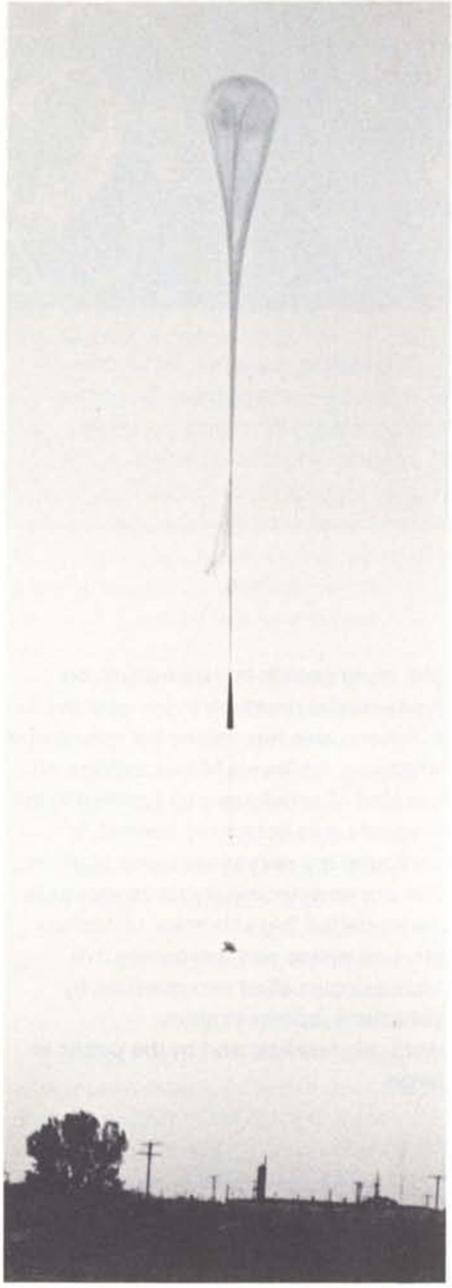
The rapid growth in expenditure on fundamental research in the past two or three decades has raised the question of whether such levels of expenditure on this kind of activity can be justified in the present socio-economic context. In particular the very large sums of money that are now necessary for research in the so-called 'big sciences' of nuclear physics, space and astronomy are increasingly called into question by politicians, administrators, environmentalists and by the public at large.

This article is based on a prior contribution to the Financial Times.

Why, indeed, should we use so large a fraction of our highly skilled scientific manpower to carry out fundamental research in these areas which seem to be so far removed from the problems of everyday life when they might, it is said, be better employed in tackling short-term problems of immediate concern in applied science and technology and in safeguarding our environment? This question presupposes that the necessary scientific manpower would always be available for deployment on these socially desirable tasks, but this is not necessarily so. There is at the present time some difficulty in attracting enough young people of the highest calibre into science in the first place and this recruitment of the brightest and best is a necessary condition that must be fulfilled if we are to have the high-grade engineers and technologists required in increasing numbers in the future. The intellectual excitement and challenge of pure science can be a powerful influence in shaping the attitudes and aspirations of young people and in leading them to opt for a science-based career.

Although this aspect of pure science as a source of interest and inspiration to young people is of great importance, there are other more important and fundamental reasons for pursuing a vigorous programme of pure research. At any particular time there are and will no doubt continue to be problems that cannot be solved using our current knowledge and understanding of the basic laws of nature. No amount of technological or engineering skill can produce a solution to such problems. Neolithic man could produce a stone axe by a simple extrapolation of his experience and knowledge of the objects that lay around him. Given the whole of the available resources of the planet at that time he could not have produced an electrically-powered, computer-controlled cutting tool. The design and construction of such a machine is only made possible by drawing on a vast store of knowledge acquired through much fundamental research in many fields.

The problem of future sources of energy is one that is now only too familiar to us all and it is clear that atomic energy from fissile material is going to be extremely important in the near future, with fusion reactors as a rather more distant prospect. So far as we know, there is no naturally occurring analogue to the fission reactor and the discovery of this particular source of energy was the direct product of fundamental research in nuclear physics. The generation of energy through the fusion of hydrogen nuclei to form helium, on the other hand, was already known to be possible more than a decade before the appearance of the first working fission reactor. Astronomers and nuclear physicists had recognised that this was the source of stellar energy. It is very hard to believe that these particular energy sources are the end of the line. What is certain is that new sources will only be revealed as a result of continued research in ever greater depth into the properties of matter, space and time. The cost of fundamental research is increasing all the time and the question may be asked 'Why should we do it; why not leave it to others?' Clearly, the



contribution which the developing countries can make is going to be severely limited for many years to come and it should be a matter of pride for all the wealthy members of the community of nations to take upon themselves this particular task.

In addition to and quite apart from the strictly practical aspects of fundamental research, man possesses an inherent curiosity about his origins, about his place in the universe, and about his environment generally. The need to satisfy this curiosity is reflected in the particularly widespread interest in astronomy, which exists both in the student population and the community at large. This interest is of long standing, but it has been much enhanced in recent years because of the developments of the past three decades which have brought about a remarkable change in the science of astronomy and in our knowledge and understanding of the universe. This revolution in astronomy is the result of extending our observations beyond the very narrow range of optical wavelengths available to classical astronomy to include radio, infrared, ultraviolet, X-rays and γ-rays. Much of this extension, particularly at the short wavelengths, is only possible through the use of space vehicles and the associated technology.

The importance of carrying out astronomical observations over the widest possible range of wavelengths first became apparent with the development of radio astronomy some thirty years ago. The early radio observations revealed a whole new set of phenomena and, amongst other things, provided the long-sought link between cosmic rays and the general body of astrophysics. Ever since its discovery prior to the first world war, the cosmic radiation had been an important but completely isolated manifestation of what were clearly extremely energetic processes taking place somewhere in the cosmos in totally unknown circumstances. The giant machines at CERN and elsewhere, which have provided much precise information on particle properties, represent the current limits of terrestrial accelerator technology, but they are small fry compared with their celestial counterparts which generate cosmic rays. To compete with the cosmic accelerators in terms of maximum available energy, a machine of the CERN variety would have to be on such a scale that the diameter of its magnet would be equal to the diameter of the earth's orbit around the sun. By combining data from radio and optical astronomy it was possible to show that one place in which cosmic rays acquire their enormous energy is in the cloud of debris generated by supernovae explosions.

The subsequent discovery of the enormous energy releases in radio galaxies and quasars has led to the serious consideration of processes in which an appreciable fraction of the total rest mass of a galaxy is rapidly converted into electrons travelling at relativistic speeds. It is as though the mass of ten to a hundred million stars had been suddenly transformed into a puff of cosmic radiation. Just how energy transformations on this scale can come about is at present a complete mystery and evidently involves processes of which we are wholly ignorant.

Of particular importance has been the discovery of pulsars, which are stars that have collapsed under their own weight to form what is in effect a single gigantic atomic nucleus having a similar mass to that of the sun and a diameter of a few kilometres. These are the so-called 'neutron stars', which start life rotating at a frequency of several hundred revolutions per second and gradually slow down whilst converting their energy of rotation into cosmic rays and electromagnetic radiation covering the whole spectrum from γ-rays to radio waves. These remarkable objects, of which 100 or so are now known, possess magnetic fields that are upwards of a million times higher than anything we can produce in the laboratory at the present time. The internal physics of these objects is a rapidly growing field in its own right and depends on an exotic combination of concepts from nuclear physics, solid-state physics, crystal-lattice theory and general relativity. Just to add generality, it may be noted that these objects suffer from time to time from the equivalent of terrestrial earthquakes – a 'starquake', which can be readily observed and measured by radio astronomers as a sudden but small increase in the rotation rate of the pulsar.

Stars are formed by the condensation of diffuse clouds of interstellar material, a process that probably starts as the result of a compressional wave propagation through the interstellar cloud. It is only recently that it has become possible through the methods of infrared and millimetre wave astronomy to investigate in detail the physical and chemical conditions in these clouds and thereby the mechanisms of star formation within them. It is now known that the clouds contain quite complex organic molecules, a surprising discovery which may be of significance in relation to the origin of life in the universe.

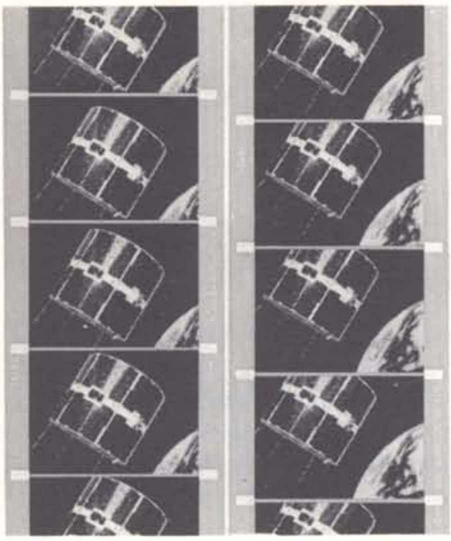
A good deal is known about the subsequent history of stars once they are formed and a virtually complete biography can be written for some. Their 'life styles' vary widely, with some passing through the spectacular supernova explosive stage, which may be followed by subsequent collapse to form the neutron stars we now identify with pulsars. Others, by virtue of their greater mass at birth, undergo gravitational collapse like the neutron stars, but their mass is so great that the mechanical strength of the gigantic atomic nucleus that constitutes the neutron star is insufficient to withstand the gravitational forces and the collapse continues beyond the pulsar stage. This leads to a bizarre situation in which the local gravitational field becomes so strong that in general relativistic terms space closes in upon itself, forming a 'black hole'. It is called a black hole because, once inside, no material or radiation or signal of any kind can escape. The material of the original star has disappeared from our sight, apparently for ever, and all that is left is an intense gravitational field, together with any other evidence there may be of other material falling into the hole. An analogy would be a bath full of opaque liquid when the plug is removed – the only optical evidence for the existence of the drain would be the vortex formed by the fluid disappearing down it.

Although the present concepts of basic physical theory lead logically to the existence of black holes, none has yet been positively identified. Such evidence as we have has come from the opposite end of the electromagnetic spectrum to that which informed us of the presence of neutron stars, from X-ray as opposed to radio astronomy. Material falling into a black hole, which comprises one component of a double star system, can be heated to such a degree that it radiates strongly in the X-ray region of the spectrum before finally disappearing from view. Whilst we cannot yet be certain that these objects exist in nature, there are now four or five X-ray objects that are possibly black holes, but further evidence is required if we are to be quite sure. Confirmation of their existence followed by a progressively more detailed study of their properties will have a profound effect on our understanding of the basic laws that govern the working of our universe.

These few examples may perhaps suffice to illustrate how nature provides us with systems in which there exist physical conditions that represent extremes far beyond anything we can hope to produce in the laboratory at the present time. Present in cosmic radiation are particles with energy far greater than anything achievable with terrestrial accelerators; pulsars provide us with an atomic nucleus of macroscopic dimensions and a magnetic field of hitherto unimaginable strength, whilst black holes have a gravitational field of such intensity that the material contained within them is shut off, perhaps for ever, from our view. Such extreme conditions enable us to test our present understanding of nature's laws, to generalise them to cover an ever widening range of physical parameters, and to discover completely new and previously unsuspected processes. To do so requires a coordinated attack using all the tools at our disposal and in this respect man's newly acquired ability to make observations from outside the atmosphere using earth satellites has enormously enhanced the opportunity for big advances in astronomy, making it for the moment one of the most rapidly advancing branches of science.

Special emphasis has been placed here on the contribution that the new developments in astronomy are making in the identification of new and unsuspected processes occurring in the universe and in the extension of the basic laws of physics to cover extreme conditions that cannot at present be simulated in the laboratory. However, we can only make progress of this kind in the context of fundamental research as a whole. We did not learn about nuclear fission from astronomical observations and it is unlikely that we will learn much about molecular biology in this way either. Astronomers would have a poor chance of understanding the internal structure of pulsars if they had not already been provided with the laboratory-developed concepts of nuclear and solid-state physics. Peace may or may not be divisible, but fundamental research certainly is not. It has to develop on a broad front or not at all. Maximum effort will sometimes be concentrated in this sector, sometimes in that; it so happens that at the present time advance is particularly rapid on the astronomical front.

It is essential to his material and perhaps even spiritual well-being that man should continue his efforts to understand the basic laws of nature. Otherwise he must inevitably lose the struggle to survive, in which he depends for his success on his ability to control and exploit the environment in which he lives. In the absence of continued basic research activity, the options open to him must gradually reduce in number and scope as the technological horizons close in. As wealthy members of the world community it is incumbent upon the nations of Western Europe to play their full share in adding to man's store of basic knowledge, but it also in our shorter term interest because a vigorous programme of fundamental research has a vital role to play in stimulating the interests of our own young people in science and technology, an interest that is essential if we are to have in the future the engineers, managers, scientists and technologists that we need for our survival.



Recent Scientific Achievements of ESA Spacecraft

D.E. Page, Head of ESA Space Science Department, ESTEC, Noordwijk, Netherlands

Successes of ESA's satellites have been described previously in, for example, ESA Bulletin No. 3 (October 1975) and in a report titled *The Achievements of ESA Scientific Satellites 1968-78,* **published during 1979 as ESA SP-1013*. Detailed reports appear each year at the time of the COSPAR meetings, the most up to date being ESA SP-1023*, May 1980.**

From both a scientific and technical point of view, ESA has reason to be proud of its scientific spacecraft programme. No doubt things will have to change one day, but the position now is such that none of the 12 missions flown has been invalidated by experiment or spacecraft-subsystem failure (Table 1). In this context of course 'ESA' includes all those experimenters and industries who have made such excellent contributions over the years.

This present article concentrates on results obtained more recently from the Cos-B, Geos, ISEE and IUE spacecraft.

* Available from ESA Scientific & Technical Publications Branch, see page 78.

The Astronomy Satellites, IUE and Cos-B

The International Ultraviolet Explorer (IUE)

By placing spectrographs behind their telescopes astronomers can look at objects at incredible distances and still manage to tell us not only what materials are present, but also the velocities and temperatures existing in different regions of those objects. In the same way that a prism splits visible sunlight into the colours of the rainbow, a spectrograph splits (resolves) the light coming from a star into spectral lines at various wavelengths. All atoms, when excited, emit energy, and they do this in such a way that each atomic species gives a characteristic pattern of spectral lines. Having studied these patterns in the laboratory for many years, the scientist is able to identify the radiating – or indeed absorbing – material in distant stars. From the shape of individual spectral lines, and the extent to which observed lines are moved relative to the pattern produced by an atom at rest, the scientist can also determine the temperature and

Table 1 – ESRO/ESA scientific spacecraft launched

	Launch date	End of useful life	Mission
ESRO-II	17 May 1968	9 May 1971	Cosmic rays, solar X-rays
ESRO-IA	3 October 1968	26 June 1970	Auroral and polar-cap phenomena, ionosphere
HEOS-1	5 December 1968	28 October 1975	Interplanetary medium, bow shock
ESRO-IB	1 October 1969	23 November 1969	As ESRO-IA
HEOS-2	31 January 1972	2 August 1974	Polar magnetosphere, interplanetary medium
TD-1	12 March 1972	4 May 1974	Astronomy (UV, X- and gamma-ray)
ESRO-IV	22 November 1972	15 April 1974	Neutral atmosphere, ionosphere, auroral particles
Cos-B	9 August 1975		Gamma-ray astronomy
Geos-1	20 April 1977	23 June 1978	Dynamics of the magnetosphere
ISEE-2	22 October 1977		Sun/earth relations and magnetosphere
IUE	26 January 1978		Ultraviolet astronomy
Geos-2	14 July 1978		Magnetospheric fields, waves and particles

Figure 1 – The International Ultraviolet Explorer (IUE) spacecraft

Figure 2 – IUE antenna at ESA's Villafranca ground station, near Madrid

velocity of the atom in the distant astronomical object.

Ground-based astronomers have been making such spectral measurements for many years and have learned a great deal. However, atoms do not obligingly display all their secrets in visible light which can penetrate the earth's atmosphere. Many of the most interesting spectral lines are to be expected at wavelengths that are absorbed in the atmosphere, and the advent of space flight has therefore opened up a whole new range of astronomy.

IUE is a spacecraft (Fig. 1) prepared by NASA, the Science Research Council (UK) and ESA to study spectral patterns beyond the blue end of the visible spectrum. The wavelength range from about 1000 Å (1 Å = 10^{-8} cm) to about 3000 Å is referred to as the ultraviolet range and spectral patterns seen there represent, in general, more energetic atomic processes than those revealing themselves in the visible range between about 3000 and 7000 Å.

IUE, launched in January 1978, is not the world's first astronomical satellite. It is nevertheless a unique astronomical space facility in that the spacecraft is geosynchronous, i.e. it orbits with the same 24-hour period as the earth's rotation, and is therefore visible for the whole of any day from one point on the earth's equator. It is still visible for a good part of every day from a ground station at Madrid's latitude, and astronomers can come to Villafranca (near Madrid) and use IUE very much as they would their ground-based telescopes. It is from this Vilspa ground station, set up and operated by ESA, that the IUE scientific harvest has been gathered in Europe (Fig. 2).

The response of the European astronomical community towards getting data from IUE might have been described as one of cautious interest a few years ago. Now, however, it has become widely recognised that Vilspa and its satellite 36 000 km away provide easy and flexible access to astronomical data that rivals the possibilities in many ground-based observatories. Indeed in many ways the data recovered from IUE may be more amenable to analysis than more traditional data. As a consequence, the 168 applications to use the telescope in 1980–81 cannot be accommodated within the available observing time and the originally planned spacecraft operational lifetime has been extended.

So many astronomers from different fields are interested in IUE data that the scientific results published are as numerous and diverse 'as the stars in the sky'. Consequently the areas of study will be mentioned to demonstrate the great versatility of the IUE telescope and a few individual highlights only will be selected from the detailed results.

To date observations have covered the areas of:

(a) Solar-system targets – the moon, planets, satellites, comets and the interplanetary medium.

(b) Stars of all spectral types – including X-ray emitters and a nova.

(c) Planetary nebulae, HII regions, supernova remnants and the interstellar medium.

(d) Galaxies, a supernova and quasars.

Some scientific highlights

It was established about twenty years ago that our own sun's corona extends to envelope the earth and far beyond. This

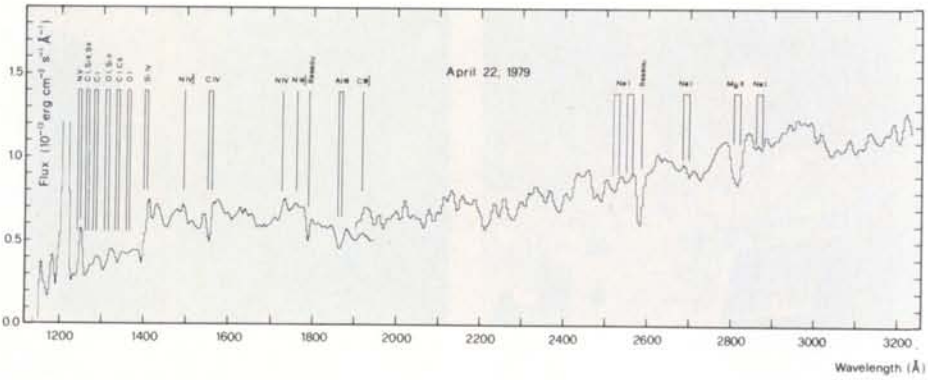


Figure 3 – The spectrum of supernova Johnson as observed by IUE as a 'target of opportunity' in April 1979. The most prominent absorption and emission features are identified

coronal plasma continuously expanding past the earth at velocities around 400 km/s is called the solar wind, and is now known to be responsible for many features of geomagnetism and phenomena in interplanetary space. This expanding corona starts in a high-temperature region above our sun's cooler chromosphere. Scientists had earlier studied features, in visible light, of the chromospheres of T Tauri stars – young stars contracting into the Main Sequence. They are now excited to find above these stellar chromospheres evidence in ultraviolet light of a high-temperature transition region suggestive of the existence of stellar winds there too. If indeed T Tauri stars have coronae, the theoretical models will have to be changed in future studies.

Mass has been observed evaporating from stars in many cases, but just as our neighbouring planets have atmospheres very different from earth and each other so the stellar winds and their composition vary tremendously, depending, for example, on local temperature. In order to explain certain ultraviolet spectral lines seen in the vicinity of the supernova remnants Cygnus Loop in our Galaxy and N49 and N63 in the Large Magellanic Cloud, it has been found 'convenient' to postulate the passage of a radiating shock wave with a velocity of some 100 km/s. This convenient explanation has of course not just been dreamt up accidentally. Scientists who had developed theories of shock waves radiating from supernovae explosions are delighted to find that the new ultraviolet observations fit their theories very well.

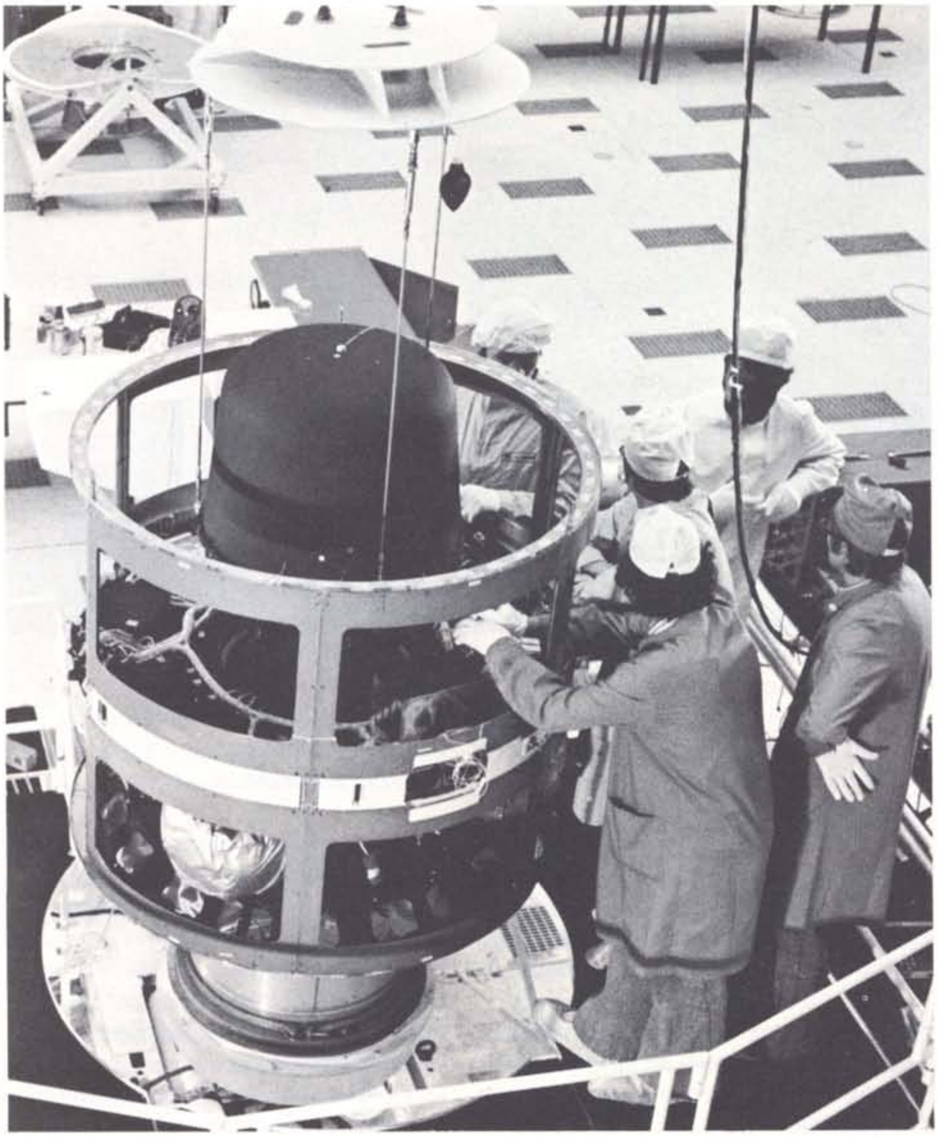
While there are quite a few supernovae remnants in the sky which can be studied, the opportunity to actually observe a supernova explosion in progress is comparatively rare. Consequently, when on 19 April 1979 supernova Johnson was reported in Galaxy M100, Vilspa urgently re-scheduled observations and within 24 hours the phenomenon was being studied (Fig. 3). One possibility presented, in principle at least, by such a study is absolute and direct determination of the distance to the supernova. This is very basic and important to astronomy, where distances are generally deduced in a step by step process, which tends to compound error. We can measure the brightness of the supernova at two different times, its temperature at the same times and derive its increase in size from the measured velocity and the time elapsed. Then using basic laws of physics which say that absolute brightness is proportional to $(\text{size})^2 \times (\text{temperature})^4$, and that the brightness we see is proportional to absolute brightness divided by $(\text{distance})^2$, the distance can be directly obtained.

Very recently a fascinating object, or rather a pair of near-identical objects, has been found in the sky. These have been labelled as the twin quasars 0957+561 A and B. A quasar is a quasi-stellar object of a class first described by the radio astronomers and characterised by having an enormous red shift in its spectrum. This spectral pattern shift toward longer, red wavelengths indicates that the object is moving away very fast and is almost certainly at a very great distance from us. It would indeed be interesting if two nearly identical quasars existed in such close proximity. The explanation finding favour seems, however, to be that there is really only one quasar. The light emitted comes to us through an intervening galaxy which acts as a gravitational lens and provides separate light paths A and B such that we see two images of the one quasar. A fundamental test of this explanation is that at all observed wavelengths the ratio of the light intensity arriving by path A to the intensity arriving by path B, should be constant. This has been found to be true throughout the radio wavelengths in which the twin quasars were observed, but there was a worrying deviation in the visible range. The results from IUE operating in the ultraviolet now confirm the radio measurements. The best explanation seems to be that the gravitational lens galaxy makes its own visible contribution to the spectrum, contributing more to path A than to path B. With this measurement IUE has again shown itself to be right at the forefront of observational astronomy.

Cos-B

The ultraviolet light that IUE has recorded to unravel the secrets of stellar atmospheres is produced mainly in atomic processes. When an atom gets excited the electrons that orbit the atomic nucleus move to higher energy orbits and it is this movement between orbits that produces light in the visible and ultraviolet regions of the electromagnetic spectrum. However, when the nucleus itself gets excited, radiations and particles are produced carrying energies several million times higher than those that manifest themselves in the ultraviolet. In the latter range the radiation has energies of a few electron volts and corresponding wavelengths around 1000 Å, while gamma-rays produced by nuclear reactions have energies of some million

Figure 4 – Integration of the prototype models of the Cos-B spacecraft and payload at MBB (Germany)



electron volts, corresponding to wavelengths around 0.001 Å or 10^{-11} cm. It was to search for these celestial gamma-rays that Cos-B was designed (Fig. 4).

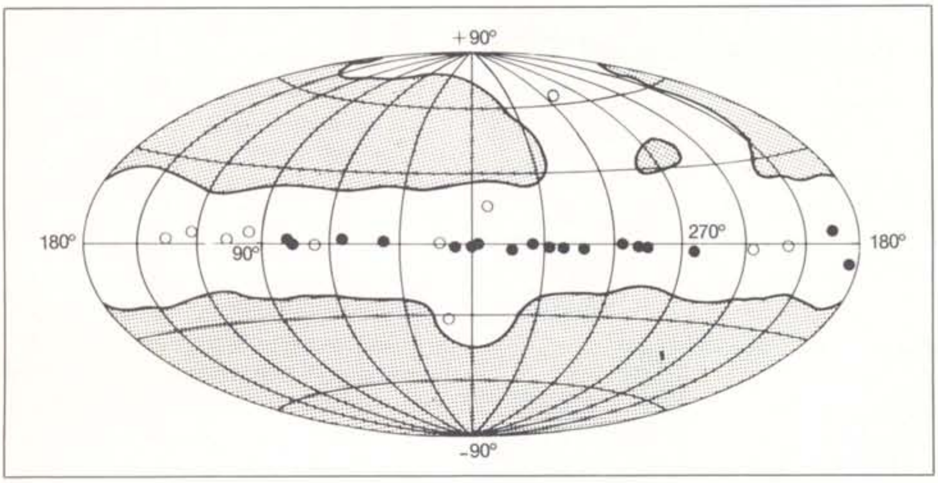
There are many problems in measuring gamma-rays and particularly in measuring gamma-rays in space. Gamma-radiation, with its very short wavelength, cannot be handled with the elegant optical or ultraviolet techniques. Rather its nature is identified by the reactions it produces in materials through which it passes and its energy is determined from the way it deposits energy in these materials. Compared with the measurements of optical or ultraviolet astronomy, gamma-ray measurements are very crude indeed. Whereas the ultraviolet telescope in space can record a source position with an accuracy of one second of arc (3600 sec = 1 deg), the gamma-ray detector can manage no better than about 3 deg, and there can be a lot of candidate sources within a 3-deg square area of the sky! Again, whereas the ultraviolet telescope can determine the energy of the arriving radiation with an accuracy better than 0.1%, the corresponding figure for gamma-rays is about 50%.

The other big problem in a space experiment is that the detectors that respond to gamma-rays also respond to other radiations including charged particles, of which there are many in the region surrounding the earth. Thus very careful calibrations had to be carried out to ensure that Cos-B measured gamma-rays and only gamma-rays. Even then the data-reduction effort is massive if one is to ensure that no spurious events are recorded as apparently genuine gamma-rays.

After four and a half years of operation it is clear that the Cos-B experimenters have succeeded admirably. Six laboratories coming together in what must be a model of European co-operation funded individually, but built jointly, a detector arrangement that has adequately rejected the interfering background radiations and is producing the first catalogues of the celestial sphere seen in gamma-rays.

It seems reasonable to conclude that most of the gamma-radiation we see originates in our own galaxy. This conclusion is drawn because the radiation comes mainly from galactic latitudes close to zero, whatever the galactic longitude, and the most intense radiation in this narrow belt of latitude comes from the direction of the centre of our own galaxy. In other words, most of the gamma-radiation which we see comes from the 'Milky Way'. Detailed analysis in latitude and longitude intervals leads to the idea that there are two main areas of production within our galaxy. There is a fairly broad region at about 1 kiloparsec (1 kpc $\simeq 3 \times 10^{21}$ cm) from the solar system and a region narrower in latitudinal extent at about 5 kpc from the solar system. Still more detailed study shows that the broad region of emission correlates well with the local matter distribution constituted by the complex of stars, gas and dust known as Gould's belt. The longitude dependence of

Figure 5 – Region of the sky searched by Cos-B for gamma-ray sources (unshaded) and sources detected above 100 MeV by spatial analysis. The closed circles denote sources with measured fluxes $\geqslant 1.3 \times 10^{-6}$ photon cm^{-2} s^{-1}. Open circles denote sources below this threshold



gamma-rays in the more distant narrow region shows features that relate to the large-scale structures seen earlier in, for example, 21 cm radio measurements.

In addition to these large-scale features, 29 point-like sources have been found (Fig. 5). The most surprising and perhaps the most frustrating thing about these is that only two – perhaps three – can be identified with objects already seen in the sky at other wavelengths. The two clearly identified sources of gamma-radiation are the Crab and the Vela pulsars discovered some years ago at other wavelengths. A pulsar flashes its radiation to us in a way that makes it seem like a lighthouse in the sky. The light pattern that arrives varies with wavelength for each individual pulsar and the rotational speed of the 'lighthouse' varies from pulsar to pulsar.

The features of these two gamma-pulsars have now been studied in great detail. For example, the amount of energy appearing in different parts of the pulsed light pattern has been computed. As far as arriving at a consistent picture of gamma-ray production is concerned, these results too present no great comfort. The gamma-ray energy spectrum measured in the Crab, for example, extrapolates well to join up with its spectrum seen in X-rays (lower energies). With Vela, however, the X-ray output is at least a factor of four too low to meet up with the extrapolated gamma-spectrum. This absence of X-rays is interesting and apparently general. Since X-radiation comes next door to gamma-radiation at slightly lower energies, we could have reasonably expected to see some of the 29 gamma-sources discovered in X- radiation also. But only one, apart from Vela and Crab, has been reported. We seem therefore to be witnessing a mechanism that produces gamma-rays and, by comparison, a negligible amount of X-radiation. This observation certainly puts limits on the theoretical possibilities.

The third source that seems to have been positively identified with an object seen at other wavelengths is that in the position of the quasar labelled 3C273. This is the only one of the 29 sources found which appears to be outside our own galaxy. It can be seen very clearly in an isolated position towards the top right of Figure 5. This quasar has been studied at many wavelengths and it is interesting to find that its luminosity (a measure of the total energy emitted) is greater at gamma-wavelengths than in any other region of the electromagnetic spectrum.

Massive data-reduction efforts have been required to get this far with Cos-B in a new domain of astronomy. Much data remains unprocessed and the spacecraft is still operating. We can therefore reasonably expect further advances in the next few years. A new generation of spacecraft is being planned (by NASA) so that directional and energy resolution can be improved. We can in the meantime take pride in the scientific achievements of Cos-B.

The Sun-Earth Satellites, Geos and ISEE

We have just seen how exciting can be the messages flashed from distant stars to detectors on IUE and Cos-B. The excitement is due, at least in part, to a sense of achievement in obtaining information, however scanty, from such great distances. But just as the mariner has to make intelligent guesses about what surrounds a distant lighthouse and how that lighthouse may be powered, so the astronomer has to speculate too. We at the earth are, however, fortunately placed in that we are sitting right in the 'works' of a lighthouse and are now beginning to understand what factors drive its complicated mechanisms.

Geos and ISEE (International Sun-Earth Explorer) carry sophisticated collections of instruments to monitor the plasma and magnetic fields ejected by the sun and the response of the earth's surroundings to changes in what the sun sends to us. In our understanding of what goes on we could say that, compared with the exploration of the earth's surface, we have reached a stage where we know roughly where the main land and water masses lie, we have monitored some ocean currents and atmospheric winds and we think we understand what causes some of these movements. Just as many voyages of many ships were required to build up a picture of currents and winds at the earth's surface, so it will take time to fill in the picture of what goes on in the earth's magnetosphere and in the sun-earth environment.

When we have found out – and the pursuit of knowledge of what goes on and why is something for which a scientist need not apologise – we should be better placed to speculate on, for example, what

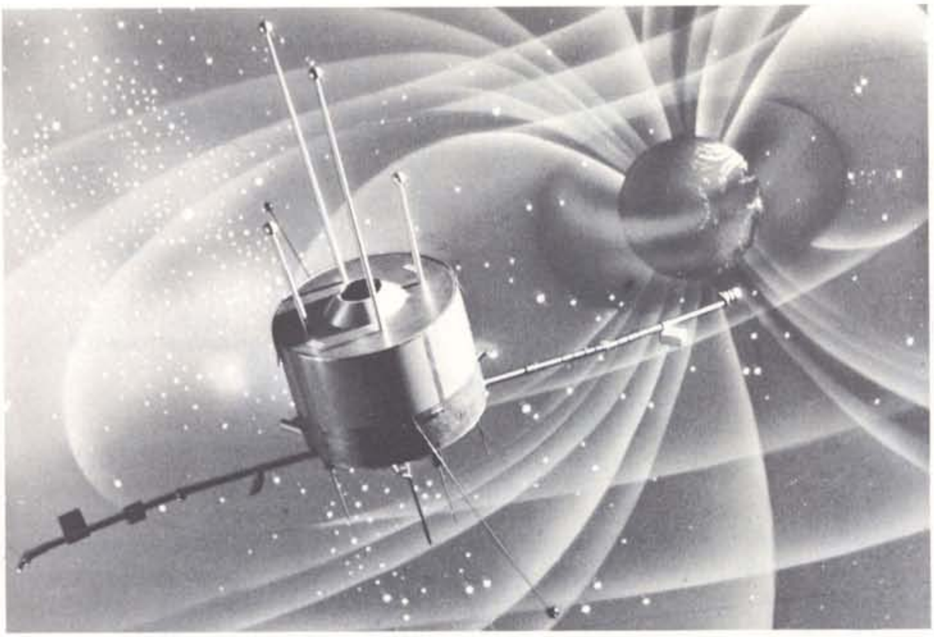


Figure 6 – Three-dimensional representation of the earth's magnetosphere, with Geos-2 in orbital configuration

goes on in distant galaxies, why plasmas behave as they do, and perhaps even on what governs our weather patterns on earth. The concept of stellar magnetospheres, developed in the light of what is known about the earth's magnetosphere, plays an important role in explaining many of the recent astronomical observations of pulsars, X-ray binaries and neutron stars. The production of controllable fusion energy is held back not by any lack of knowledge of nuclear science, but by the undisciplined and poorly understood behaviour of plasmas. The accessible earth environment provides an excellent laboratory, free from artificial constraining walls, where satellites such as Geos can and do identify new plasma behaviour modes. It has long been suspected that in some way changes in the sun-earth environment lead to changes in atmospheric circulation and to changes in the earth's weather. There is, for example, evidence that droughts in some parts of the world tend to occur more readily at particular phases of the sunspot cycle. So far no convincing explanation has been put forward, but the pursuit of one is of great interest to a great many people.

Geos

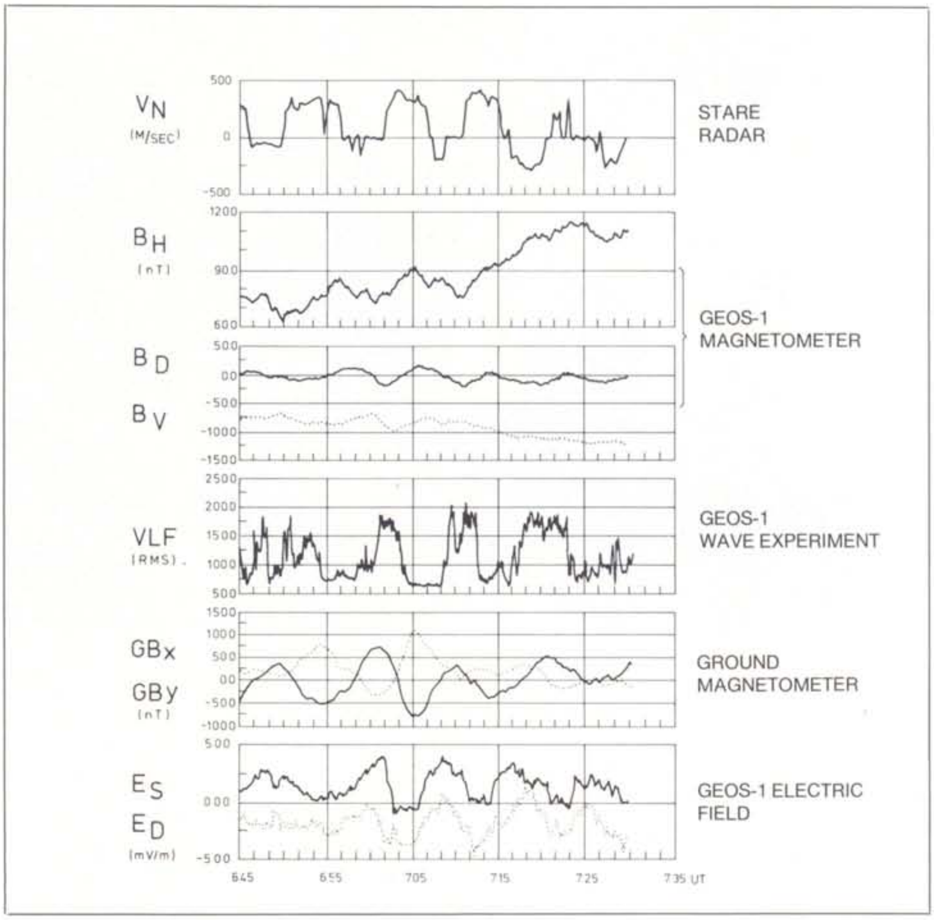
Geos-1 was launched in April 1977 (Fig. 6), but because the launcher misbehaved it was not possible to place the satellite permanently at the geostationary position. It did prove possible, however, to find an orbit such that twice per day the spacecraft apogee hovered around the geostationary point. Geos-1, although having some advantages in being able to scan through many parts of the magnetosphere out to the geostationary orbit at 36 000 km, had to be classified as a 'failure' because it was unable to operate as the reference spacecraft for the International Magnetospheric Study (IMS). Consequently Geos-2 was launched in July 1978 and it has since been used successfully as a reference for many ground-based studies and for numerous sounding-rocket and balloon campaigns around the world.

When Geos was being built, the science of the earth's magnetosphere had passed the crude exploratory stages and it was clear that if significant advances were to be made then sophisticated instruments, carefully intercalibrated and controlled, had to be flown. It had been the ambition of magnetospheric scientists for many years to measure DC electric fields, but because these were thought to be only a few millivolts per metre the spacecraft had to be made electrostatically clean. Before Geos, no reliable electric-field measurements had been possible in much of the magnetosphere. The coating of the spacecraft's solar cells with conductive material to achieve this cleanliness represented a significant technical achievement, and the scientific results confirm that the effort was extremely worthwhile.

Geos has two experiments that measure DC electric fields directly and at least one other from which the electric field can be inferred. One experiment fires a beam of electrons which follows an almost circular path of several kilometres around the local geomagnetic field and returns to be detected again at the spacecraft. The deviation of the beam from a perfectly circular path gives the electric field in one plane. Another experiment holds two very special ball detectors 40 m apart so that the electric field between them can be monitored. Another elegant experiment measures how magnetospheric ions drift relative to the geomagnetic field and this drift again allows the electric field to be deduced. The results agree very satisfactorily and provide the confidence that a tricky measurement is at last being made reliably.

It has now been established that at nearly all times there is an electric field of 1 or 2 mV/m directed from dawn to dusk across the sunward side of the magnetosphere. If we assume that these values hold simultaneously at all points across the magnetosphere, this means that there is a difference in potential of 250 000 V between the dawn and dusk boundaries of the earth's magnetosphere. There are, of course, wide variations in this value from day to day and when magnetic substorms occur electric fields as large as 20 mV/m can be seen for short periods. (Magnetic substorms are seen as vivid aurorae and intense magnetic disturbances. They probably occur in

Figure 7 – Pulsations occurring at the geostationary orbit, in the lower ionosphere and at the ground, indicating that these pulsations are a global phenomenon



response to changes in the solar wind impacting on the earth, but we still do not know the mechanism involved.) Immediately following substorms it is not unusual to find large electric-field oscillations with amplitudes of more than 10 mV/m and periods of several minutes occurring at the geostationary position. These oscillations are apparently transmitted all the way down to the ionosphere (a few hundred kilometres above the earth's surface) and show up there in both plasma motions as detected by radar and ground-based magnetometers. Figure 7 illustrates measurements made simultaneously by various Geos experiments and ground-based facilities.

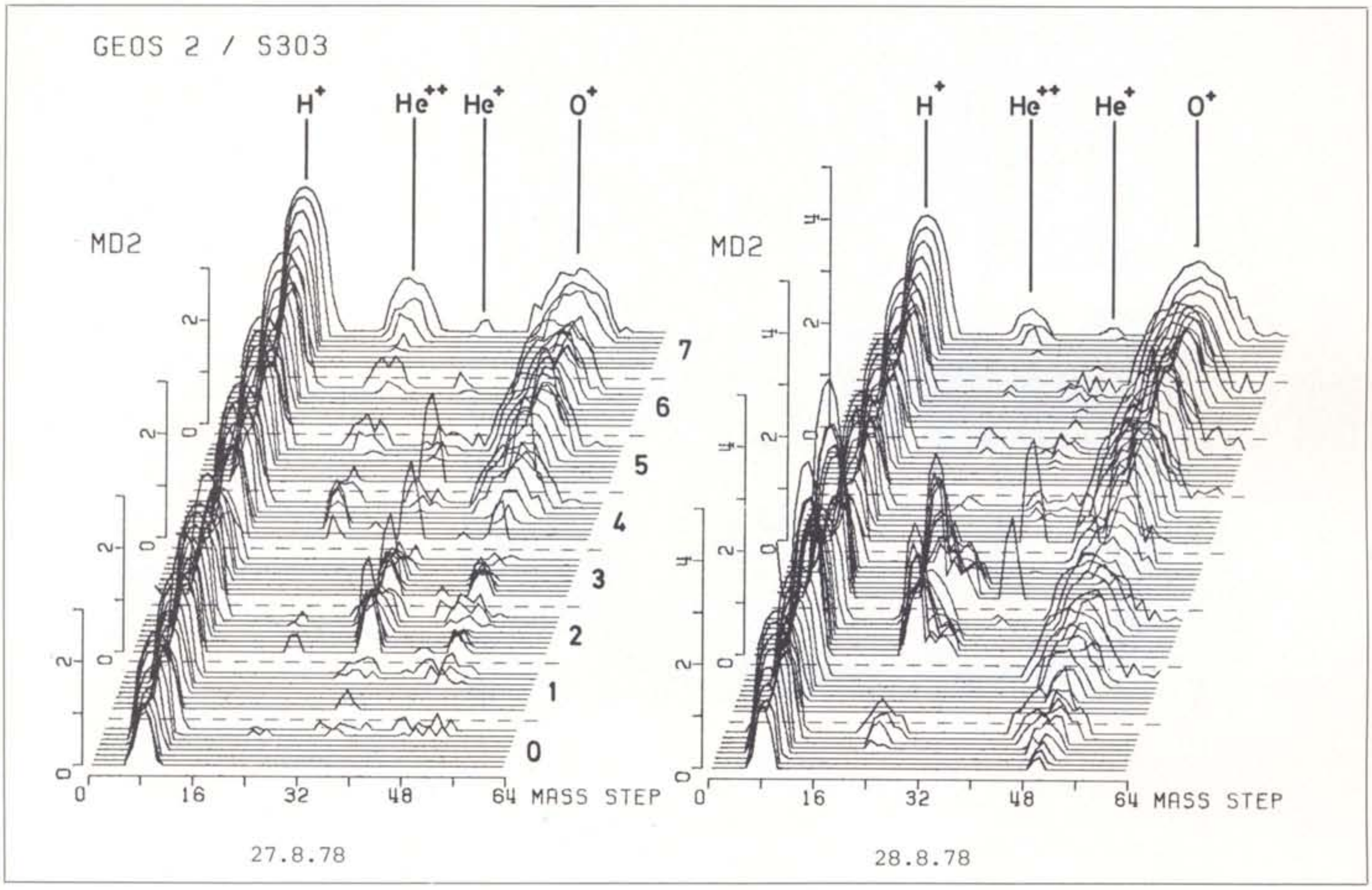
An interesting set of measurements obtained by Geos's charged-particle and electric-field detectors shows that at certain times when there is an increase in the electric field, a large fraction of the particle population at the geostationary position in the dayside magnetosphere just disappears. Comparison with plasma data from the American ATS-6 spacecraft indicates that this dropout of particle flux extends over a distance of at least several earth radii. The magnetosphere thus evacuated apparently by a change in the plasma convection pattern, as indicated by the change in electric field, stays evacuated until another burst of particles is injected, presumably from the direction of the magnetotail. It is not clear where the particles that drop out actually go. Nor is it clear whether a change in electric field causes the particle dropout or vice versa. It may be that the changes in both parameters are in response to changes in the solar-wind conditions.

Plasma and particles, appearing and disappearing as described above, are of great interest in trying to unravel the behaviour of the earth's magnetosphere. It was suspected many years ago from magnetic measurements on the ground that at times of magnetic storms a large ring current flowed around the earth. Space measurements have confirmed that such a current does indeed flow at distances from about 3 earth radii out to the geostationary position, but we still do not know why the current is set up, where the constituent charged particles originate, or where they go when the current decays.

An elegant mass-spectrometer on Geos was designed to monitor magnetospheric ions, measuring both the ion species and the extent to which it was ionised. It was hoped that the results would tell us whether the ions seen in the ring current, for example, come up from the earth's atmosphere or in from the solar wind. If the ion found is oxygen, and only singly charged, we can reasonably conclude it is from the earth's atmosphere or cold ionosphere; if it is helium and is doubly charged then it probably comes from the hotter solar wind. While the experiment has worked extremely well and resolved with precision how the ratio of various ion species varies during different phases of geomagnetic storms, it has not provided a conveniently tidy explanation for the origin of magnetospheric plasma (Fig. 8). With hindsight it is probably no great surprise that sometimes most ions come from the solar wind, but at other times from the earth's atmosphere. That ions found at the geostationary position have come up from the atmosphere is a relatively new result and Geos has provided convincing confirmation of its validity. It has now become even more compelling to find the nature of the interaction between the solar wind and the earth's plasma environment.

Already then, with only a fraction of the available data analysed, Geos has made significant steps towards identifying the

Figure 8 – Results from the Geos-2 ion mass spectrometer, illustrating the development of a large geomagnetic storm over two consecutive days. Data are 3-h averages of mass/energy spectra arranged by local time (the numbers 0, 1, 2 . . . 7 correspond to the sectors 0-3, 3-6... 21-24 h local time). The abscissa is ion mass per charge in arbitrary units (see peak identification at top), the ordinate is $\log_{10}$ of detector count rate and oblique axis is energy (8 steps covering the range 4 eV to 16.4 keV) and local time



composition and movement of plasma around the earth's magnetosphere. Clearly many of the features seen map down to the ionosphere and atmosphere and it will be particularly interesting in this respect to see what Geos eventually establishes as an average plasma-flow regime. The relation between Geos and ISEE results has already been established in a few cases and there is considerable potential for establishing how these plasma motions relate to interplanetary and solar inputs.

In an article such as this it is difficult to describe detailed processes in plasma physics. It should perhaps be pointed out, however, that the hopes of confirming theories of wave/particle interactions and indeed of discovering new interactions have not been disappointed. For example, a theory for the production of electro-magnetic hiss has been beautifully confirmed by watching the hiss appear and disappear as a critical value of charged-particle anisotropy is passed. The first observation in space of so-called f_q resonances – a special type of electrostatic wave resonance – has also been reported. Perhaps most dramatic of all is the solid physical evidence for the theoretically predicted process of magnetic-field reconnection, described below under ISEE.

ISEE

The International Sun-Earth Explorer project is a combined NASA/ESA attack on problems that lie, as the name suggests, in the field of sun/earth relations (Fig. 9). Whereas Geos has concentrated on making very detailed measurements inside the magnetosphere, the ISEE project uses three spacecraft simultaneously to try and elucidate a basic problem that cannot be solved with a single spacecraft. One spacecraft, ISEE-3, is anchored in the solar wind approximately 1.5 million kilometres from the earth. There it continuously monitors the undisturbed solar wind which will impact on the earth a short time later. ISEE-1 and ISEE-2 orbit the earth as a tandem pair, going out to apogee distances of around 20 earth radii ($1\ R_E = 6400$ km). (The boundary of the magnetosphere lies at approximately 10 earth radii and the magneto-hydrodynamic shock that stands in front of the earth in response to the supersonic solar wind is at about 20 earth radii.) The basic idea is to monitor with ISEE-3 the solar input to the earth and to use ISEE-1 and 2 to study the response of the earth's magnetosphere to this input.

Figure 9 – The ISEE-1 and ISEE-2 spacecraft being readied for a tandem launch

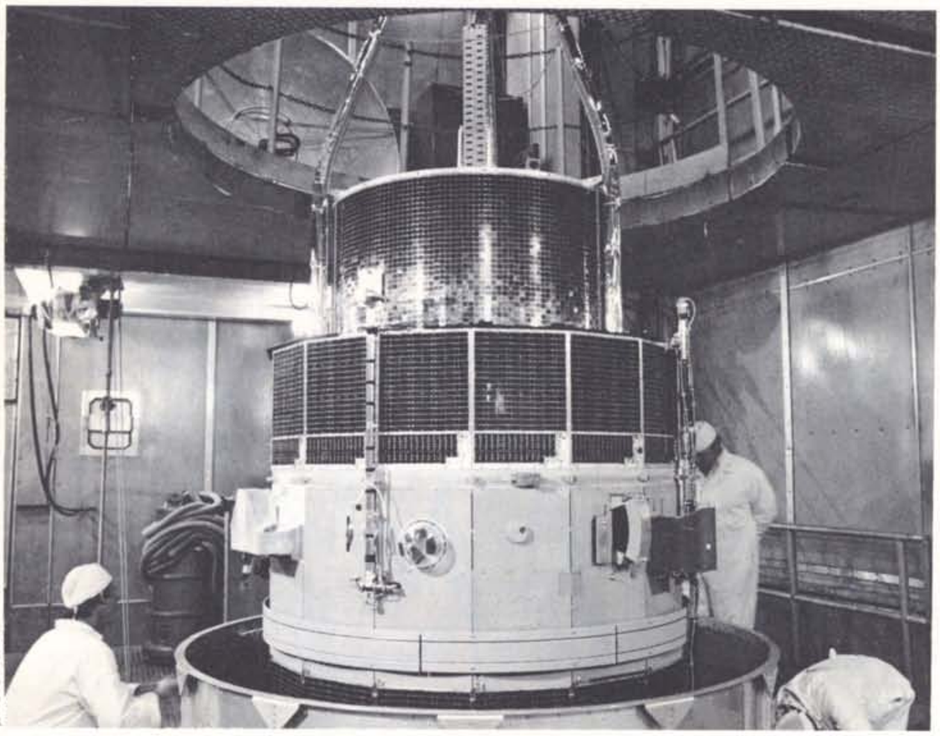


photo nasa

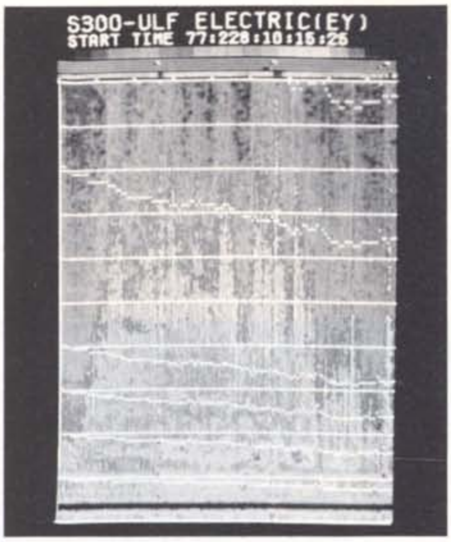
Two tandem spacecraft are used because with a single spacecraft it is frequently impossible to distinguish between spatial and temporal variations in the features that are encountered. A pilot flying at a known speed through a cloud may calculate the extent of the cloud if he assumes that the cloud is at rest. If, however, he were to meet a superfast cloud moving in the same direction as his aircraft it would seem very thick, whereas a cloud moving in the opposite direction would seem very thin. But with two airplanes flying at known speeds and a known distance apart, it would be possible to tell a great deal more about cloud thickness and velocity! ISEE-1 and 2 have, in an analogous manner, made detailed studies of the thickness and velocity of motion of several magnetospheric boundaries which with single spacecraft could only be crudely estimated.

Magnetopause thicknesses have been recorded in the range from 200 to 2000 km, depending on the orientation of the interplanetary magnetic field carried by the solar wind (the magnetopause marks the boundary of the magnetosphere). The thickness is a minimum for south-pointing interplanetary fields. Magnetopause velocities seem in general to be around 10–20 km/s, but on occasions speeds of up to 50 km/s have been encountered. These seem such simple and basic measurements that it comes as a surprise to many that only now can such values be assigned with confidence.

Many interesting detailed measurements have been made and correlations with Geos have proved fruitful, but the most fundamental measurements obtained are undoubtedly those providing evidence for magnetic merging. This merging process, by which interplanetary magnetic field lines join up with geomagnetic field lines to eventually form the magnetic tail that stretches far behind the earth in the anti-sunward direction, was outlined theoretically some 20 years ago. Although many things could not be explained unless magnetic merging or reconnection were invoked, there was no direct experimental evidence for the process. ISEE and Geos have now provided that evidence through detailed measurements at the sunward magnetopause. Earlier satellites did not find the evidence because, in general, they lacked the time resolution necessary to get a snapshot of what is a transient phenomenon and because they did not carry the necessary sophisticated instrumentation. A critical indication of merging in progress is the detection of a tangential electric field on both sides of the magnetopause, together with an identifiable change in the magnetic field as the magnetopause is crossed. These changes, now recorded, establish that significant power is generated in the merging process. Plasma has also been found jetting away from candidate merging sites – as identified by magnetic orientation – and this again is clear evidence of the process in operation.

One interesting set of results from the ISEE-3 spacecraft should be mentioned in closing. This spacecraft, placed 1.5 million kilometres from the earth in order to monitor the undisturbed solar wind as it speeds towards us, has found that even at that distance effects of the earth are clearly evident. For example, charged particles carrying energies of several kilo-electron volts are found travelling from the earth toward the sun! Their presence is particularly obvious when the orientation of the interplanetary magnetic field is such that it provides a direct link from the earth to the spacecraft. It is becoming clear that to an observer in space our planet earth must appear as an exciting generator of charged particles, and indeed of radio waves over quite a frequency range.

As in the case of the astronomy satellites, the harvest has been rich and the data still arriving can be expected to provide much exciting work for some years to come. It is unfortunate that ESA's limited resources do not provide sufficient flight opportunities in this field – and in other areas too – for a reasonably continuous programme.



Some Results from the Space Science Department Research Programme

D.E. Page, Head of ESA Space Science Department, ESTEC, Noordwijk, Netherlands

This article aims not to report comprehensively on the research programme of ESA's Space Science Department (SSD), but rather to describe some of the more recent scientific results arising from the projects in which SSD participates. Detailed reports of what SSD does, and how this relates to the overall ESA programme can be found in, for example, ESA/SPC(78)1 and SPC(80)15.

Since the SSD programme is continuously adjusted to support the ESA programme and since almost all of the research is carried out in partnership with other scientific groups, it is unavoidable that the scientific areas described here to some extent overlap with those mentioned in the preceding article (see page 10), which describes the successes of the Agency's satellites. In what follows it is assumed that the reader will already have read that story of the satellite programme. The results that are highlighted here are presented under the specialities of the four Divisions of SSD, which are the Astronomy Division, the High-Energy Astrophysics Division, the Space Plasma-Physics Division and the Cosmic-Ray Division.

Astronomy

In the Astronomy Division research has been carried out across a wide field of ultraviolet, optical and infrared astronomy and has also included laboratory studies that should help explain the properties of interstellar grains.

The infrared region of the electromagnetic spectrum lies between the red end of the visible and the highest frequency end of the radio range. The techniques required to examine infrared radiation tend to be similar to those used by radio astronomers at the long-wavelength end of the range (600–1000 μm), but similar to those used by optical astronomers at the short-wavelength end, around 100 μm (1 μm = 10^{-6} m). Instruments for both ends of the spectrum have been developed in the Division.

As explained in the preceding article, each part of the electromagnetic spectrum can help identify constituent species in objects that may be very far away, and may in addition tell us about local velocities and temperatures. While ultraviolet signals come mainly from atoms and gamma-ray signals from nucleii, infrared tends to be produced by lower energy processes. Much of it in fact comes from vibrating and rotating molecules. When molecules are getting together in the universe to begin a process that may eventually lead to the formation of galaxies their 'mating' signals come to us in the infrared range. Very cold, old stars also emit in the infrared.

It could be said then that study in the infrared provides us with information on birth and death phases in the universe. Infrared radiation is also a useful probing tool, which enables us to see, for example, deep into our own galaxy. Whereas blue light is scattered by dust and interstellar grains, the infrared travels with relatively little scattering. (It is just such scattering in the atmosphere that makes the sunset look red and dictates that spy agencies be expert in infrared technology.) Yet another attraction of working in the infrared is the possibility it offers of one day being able to measure the 'microwave background radiation' accurately. Theories of the big-bang origin of the universe say that we should be able to identify arriving from the sky a radiation with a characteristic hump in the infrared.

Infrared radiation can penetrate our atmosphere, but it is attenuated irregularly depending on wavelength, and making accurate corrections is very difficult. Because no spacecraft flights have been available so far, the Astronomy Division has been obliged to place its detectors behind telescopes at mountain observatories or to fly them on aeroplanes and balloons (Fig. 1). A Michelson-interferometer system has been flown on a NASA aircraft in a collaborative effort with French experimenters and on a balloon in co-operation with a British group. Several emission lines which are of considerable interest to the specialist have been detected and studied. This has made it possible, for example, to detect high-density clumps of matter in highly ionised nebulae. Information from oxygen, sulphur and nitrogen in these areas has allowed local electron densities and

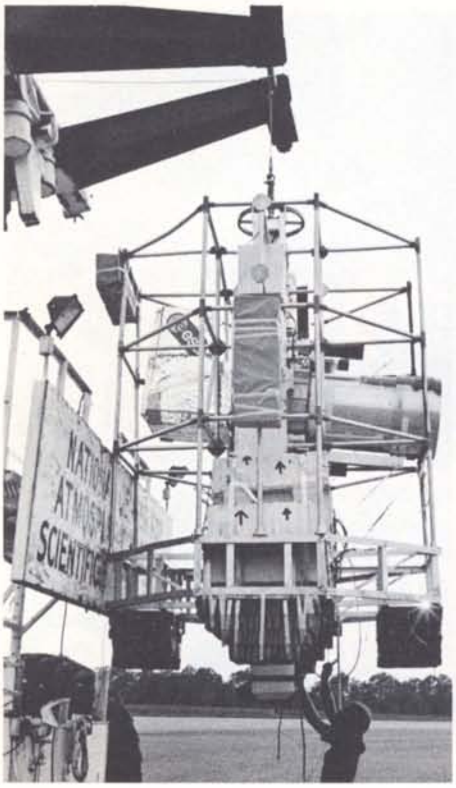


Figure 1 – Final checking before flight of University College London's balloon-borne infrared telescope with ESA's Michelson spectrometer for studies of IR line emission from gaseous nebulae

Figure 2 – Image of Comet Bradfield taken on 10 January 1980 with the finder telescope of IUE and processed by the IUE computer facilities

temperatures to be calculated. The clumps found are presumably forerunners of the stars of the future.

Working together with Dutch scientists, the Astronomy Division has developed a 'heterodyne' detector system for the wavelength range 600–1000 μm (aircraft flights are scheduled and some measurements have already been made from mountain observatories). As radio measurements have been extended over the years to these shorter wavelengths, some very interesting new molecules have been identified in molecular clouds. An observation of the Magellanic Cloud by the Astronomy Division failed to detect any sign of the CO (carbon monoxide) molecule although since carbon and oxygen are very common this molecule might be expected to exist. The observations will be repeated later this year with more sensitive instruments. On the other hand it does look as if the first ever measurement of the PH_3 molecule (phosphine) in interstellar space has been achieved. These exciting studies are continuing.

The Astronomy Division also supervises the work of the 'resident astronomers' at Villafranca who assist visiting European astronomers in carrying out their observing programmes with the IUE (International Ultraviolet Explorer) satellite. Whereas major efforts have to be made to detect just one infrared line as described above, an eight-hour shift at Villafranca can produce hundreds of lines in the ultraviolet. So many different features of different types of stars have been studied that it is impossible to fit the results into neat categories or to present general conclusions.

Observations have been made of the Quasar 3C273, of a Seyfert galaxy NGC 451, of globular clusters NGC 5824 and NGC 6093, of supernova Johnson, of 'peculiar' binaries, of superluminous stars and even of comets (Fig. 2).

One of the many reports reads as follows: 'A study of the binary WR star γ^2 Vel (WC8 + O9I), was made jointly by the Division staff at ESTEC with Dutch and UK astronomers. High-resolution spectra have been obtained at six different phases in one binary cycle and show substantial differences in strengths and profiles of many resonance and low-excitation ionic lines, but not in the higher excitation lines. These variations are explained in terms of an eclipse model. The CIII 1909 Å intercombination line, which shows eclipse absorption, has been used to deduce a mass loss rate of 10^{-4} solar masses per year from the WC8 star. Eclipse-path column densities inferred for the lower levels of the CIII λ 1909 and CIII λ 2297 transitions have allowed the excitation temperature in the outer region of the WC8 stellar wind to be determined as 10 000 K.'

A small amount of observational optical astronomy has also been carried out to complement IUE ultraviolet results.

Increasing emphasis is now being given to optical astronomy as the Division supports the development of the Faint Object Camera, which is one of ESA's contributions to the Space Telescope (a joint NASA/ESA project), which will be put into orbit at the end of 1983.

High-energy astrophysics

This Division of SSD supports ESA projects in the fields of X- and gamma-ray astronomy and carries out research in these areas. Its main research efforts have been in the analysis of data arriving from Cos-B and in the development of detectors suitable for future generations of X- and gamma-ray satellites.

Gamma-ray astronomy

The achievements of Cos-B have been described in detail in the preceding article. Six laboratories have contributed to the project and results are published jointly. For SSD's High-Energy Astrophysics Division, Cos-B has been a major workload for many years through the payload development, spacecraft operations, data reduction and scientific evaluation. The Division takes great pride in the success achieved. The results obtained so far can be summarised as follows:

(i) Most of the gamma radiation we see appears to come from our own galaxy

(ii) Twenty-nine 'sources' have so far been detected, but only three of these match up with objects seen in the sky at other wavelengths. The identified sources are in the regions of the Vela and Crab pulsars, and at the position of the Quasar 3C273. This quasar is the only gamma source found outside our own galaxy.

(iii) The Vela and Crab pulsars seen already at various wavelengths are also gamma-ray pulsars.

Gamma-rays, which provide information on high-energy nuclear reactions, can at present be detected only with rather crude resolution, both in terms of energy and direction. Nothing approaching the precision available in optical astronomy is ever likely to be possible because of the very nature of gamma-rays, but significant improvement over the present generation of instruments seems quite possible. Being painfully aware of the number of objects in the sky that could fall within the 5° or so resolution provided by Cos-B, the High-Energy Astrophysics Division set out to improve the detector known as a drift chamber for future gamma-ray missions. They quickly achieved a resolution of about 1.5 deg at gamma energies of 100 MeV, but then interrupted the development as there seemed to be no opportunity for a suitable spaceflight in the forseeable future.

The Division has, however, become involved in a project that will hopefully be assigned a flight to study very low energy gamma-rays of around 1 MeV. It is at just about this energy that gamma-rays begin to be called X-rays, and the classification is not entirely arbitrary because it is at these energies that the processes responsible for producing the radiation change in a rather basic way. Consequently, reliable measurements which so far have not been available because of instrument problems, should make possible major advances in understanding.

X-ray astronomy

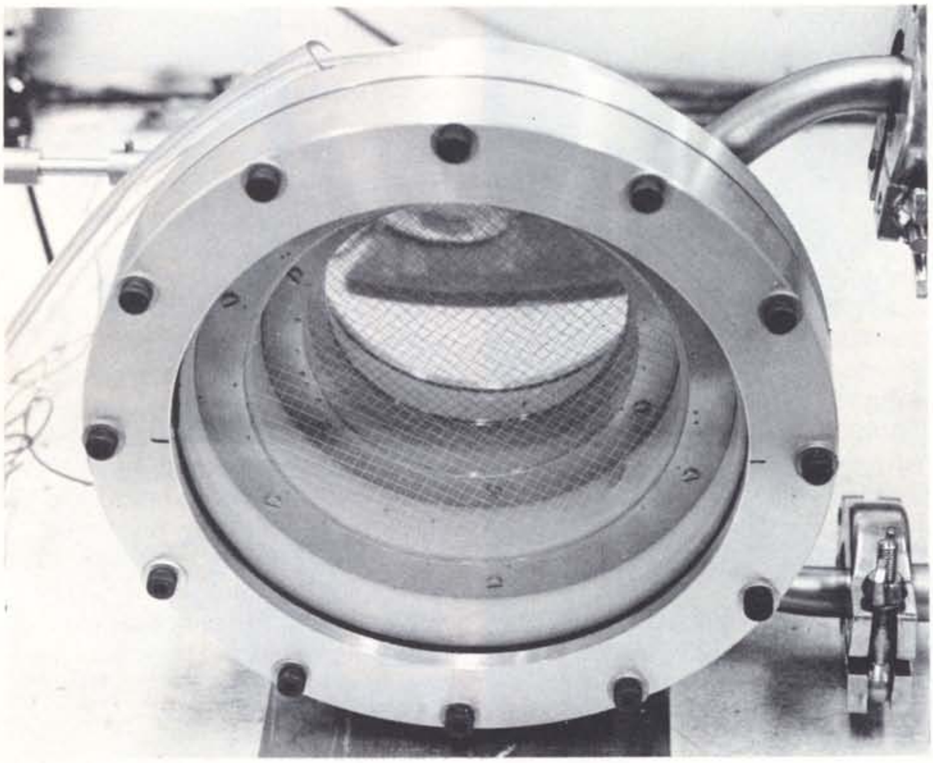
Considerable effort has been given to perfecting a detector for X-ray astronomy and the results have been highly satisfactory. X-radiation originates from high-energy atomic processes and as 'thermal' emission from plasmas with temperatures of one million to one hundred million degrees Kelvin. Some of the most dramatic astronomical discoveries of recent years have been made through measurements at X-ray wavelengths.

It was the X-ray information from what appear to be eclipsing binary stars that led to the conclusion that one of the binary pair was at least a neutron star or perhaps even a black hole! X-rays are produced as material from the large star of the pair is accreted onto the very high density small companion.

Most X-ray detecting satellites so far flown have concentrated on identifying sources and measuring their time variability. While the instrumentation has become more and more sensitive in terms of being able to detect fainter sources, little has been achieved in what might be called 'X-ray spectroscopy'. Now, just as traditional optical astronomers were not satisfied with counting the stars but studied optical spectra to be able to identify the atoms in stars and the speeds with which these atoms move, so the X-ray astronomers want to progress to measure X-ray spectral lines. At energies around 1 keV X-rays behave rather like the adjacent ultraviolet light and can be analysed by mirrors and gratings with reasonable precision. However, at higher energies – above say 5 keV – they behave more like gamma-rays and need to be absorbed in some material in order to reveal their properties. To examine X-ray lines thought likely to appear in this energy range it was necessary to develop a detector with a large area, high efficiency, good energy resolution and at the same time the ability to operate over a wide energy range. No existing detector satisfied all these requirements.

The High-Energy Astrophysics Division has therefore developed the Gas-Scintillation Proportional Counter (GSPC), which can operate over an energy range extending from about 2 keV up to about 80 keV (Fig. 3). As the name suggests, the electrical pulse given out by this counter is directly proportional to the energy of the X-ray detected. The incoming X-ray is photo-electrically absorbed in a gas, typically xenon, and the free electrons resulting from the event are drifted to a high-electric-field region where they acquire kinetic energies large enough to excite light-emitting levels of the gas. The field is kept below the value at which secondary electron multiplication would occur. The light, generated as a burst,

Figure 3 – A laboratory prototype planar gas-scintillation proportional counter, mounted on the gas purifier. In the foreground the UV transmissive exit window, to which is coupled an Auger camera, and the grids defining the high-voltage scintillation region



may be observed by a photomultiplier, the output signal of which is proportional to the energy of the absorbed X-ray. The light produced in the scintillation process in xenon is found mainly in the UV region between 1500 Å and 2200 Å. Given good light generation and collection, so that photon statistics do not play a role, the energy resolution of the device is limited only by the statistics of the original photo-absorption, and a resolution of about 6% at 6 keV is obtainable.

Such a GSPC detector will be flown on Exosat, now scheduled for launch in late 1981. Work is under way to take the detector one stage further and make it a position-sensitive gas-scintillation proportional counter. Such a detector used behind imaging optics can identify not only the energy of the radiation arriving, but also the position on the X-ray source from which the radiation emanates.

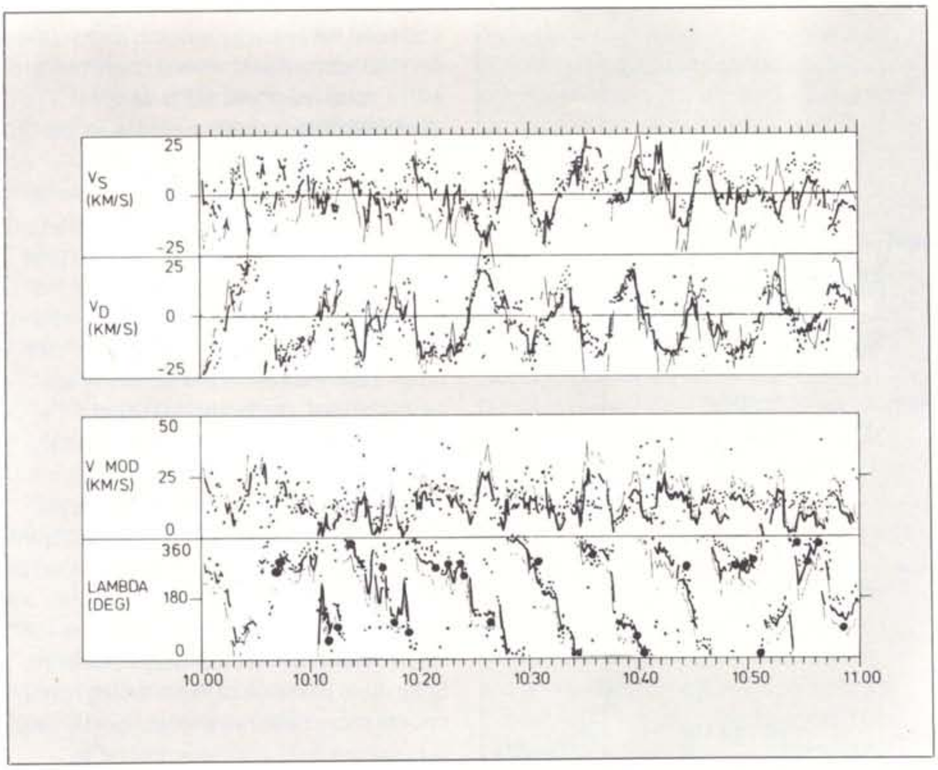
Space plasma physics
It has long been the ambition of plasma physicists to discover how plasmas move in the earth's magnetosphere and how these movements depend on the varying inputs received from the sun by way of the interplanetary medium. Interplanetary space is filled with the solar-wind plasma, which 'blows' continuously from the sun with average velocities of some 400 km/s in the vicinity of the earth and carries with it solar magnetic fields averaging around 5 gammas (1 gamma = 10^{-5} gauss). The solar wind is gusty, however, and may occasionally reach velocities above 1000 km/s and carry magnetic fields of 20 or even 30 gammas to the earth. The direction of the interplanetary field changes in a fairly regular way, being directed for about seven days away from the sun and for the next seven days towards the sun. Thus in the 28 days the sun requires to turn around once, it directs four magnetic sectors at the earth, and each time there is a change of sector magnetic polarity the plasma motions close to the earth are affected. There is thus in the vicinity of the earth an ideal plasma laboratory with input stimuli freely supplied.

The study of these plasmas is interesting if only to find out how they affect geomagnetism and the earth's ionosphere. Some people suspect that there may be a relationship between the motions of the plasmas and the earth's atmosphere, which will in turn affect our weather patterns. The understanding of how plasmas behave in the presence of varying magnetic and electric fields, while of great interest to fundamental science, may also have significant value in the development of controlled-fusion energy.

The possibility of measuring electric fields accurately has only recently become available to space plasma physicists and such a measurement is basic to any study of magnetospheric plasmas.

With this in mind the Space Plasma-Physics Division began many years ago to design and test a detector system capable of measuring the few millivolts per metre electric field which theory suggested would be found. In this technique two vitreous carbon spheres are held 40 m apart and the small voltage developed between them is measured by high-impedance amplifiers. Vitreous carbon was chosen because it has low and uniform photoemission. This is important because the voltages generated by surface charges, which vary from sunshine to shadow conditions, are significant compared with the millivolts to be measured. Another problem to be overcome was that of spacecraft charging. There were clear indications that the voltage between the sunlit and dark sides of a spacecraft in plasma conditions typical of the geostationary orbit could reach several hundred volts. There was little point in trying to measure millivolts in these circumstances! Special efforts were made to make the whole surface of the Geos spacecraft conducting, and this provided a unique opportunity for the experimenters.

Figure 4 – Comparison of plasma drifts measured by three different experiments on Geos-2. Data from the electron-beam experiment are indicated by dots, corrected double-probe measurements by lines. The large dots in the bottom scale show results from the low-energy particle experiment



The results of the attempts to measure electric fields from Geos and ISEE are excellent and the experiment provided by the Division indicates that the years of hard work were very worthwhile. Figure 4 shows the agreement between two experiments on Geos which measure electric fields directly by different techniques (and over slightly different ranges), and a charged-particle experiment where the particle drift velocity is measured. What is plotted is in fact the plasma drift velocity, which is dependent on the local electric field.

This figure, as well as illustrating the agreement between the different measurement techniques, also provides a good example of so-called 'PC 5 waves', which have frequently been seen by Geos. The plasma motions perpendicular to both the local magnetic and electric field caused by these waves have amplitudes of around one earth radius (6400 km).

It has been found that, generally speaking, across the sunlit side of the magnetosphere there is an electric field averaging 1 to 2 mV/m. As we go around the magnetosphere there appears to be at least one interesting inversion of field direction and therefore a reversal of plasma flow direction. During magnetic substorms, which show up particularly at auroral and polar latitudes, electric fields as high as 20 mV/m have been seen at the geostationary position. These high fields tend to arrive in pulses, typically 30 s long and distributed over a period of several minutes, and are probably associated with the injection of fresh plasma into the magnetosphere. Many other interesting observations have been made and there are striking correlations between electric-field variations seen at the Geos position and measurements made by, for example, ionosphere monitoring radars on the ground.

But perhaps the most significant result is the observation of magnetic merging in progress. This phenomenon in which the interplanetary magnetic field was thought to join up with the earth's field and then travel on with the solar wind to form the geomagnetic tail was suggested theoretically many years ago. The magnetopause is the boundary between the solar wind, which carries the interplanetary magnetic field, and the earth's magnetosphere. A critical indication that merging is in progress is that we can find a tangential electric field on both sides of the magnetopause and a magnetic-field change at the magnetopause telling us that the current flow is in such a direction that power is being transmitted to plasma particles from the electric and magnetic fields in that region. Another extremely interesting result in plasma physics is that when the same observation is made at the earth's bow shock it appears that the opposite process is occurring, i.e. the kinetic energy of solar wind particles is being transformed into electromagnetic energy.

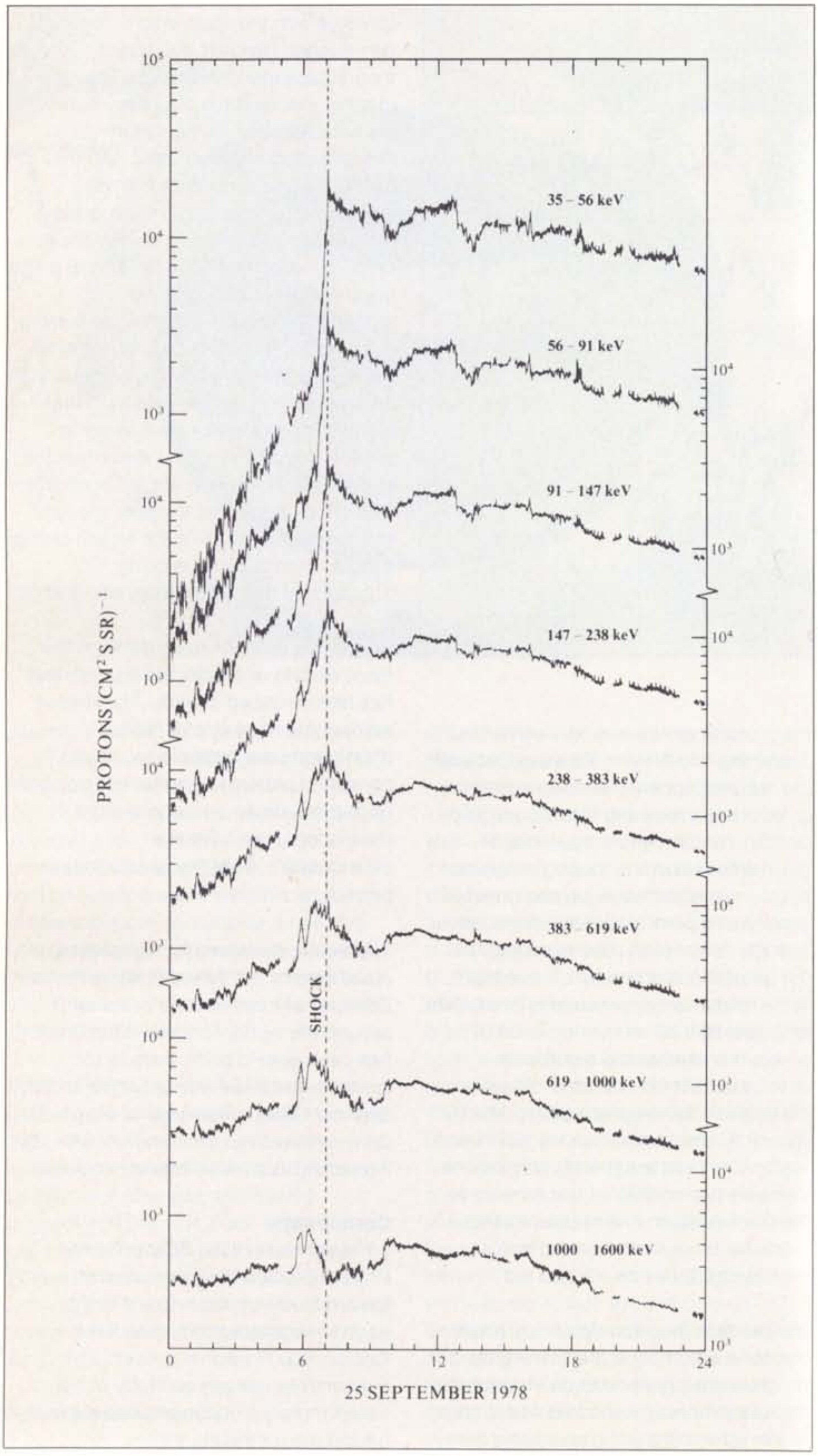
Much work remains to be done on the mass of data available, but a great deal has been reduced already. The various manifestations of electric-field phenomena are beginning to fit into consistent patterns and the next step will be to produce an 'average' picture of electric field – and thereby plasma flow – near the geostationary position.

The electric-field-measuring spheres developed by the Space Plasma-Physics Division have been much in demand around the world. As a result the Division has been able to participate in, for example, the NASA Venus Orbiter mission and in a USSR mission called Magik. The data recovered so far from both look very interesting, but await detailed analysis.

Cosmic rays

While the work of the Space Plasma-Physics Division has been directed mainly toward studying plasmas within the earth's magnetosphere, that of the Cosmic-Ray Division has been concentrated largely on study of the interplanetary medium and the outer boundaries of the magnetosphere.

Figure 5 – Low-energy proton intensities observed by ISEE-3 around an interplanetary shock (vertical line)



The solar-wind plasma which passes the earth at some 400 km/s not only carries with it solar magnetic fields which influence plasma motions close to the earth, but within its magnetic field structure it traps and steers high-energy charged particles. Many of these charged particles originate on the sun at the time of solar flares and are shot towards the earth at velocities approaching the speed of light. The way in which these particles travel from the sun to the vicinity of the earth can tell us a great deal about the magnetic structure of the interplanetary medium between the earth and the sun. The degree to which the charged solar-flare particles can or cannot penetrate the earth's magnetospheric shield provides us with information on the structure and nature of the earth's magnetosphere under different interplanetary conditions. Solar-flare particles of lower energy are of course more sensitive probes, but by their very nature they are more difficult to detect and are subject to disturbance by many factors in addition to those we would like to study. Whereas the Division's experiment on the HEOS-2 satellite detected particles having energies of millions of electron volts, an experiment on the recent ISEE-3 spacecraft concentrates on the energy region around a few tens of thousands of electron volts.

Studies of the HEOS-2 data have now been concluded. One of the most striking results obtained by the Cosmic-Ray Division was the discovery of a layer of very high-energy electrons, which now seems to be a nearly permanent feature of the high-latitude magnetosphere. Recent work has concentrated on trying to identify the origin of these particles carrying energies of millions of electron volts. The numbers observed increase significantly when the interplanetary field is directed southward and when the magnetic energy carried towards the earth by the solar wind is a maximum. The production mechanism would therefore seem to be the magnetic merging process discussed earlier in relation to ISEE results and the SPP Division. It may well be that an observer in space, remote from the earth, sees our earth as an exciting generator of MeV electrons at times when the magnetic path to his observing position is suitable.

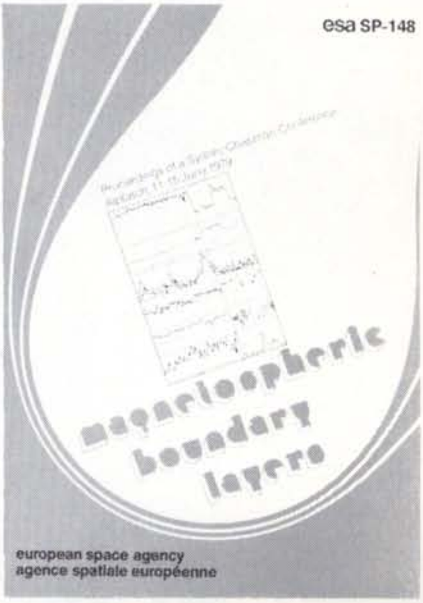
The ISEE-3 spacecraft sits 235 earth radii (1.5 million km) from the earth in the direction of the sun at a point where the earth's gravity just balances the pull of the sun. It carries 12 experiments, one of which is supplied by a team drawn from the Cosmic-Ray Division of SSD, the University of Utrecht and Imperial College London. These experiments aim to monitor the interplanetary medium uncontaminated by the presence of the earth. The experiment from the Cosmic-Ray Division concentrates on measuring, in three dimensions, the populations of protons with energies of tens of thousands of electron volts.

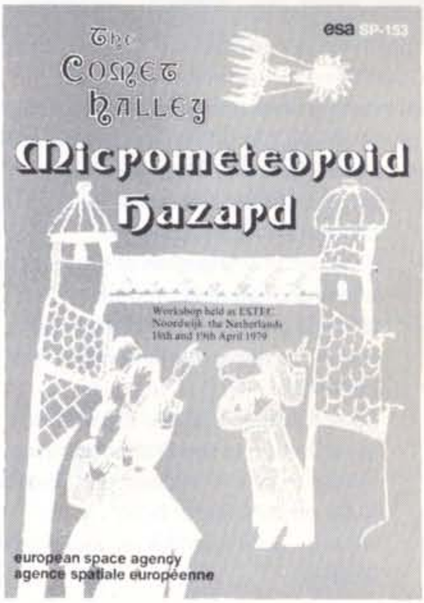
At these energies the velocity of the solar wind is significant compared with the velocities of the protons. The protons then look like surfers in the waves at the sea shore and it may not be immediately obvious to the casual observer where the surfer comes from and where he is trying to go. However, detailed study can be rewarding and some very interesting results have been obtained at 'shock' wave fronts. Figure 5 illustrates the situation at one shock front encountered in the solar wind (the high-energy particles were monitored by other detectors on ISEE-3). Some low-energy particles arrive before the shock reaches the spacecraft, but the most obvious feature is the pile-up after the shock has passed, i.e. in the upstream region. Directional analysis of the upstream region indicates that many of the particles were in fact accelerated at the shock. This is a clear example of interplanetary acceleration of charged particles. While the physics of the shock acceleration is of great interest because it may be applicable to many processes on the sun, around the earth, throughout the universe and even in the laboratory, there is clearly a nuisance value too in that in the study of solar-particle propagation suitable corrections have to be made – if possible.

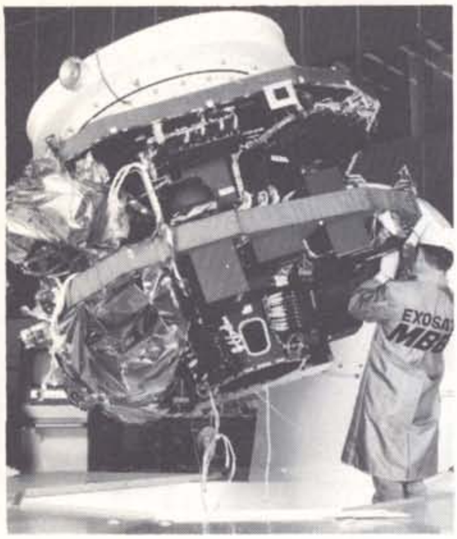
Some of the most interesting and unexpected results obtained by ISEE-3 appear to arise because of similar acceleration processes near the earth and probably at the earth's bow shock. (The earth's bow shock is formed about 130 000 km sunward from the earth as a response of the supersonic solar wind to the presence of the obstacle earth). ISEE-3 was supposed to establish the undisturbed interplanetary conditions well clear of the earth and we think, in general, that this goal is being achieved. However, not infrequently beams of particles are found streaming from the direction of earth past the spacecraft towards the sun. Studies are under way to find how the spacecraft is magnetically connected to the earth during the periods when these particle bursts are seen. The prime aim is to discover whether the earth produces the particles more or less continuously and the spacecraft sees them only when a suitable magnetic path exists, or whether the earth fires the particles like bursts from a gun perhaps when triggered by changes in interplanetary conditions. It could be that both conditions apply.

A natural progression for the Division's research is its participation in the mission out of the ecliptic plane. This, called the International Solar-Polar Mission, will use spacecraft to fly over the solar poles and make the first ever measurements of the 'third dimension' in the interplanetary medium. It is described in more detail in the next article, 'Scientific Projects under Development'.

Recent publications from ESA Space Science Department







Scientific Projects under Development

M. Delahais, Head of ESA Scientific Programme Department, ESTEC, Noordwijk, Netherlands

The five scientific projects currently under development within the Agency are those projects that have been approved by the Science Programme Committee for inclusion within the mandatory scientific programme budget (presently 85.13 million accounting units at mid-1979 prices). They are:

- **Exosat, for the observation of cosmic X-ray sources**
- **Sled, for investigation of the effects of weightlessness on man**
- **ISPM, a cooperative mission with NASA for exploration at high solar latitudes**
- **Space Telescope, the European contribution to the first unmanned multipurpose telescope observatory to be put into earth orbit**
- **Hipparcos, a satellite for astrometry studies.**

Two of these spacecraft will be launched by Ariane (Exosat and Hipparcos), two by the Shuttle (Space Telescope) or the Shuttle complemented by an Inertial Upper Stage (ISPM). The Sled is to be carried on a Spacelab flight. What follows is essentially a brief recapitulation of the scientific aims of the five missions, together with the attendant spacecraft designs, the essential features of the operational phases, and the status of development.

The European X-Ray Observatory Satellite (Exosat)

The scientific goals of the Exosat mission are to determine the position, structural features and spectral and temporal characteristics of cosmic X-ray sources in the energy range from approximately 0.1 to 50 keV. Using the moon as occulting body, bright sources of medium/hard X-rays can be positioned with an accuracy of 1 arc s, comparable to the resolution attainable at other wavelengths for correlative purposes. By using imaging telescopes, the position and structure of extended sources of soft X-rays can be determined with an accuracy of 10 arc s.

The scientific payload comprises an array of collimated gas-filled proportional counters for the measurement of medium/hard X-rays and grazing-incidence X-ray reflecting mirrors with proportional counters and channel plates as focal-plane instruments for the measurement of soft X-rays. Spectral features in sources are to be determined by using the intrinsic, relatively broad, energy resolution of the gas-filled counters, together with broad-band filters, while for point-like sources of soft X-rays high-resolution spectroscopy will be achieved by using a transmission grating as a dispersive element in conjunction with the imaging telescope (Fig. 1).

The time structure of X-ray emissions from sources can be determined down to fractions of a millisecond by using a highly stable clock on board the spacecraft.

The detection of X-rays down to a fraction of a kilovolt requires that the detectors be equipped with ultra-thin windows (37 μm beryllium).

Exosat is a three-axis-stabilised satellite with an approximately cylindrical body, with a maximum diameter of 218 cm and a height of 134 cm. A rotatable solar array with an area of 3 m^2 is mounted on the spacecraft (Fig. 2). Two S-band antennas are deployed on booms below the cylinder. The experiments are mounted in a light-tight clean bench and look out of the side of the cylinder. They may be protected by deployable covers. Two star trackers are also mounted alongside the experiments. All on-board items having high alignment requirements are mounted on the same central platform, which consists of a skin of carbon-fibre-reinforced plastic over a thick aluminium honeycomb core.

An attitude and orbit control subsystem provides for three-axis control and stabilisation of the satellite body, and for orbit-correction gas-jet impulses needed to achieve lunar occultation of X-ray objects of interest. Attitude reference is provided by a gyroscope platform, calibrated and reset periodically from a precision star tracker. An on-board computer forms a basic part of the data-handling system, being used primarily for experiment data reduction.

The Exosat observatory is to be launched into a highly eccentric orbit (apogee around 200 000 km, perigee 300 km, inclination approximately 80°) by an Ariane-1 vehicle supplemented by a fourth

Figure 1 – Exploded view of the Exosat satellite, showing the major elements of both spacecraft and scientific payload

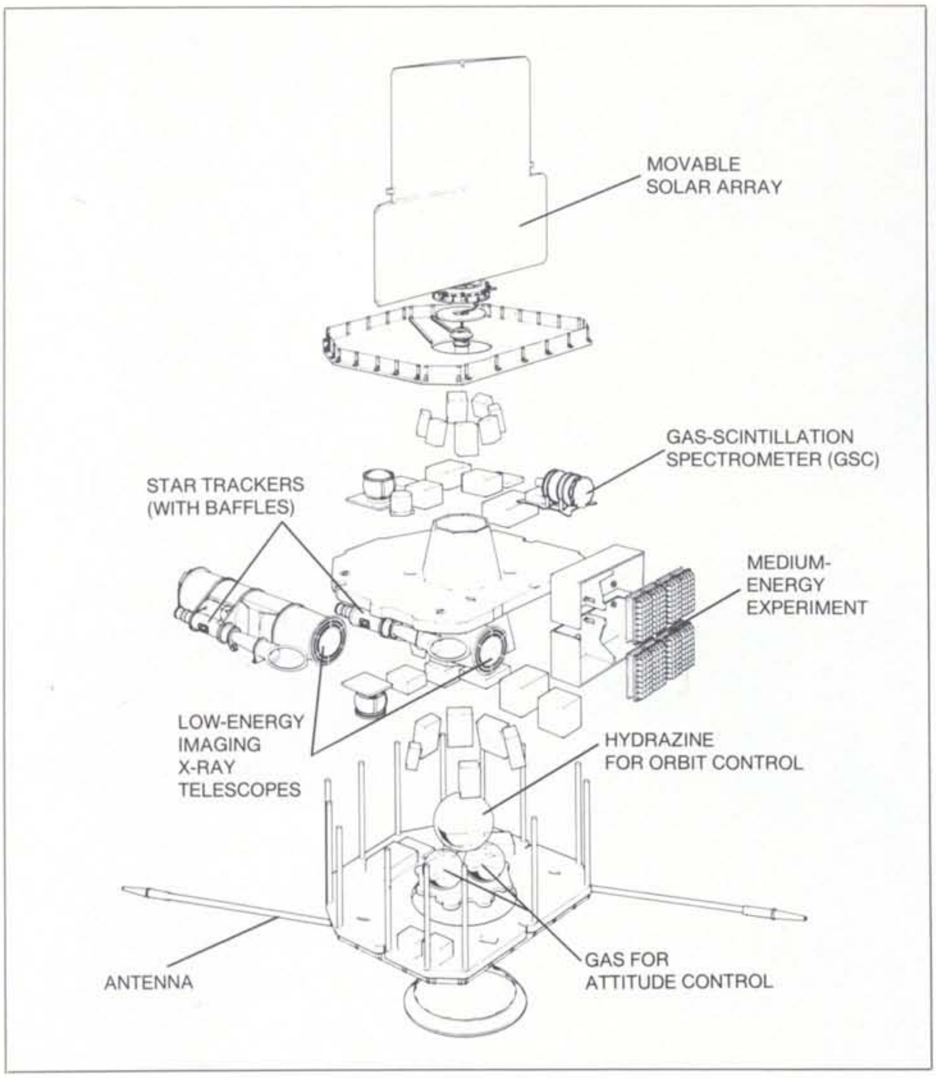
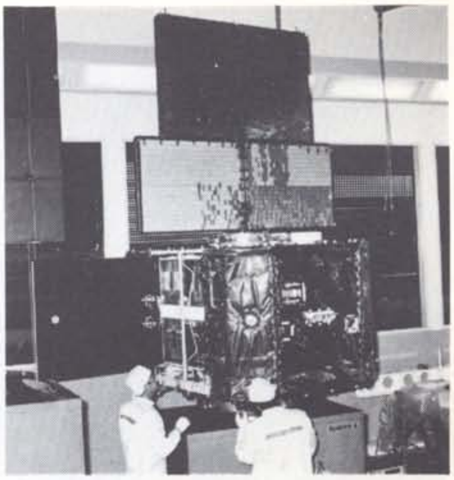


Figure 2 – The Exosat engineering model



stage. The choice of orbit has been dictated primarily by the requirement to maximise the number of possible occultations and to permit long uninterrupted contact times with the ground-station at Villafranca (Madrid), whenever the experiment provides useful data, i.e. during the 80 h spent outside the Van Allen Belts during each 96 h orbit.

The two operating modes of the experiment are:

(i) An occultation mode, in which primarily the moon and occasionally the earth will serve as occulting bodies. This mode will allow at least a 20% coverage of the sky in one year. The same classical technique when used from the ground (moon occultation) leads to a mere 8% coverage over a period of 18 years.

(ii) An arbitrary pointing mode, which requires long time intervals to study the temporal and spectral variability of sources.

The programme schedule is aimed at a launch date at the end of November 1981, nominally the 24th. The engineering model, used for a range of functional and environmental tests and fitted with real on-board units, has progressed considerably at the main contractor's plant (Messerschmitt-Bölkow-Blohm GmbH), but has suffered from the late delivery of certain units. The protoflight model programme is expected to suffer from similar delays and the integration sequence, due to start towards the end of 1980, will have to be reviewed accordingly.

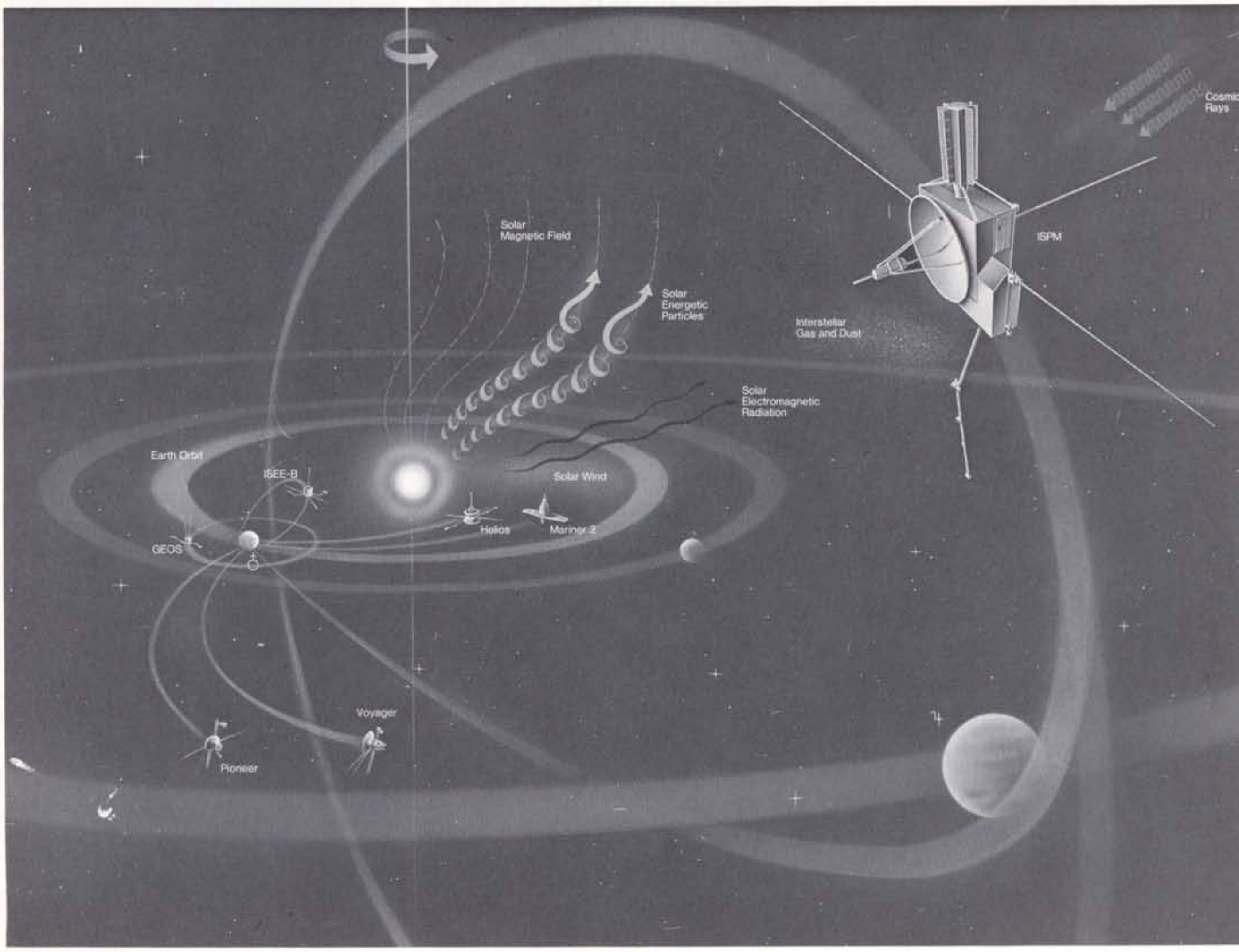
The Exosat ground-station antenna for Villafranca has recently been ordered.

Overall, the programme schedule appears to be tight, but still realistic. The first and successful Ariane development flight provided a check on the environment to which the satellite will be subjected during launch, and this has served to increase confidence in the mission.

The International Solar-Polar Mission (ISPM)

The International Solar-Polar Mission (ISPM) is a two-spacecraft, ESA/NASA collaborative programme and it will be the first project in which spacecraft have been placed in heliocentric orbits almost at right angles to the ecliptic plane (Fig. 3). In view of the number of spacecraft that have been launched in the last two decades, it is worth recalling that, with one exception, all have been confined essentially to the ecliptic plane and that observation of the sun has therefore been limited to solar latitudes within ±7° of the solar equator (the exception is Pioneer-II, which reached 17°).

Figure 3 – Artist's impression of the concept of the International Solar-Polar Mission (ISPM)



The main scientific goal of ISPM is to replace this current parochial view by an exploration of the heliosphere over the full range of heliographic latitudes and thereby obtain a more accurate assessment of the total solar environment.

The main items to be addressed by the ESA mission are solar coronae, solar winds, structure of the sun/wind interface, heliospheric magnetic fields, solar and nonsolar cosmic rays, and interstellar and interplanetary neutral gas and dust.

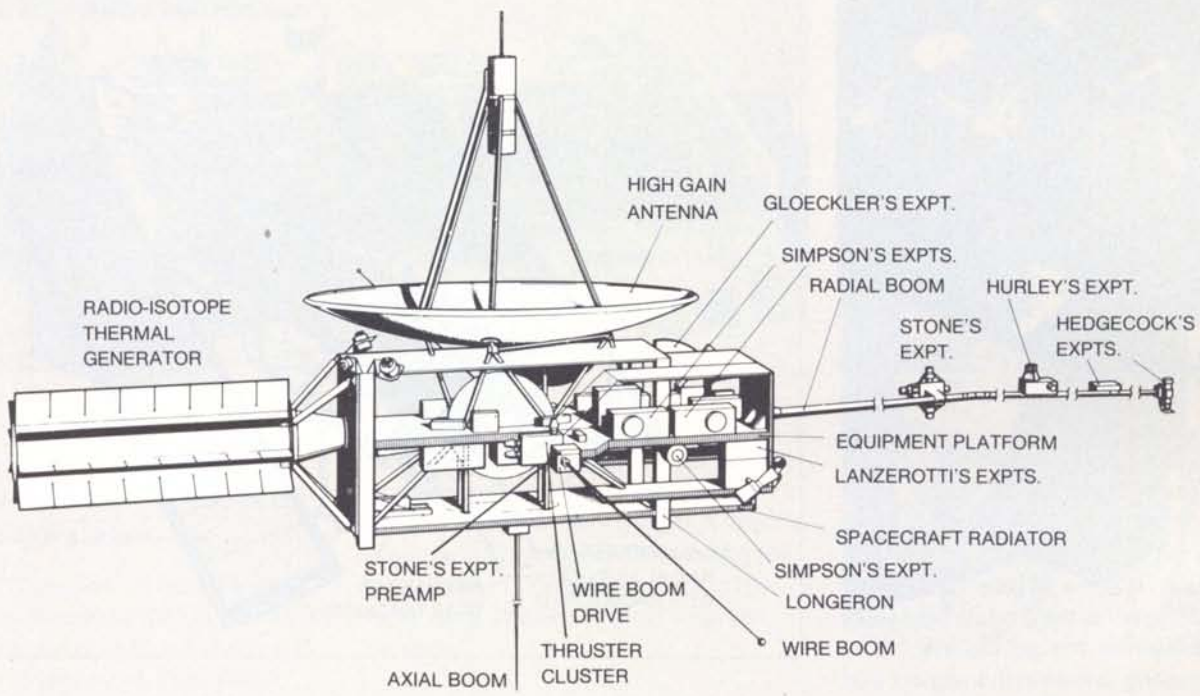
It is also intended to make use of the spacecraft telemetry system for radio-science observations.

The wide interest of the world scientific community in the ISPM mission is reflected in the large number of investigators taking part – a total of more than 200 scientists, both principal and co-investigators, from 65 universities and research institutes in 13 countries.

The satellite will spin at approximately 5 rpm during the operational part of the mission, but will have to cope with a 70 rpm spin during the IUS powered flight. A number of essential features of the 2.44 m × 1.52 m satellite (Fig. 4) are dictated by mission requirements:

- A 1.65 m dish antenna fed by a 20 W X-band transmitter will satisfy the communication requirements at Jupiter distances.
- A data store (two redundant tape recorders) will ensure continuity of data when the spacecraft is not being tracked by the ground network.
- The spacecraft is to be powered by a radio-isotope thermal generator (RTG), provided by NASA and producing 9000 W.
- A hydrazine reaction control system has been provided to undertake both the major targeting manoeuvre near Jupiter and the frequent attitude manoeuvres to keep the spacecraft antenna pointing towards earth.

Figure 4 – Overall layout of the ESA spacecraft for the ISPM mission



The ISPM mission was originally scheduled for a launch in February 1983 using the Shuttle and the Inertial Upper Stage (IUS) in a double-launch configuration. As a consequence of the severe cuts that NASA was obliged to make in its programme in March this year, it has recently been announced that this baseline programme is no longer feasible and a new baseline has been defined with two separate launches in March 1985. After consultation with the Agency's deliberating bodies, the ESA Executive has decided to continue with the programme, despite the inevitable financial consequences of this two-year delay.

From a mission profile point of view, however, the separate launches do not essentially change the strategy or the operational phase. After separation from the Shuttle of the IUS/spacecraft combination, the IUS will be fired so as to put the combination on an interplanetary trajectory towards Jupiter. Following burn-out and separation from the IUS, the spacecraft will be targeted to go slightly north or south of the Jovian equator. By using Jupiter's gravitational well, the spacecraft will undergo a sling-shot effect and be thrown out of the ecliptic plane over one pole of the sun.

The jovian encounter will occur some 16 months after launch and the full mission is planned to last about four and a half years. The main characteristics of the operational phase are:

- closest approach to the sun (perihelion) 1.2 astronomical units, for thermal reasons
- maximum distance from the sun at maximum latitude 2 astronomical units, for scientific reasons
- total time spent above 70° latitude 215 d $\pm$ 25 d, depending on whether a northbound or southbound pass over the sun
- north and south-travelling spacecraft to have approximately mirror-image solar orbits to allow simultaneous observations.

NASA's decision to postpone launch by two years has been taken shortly after the beginning of the development phase, that is to say at a time when the European Consortium led by Dornier System GmbH has reached maximum strength and when all long-lead items have been ordered. As a result, the financial consequences will be severe, even with the cooperation of all participants in minimising them by rearranging the programme in the least damaging way. In principle, however, this unforseeable setback should not affect the ISPM mission's final success.

The Space Telescope (ST)

The Space Telescope is an unmanned, multipurpose optical telescope observatory planned for launch into earth orbit by the Space Shuttle in the last quarter of 1983 (Fig. 5). The major scientific goal of the Space Telescope is quite simply to enhance the astronomer's capacity for observation by removing the effects of the earth's atmosphere. Compared to observation from earth

Figure 5 – The Space Telescope

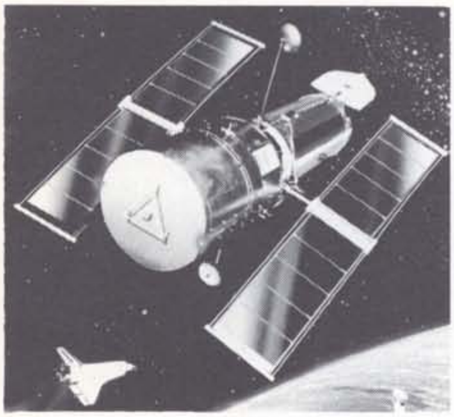
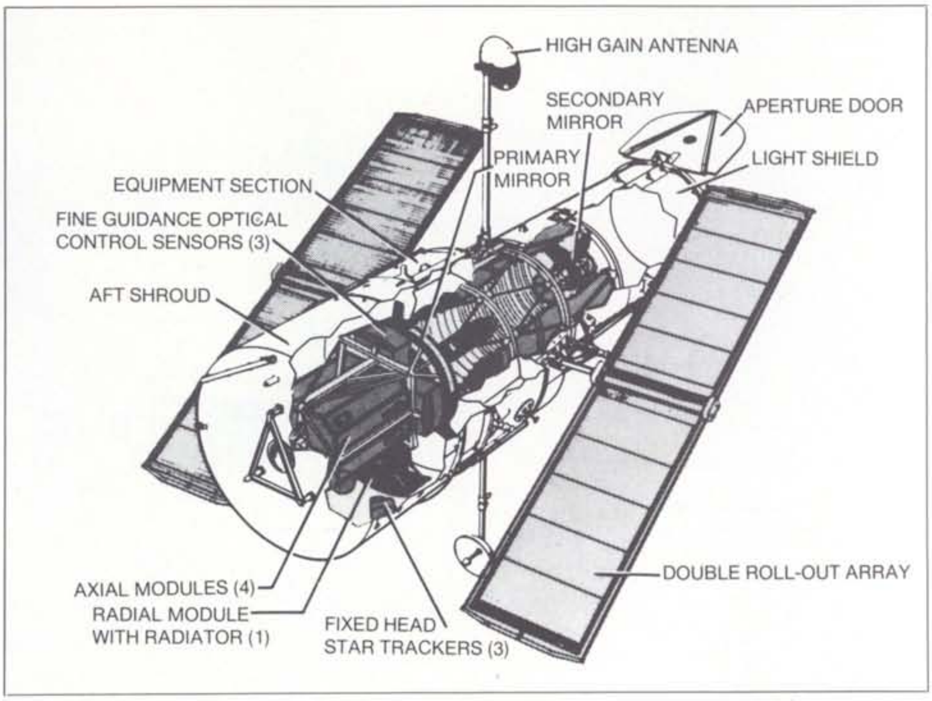


Figure 6 – Main elements in the Space Telescope's make-up



using the best ground-based telescopes, the privileged position of the Space Telescope will allow the astronomer to:

- see further into space, and therefore in time, i.e. some 14 billion light years as opposed to the 2 billion light years possible from the ground. It is interesting to note in this respect that some scientists believe that the universe was formed nearly 14 billion years ago
- see objects that are 50 times fainter
- get sharper images (by a factor 10) because of the possibility of making long exposures
- obtain an extremely good spatial (angular) resolution
- gain access to ultraviolet and infrared radiation normally absorbed by the atmospheric material
- more than double available observation time each year (4500 h compared to 2000 h with an excellent ground observatory).

A comprehensive list of all the problems that will be put within reach of study by the launch of the Space Telescope would be too lengthy for inclusion here. Suffice it to mention:

- little-understood energy problems in celestial objects
- early stages of star and solar-system formation
- highly evolved objects such as supernovae remnants and white dwarfs
- the origin of the universe
- search for planets orbiting stars other than the sun, with an indication of the likelihood of the existence of other life-supporting planets.

Europe's contribution to the Space Telescope (Fig. 6) is threefold, embracing

- the solar array
- one of the five focal-plane instruments, namely the Faint Object Camera (FOC)
- participation in the institution that will be set up to exploit the Space Telescope.

The solar array will be the prime power source for the Space Telescope and ESA is providing both the array and its primary and secondary deployment/retraction and drive mechanisms. A total of 45 000 cells (each 2 cm × 4 cm) will be arranged on the 13 m × 2.5 m surface of this so-called 'flexible, roll-out type' array, designed to deliver 4000 W after 2 yr in orbit. Cell efficiency and radiation damage call for particular attention. The most stringent mechanical requirement placed on the solar-array subsystem and one that surfaced during the development of the Telescope's pointing and stabilisation control system, is the need to limit the interaction torque during slewing manoeuvres to 0.1 Nm (equivalent to the force exerted by a 10 g mass at the end of a 1 m long arm on earth).

The Faint Object Camera is the only instrument that will fully exploit the light-collection power and angular-resolution capabilities of the Space Telescope. The heart of the system is a photon-counting system coupled to two optical relays (*f*/48 and *f*/96) and associated electronics and other optical equipment in the so-called 'Camera Module' (Fig. 7). The Camera, which has a field of view ranging from 11×11 arc s^2 to 44×44 arc s^2, can operate in a number of modes, including a very high resolution mode included in *f*/96 so that *f*/288 is achieved; a spectrographic mode to achieve two-dimensional spectroscopy imaging; and a coronographic mode utilising a mask and apodizer.

The temperature of the optical-bench enclosure has to be maintained within ±0.5°C by active thermal control. The

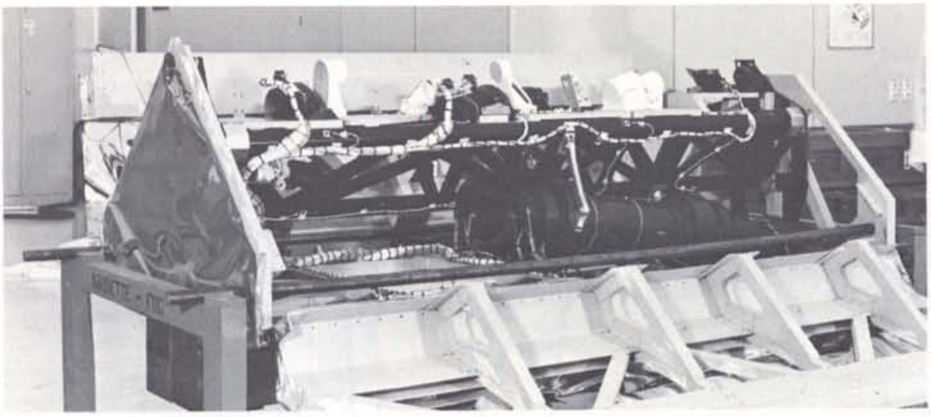


Figure 7 – The Space Telescope's Faint Object Camera (FOC)

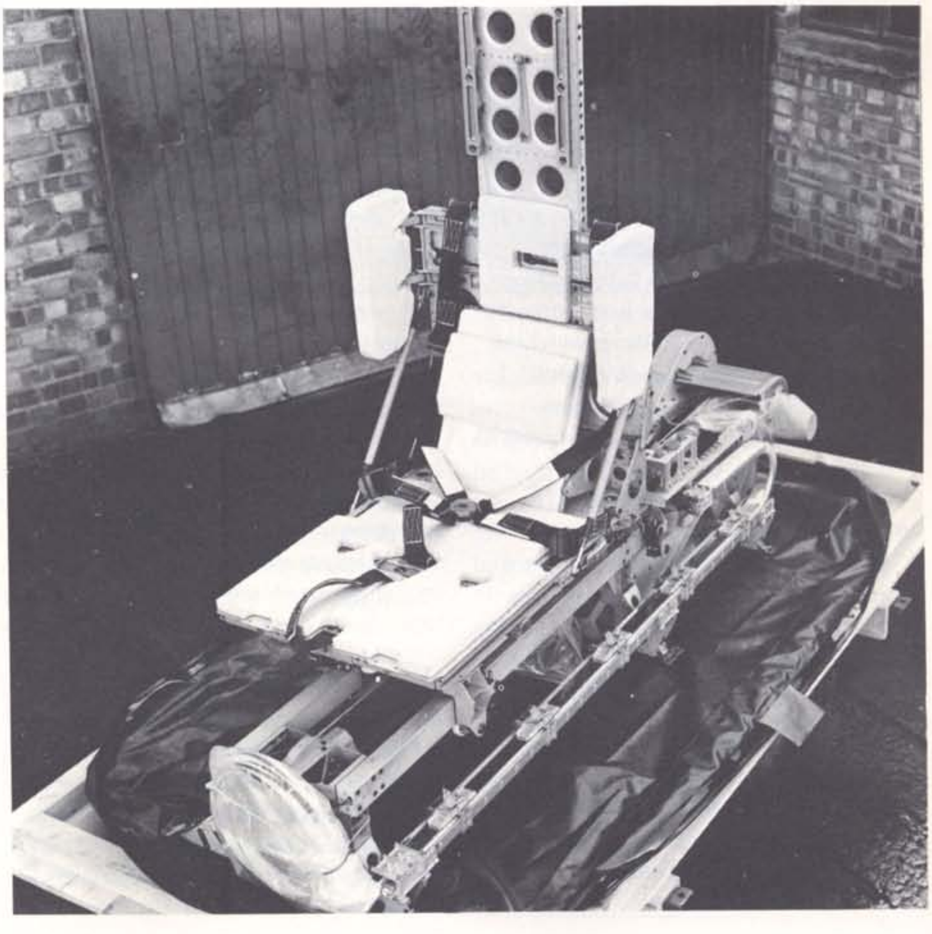


Figure 8 – Protoflight model of the Space Sled, built by Marshall of Cambridge (Eng.) Ltd.

Figure 9 – Simulation of the in-orbit replacement of the Space Telescope's Faint-Object Camera (tests performed in the neutral-buoyancy facility at Marshall Space Flight Center).

mass of the FOC is specified to be less than 317 kg, its power usage 150 W, and its dimensions 2 × 1 m^2.

The Space Telescope will orbit the earth at a nominal altitude of 500 km with an orbital inclination of 28.8°. It is planned to operate for 15 yr or more, and periodic refurbishment and/or updating of the equipment is foreseen in orbit. This of course imposes constraints on the design, since equipment units must be capable of being handled efficiently and safely by space-suited astronauts (Fig. 9). It is also intended to bring the Telescope, or sections of it, back to earth for extensive maintenance and overhaul.

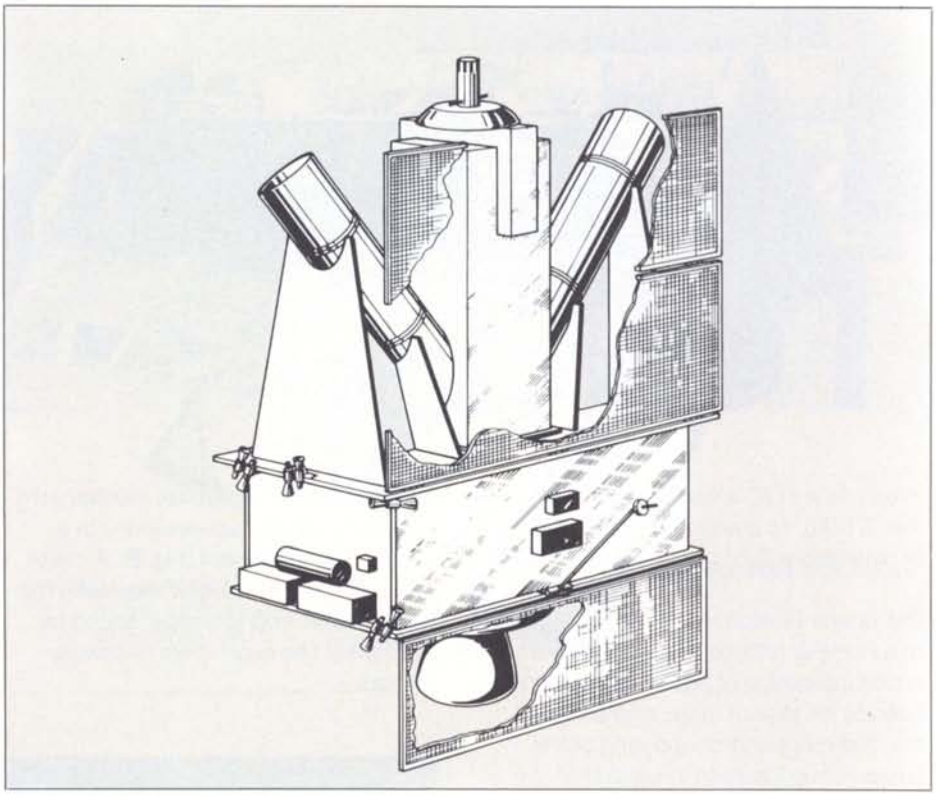
The five instruments aboard the Space Telescope will all be used for specific observations and their utilisation on targets of interest will be regulated by a continuously updated operations plan. Data will be transmitted back to earth via the American Tracking and Data Relay Satellite System (TDRSS).

The European portion of the project has entered the hardware phase and most of the units are almost ready for integration. Subsystem and environmental testing is scheduled to begin later this year. Delivery to the USA is foreseen for mid-1982.

The Sled

The Space Sled is a facility carrying experimental hardware for life-science investigations aboard Spacelab to determine human response mechanisms to controlled linear accelerations in a weightless environment (Fig. 8). A major objective is to find ways of alleviating the space motion sickness experienced by astronauts. The experiment hardware includes:

Figure 10 – The Hipparcos satellite



- sensors for making physiological measurements
- TV and photographic cameras for recording eye movements and skin pallor
- a TV monitor for producing visual stimulation patterns
- Peltier elements for heating and cooling balance organs, and
- an electrical stimulator for exciting muscle movements.

The Sled's design and its development programme have been described in detail the last issue of the Bulletin (No. 22, page 59) and these aspects will not be covered further here.

The Sled has been developed for and was to be flown on the First Spacelab Payload (FSLP). However, within the framework of a descoping exercise carried out to reduce the total mass of FSLP, it has now been decided to transfer the Sled to a later flight. Negotiations are presently under way to decide exactly which Spacelab flight will carry this experimental facility.

Hipparcos

The scientific goal of Hipparcos (Fig. 10) is to measure the five main astrometric parameters – distance (or trigonometric parallax), position (latitude and longitude) and proper motions (variations with time of latitude and longitude) – of about 100 000 selected stars, most of them brighter than magnitude 10. The expected average accuracy is in the range 1 to 2 marc s for the parallaxes and in each coordinate of the positions and proper motions per year.

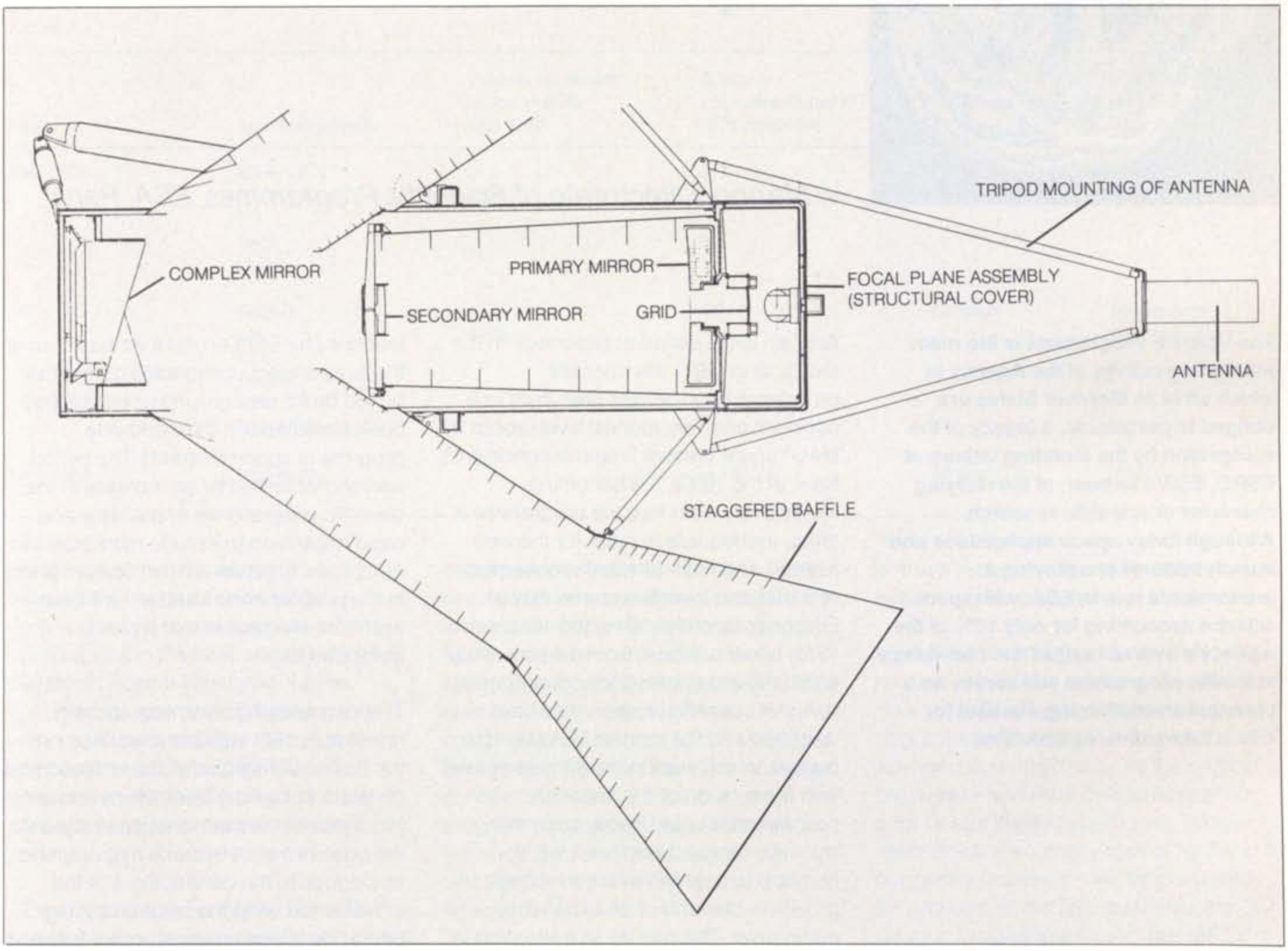
Such an order-of-magnitude improvement in precision and amount of data compared to present and imminent alternative possibilities can only be achieved with a dedicated astrometric instrument, operating in space and taking advantage of the zero gravity, the full-sky visibility, the constant thermal environment, and the absence of a refracting atmosphere.

The Hipparcos payload will contain a telescope with two fields of view separated by a large angle (about 69°) and imaged at a common focal plane, where there will be a set of grids in front of a photon counting detector. The angle between the two fields of view is to be maintained by a complex mirror in front of the telescope. The scanning motion of the satellite will cause the stellar images to travel across the telescope focal plane, allowing the angles between stars separated by approximately 69° to be measured. By numerically combining several million such angular measurements collected over a period of years, it will be possible to derive each star's astrometric parameters with the desired precision. While the design and development of the satellite/payload combination together with the collection of the raw measurements is the direct responsibility of the ESA scientific programme, falling within its mandatory budget, processing of the scientific data is to be the task of participating scientific establishments.

A tentative satellite configuration for Hipparcos has been derived based on the results of a Phase-A study conducted within ESA (Fig. 11); the final design will be the result of a competitive Phase-B (definition-phase) study by European industry.

The spacecraft structure has to accommodate the subsystem equipment, the apogee boost motor and, last but not least, the payload attached to a platform at three hard points with an isostatic mount. The satellite's power requirements (280 W average during the mission, and 73 W average during transfer orbit) can be satisfied with a large fixed solar array and two smaller deployable panels. The antenna configuration must provide spherical coverage for all modes of operation: fixed antennas on the top and bottom of the satellite will satisfy this requirement. The data-handling subsystem is to be based on the standard on-board data-handling concept, and may feature either a dedicated processor

Figure 11 – General layout of the Hipparcos payload



or several independent micro-processors. A continuously acting control system with reaction wheels has been selected as the attitude and orbit control system baseline for cost reasons, although a solution based on intermittent control with cold gas jets is theoretically possible. In view of the very widely differing thermal-control requirements of satellite and payload (e.g. temperature gradient across the complete mirror not to exceed 0.05°C during 3 h), it is considered advisable to decouple thermally the spacecraft and its payload.

Hipparcos will be launched by Ariane – either an Ariane-1 or an improved version such as Ariane-2 or 3. In all cases the spacecraft is compatible with a dual launch using the Sylda (Système de lancement double Ariane) facility. Active nutation damping during the transfer orbit will make the configuration stable during this phase. The final orbit will be almost geostationary, with an inclination of less than 3°. The satellite's scanning motion will result from the composition of two rotations:

- a spinning motion about the axis perpendicular to the plane containing the axis of the two fields of view at a rate of 10 rev/d, allowing a great circle to be scanned in 2.4 h
- a slow revolution of this same axis around the satellite/sun line at a rate of 7.5 rev/yr.

The raw scientific data are to be processed iteratively on the ground in order to achieve the requisite final accuracy in the observed parameters.

The Hipparcos programme was selected by the Scientific Programme Committee for inclusion in the Agency's mandatory scientific programme in March 1980, after completion of a feasibility study. Efforts are now underway to prepare the Invitation to Tender with a view to selecting two industrial contractors to undertake the competitive design phase. The commencement of this industrial phase is presently scheduled for mid-1981.

ESA's Science Programme: The Present Situation and Future Perspectives

V. Manno, Directorate of Scientific Programmes, ESA, Paris

The Science Programme is the main mandatory activity of the Agency in which all of its Member States are obliged to participate, a legacy of the recognition by the founding fathers of ESRO, ESA's forbear, of the unifying character of scientific research. Although today space applications and launch systems are playing a predominant role in ESA, with space science accounting for only 15% of the Agency's overall budget, the mandatory scientific programme still serves as a core and strengthening element for ESA's future diverse activities.

After an initial period of expansion in the sixties, since 1971 the scientific programme budget has been held to a constant and very modest level (about 80 MAU* under present financial conditions). Now, in the 1980s, it is becoming increasingly clear that the programme is totally inadequate to cater for the well-justified and multi-facetted requirements of a vital and inventive community of European scientists. Over the years since 1971, under pressure from the potentially profit-making applications programmes, national scientific programmes have dwindled and the modest ESA scientific budget, which even in the early seventies, with the support of the national programmes, could barely cope with scientific demand, has been left in isolation to contend with the normal growth in demand of an expanding community. This has led to a situation in which, while both the size of the community and its scientific needs have been increasing as space science has matured and developed towards more complex and sophisticated systems, and while NASA has been planning for major facilities and a breakthrough in space science, ESA has only been able to proceed at a comparatively slow pace, which has rapidly become subcritical. This scenario is borne out by an examination of the accompanying table (Table 1), where the main characteristics of past and present scientific programmes are indicated, and where a number of clearly distinguishable 'periods' emerge.

In the first, pre-1970 period, all projects were totally conceived and realised in Europe, NASA only providing free launches for ESRO-I and II. At least four of the eight projects conducted during this period broke new ground or established basic landmarks in the worldwide progress of space research. The period was characterised by an increase in the scientific programmes and a clear and rapid expansion to include more scientific disciplines, together with an upward trend in the political will to support ambitious and front-line research at a purely European level.

This encouraging trend was abruptly reversed in 1971 with the imposition on the Science Programme of a reduced and constant budgetary level, which was only two-thirds of the then forecasted need. All the positive trends became negative and analogous to the development of the universe following the creationary 'big bang', 'deceleration and cooling' followed the initial excitation. Only one parameter showed an upward trend, namely cooperation with NASA, which came to be part of two projects in every three.

This last development deserves further analysis. Space science, in passing from infancy to maturity, followed a path of increasing sophistication, complexity and cost, just like any other branch of science. Certainly a learning process has occurred in ESA as well as in industry and systems have become less expensive. However, the progress of science and the growth in requirements has far outweighed the reduction in costs associated with increased experience and efficiency. The 'straight-jacket' of an inflexible budgetary situation has placed ESA in a position of

* 1 Accounting Unit (AU) = ± 1.2 US $

Table 1

Period	Approved projects	Projects conducted in cooperation with NASA	Budgetary commitments (MAU*) 1978 conditions	Budget profile	Scientific programme value trend
1964–1970	ESRO I, II, IV HEOS I, II TD Geos Cos-B	2 (25%)	811	increasing	'little bang'
1971–1977	Geos-2 IUE ISEE Exosat ISPM Space Telescope	4 (66%)	498	constant	'deceleration and cooling'
1978–1984	Hipparcos		~440 (?)	constant (?)	'collapse' (?)

being increasingly incapable of meeting the needs of a scientific community that has to compete with its counterparts in the USA and the USSR. It therefore became imperative for the European groups and ESA itself, if they were not to be completely excluded from front-line research, to enter into cooperation with NASA on what are at present the major projects in space science.

Consequently, the European scientific programme is presently heavily committed to cooperative ESA/NASA projects. Of the four projects now in the course of development, the International Solar Polar Mission (ISPM), the Space Telescope and, albeit for a different reason, the Sled, are being conducted in cooperation with NASA, and only Exosat stands out as a purely European enterprise. This should in no way be understood as implying a criticism of the basic principle of cooperation. Indeed, quite the contrary; cooperation on major projects may be advantageous for both parties as it can present an intellectual challenge that can only be met on a worldwide scale. However, the freer the motivation from plain economic constraints, the more fruitful the cooperation will be.

In the European context, however, cooperation with NASA has all too often been taken as a convenient substitute for an increased effort on a European scale. Such a situation cannot be allowed to continue much longer because NASA is itself becoming more and more conditioned by external constraints, and Europe and ESA can therefore no longer confidently take as the basis for its programme projects that are subject to the uncertainties of the political circumstances prevailing across the Atlantic.

The third period identified in our tabulation (1978–1984) has only just started. The first approved future project is Hipparcos, an ambitious facility designed to measure the five principal astrometric parameters of some 100 000 stars with an as yet unparalleled accuracy of a few milliseconds of arc. No doubt the use of Hipparcos will have an impact extending well beyond the spheres of the classical 'customers' of ESA's Science Programme. It is a difficult project and, in the interests of all parties concerned, ESA will exercise the utmost control over its development.

What then is next after Hipparcos? As indicated in the table, if the budget remains constant and the project funding philosophy continues unchanged, ESA will only be able to approve a further two or three projects in the 1978–1984 period, depending on the total cost of each.

A prominent candidate for the next mission selection is a flyby of Comet Halley in 1986 (Fig. 1). This project, the only potential cometary mission to be salvaged from the demise of the originally proposed ESA/NASA cooperative effort on a Comet Halley flyby/Comet Tempel 2 rendezvous – another victim of NASA's budgetary problems – will be presented for approval at the July session of the ESA Science Programme Committee (SPC)*. It is possible that NASA may eventually propose to participate in this venture by supplying a Thor-Delta launcher and the deep-space network. As part of that agreement, NASA would then furnish some experiments for the payload.

Looking a little further ahead, the projects presently being considered in the planning cycle with a view to a decision in 1982 consist of one proposal in the planetary domain, the Polar Orbiting Lunar Observatory (POLO), a second in the magnetospheric research area (Eiscat-Sat) for observation of the auroral zone in combination with the ground-based Eiscat facility, a third, the Grazing-

* Approval given by SPC on 8 July. Further details will appear in ESA Bulletin No. 24.

Figure 1 – Spacecraft concept for the Comet Halley rendezvous in 1986

Incidence Solar Telescope on Spacelab (Grist) conceived to measure, simultaneously with a NASA-produced optical telescope (SOT), the emission of the sun, and a fourth, the Infrared Space Observatory (ISO). These missions will be the subject of rigorous feasibility studies throughout 1980 and early 1981.

A new planning cycle will soon be initiated, to lead up to the decisions subsequent to those relevant to the above projects.

A planning cycle is started approximately once every two years, before project approval by the SPC, with an initial Call for Mission Proposals to the scientific community. The replies are evaluated by the Agency's scientific advisory groups – for example, for the classical disciplines, by the Astronomy Working Group (AWG) and the Solar System Working Group (SSWG) – and by the senior scientific advisory body of ESA, the Science Advisory Committee (SAC). The missions selected (eight or nine) are subjected to an initial assessment in which their scientific, technical and programme contents are assessed and costs established on a preliminary basis. After a further screening by the scientific advisory bodies, a reduced number of missions (three or four) are carried forward to an in-depth feasibility study. It is only at the termination of such studies that a decision on the development of one or more of the projects still in contention is taken.

It is difficult to say at this moment what will be the content of the next planning cycle as this will depend very substantially on the results of current discussions on the aims and priorities of the Agency's scientific programme. There is no doubt that the programme is at a crossroads, and that an increase in its budget is absolutely essential. Failing this, analogous to the evolution of a 'closed' universe, the ESA Science Programme may eventually collapse. In fact, if the trends apparent in the second period (1971–1977) that we have reviewed are allowed to continue, it can confidently be predicted that European space science will eventually be excluded from many fields where a certain maturity has already been attained and where complex systems costing several hundred million dollars are required, such as:

- optical astronomy and UV astronomy today's front-runner being the NASA Space Telescope to which the European contribution is only marginal
- X-ray astronomy the future front-runner being the NASA-proposed AXAF telescope
- gamma-ray astronomy the Gamma-Ray Observatory studied by NASA being the front-runner
- solar/terrestrial relations where programmes such as the NASA multisatellite OPEN system are the front-runners
- solar observations where simultaneous observations will be needed, requiring either several Spacelab flights of integrated payloads or a free-flying solar observatory.

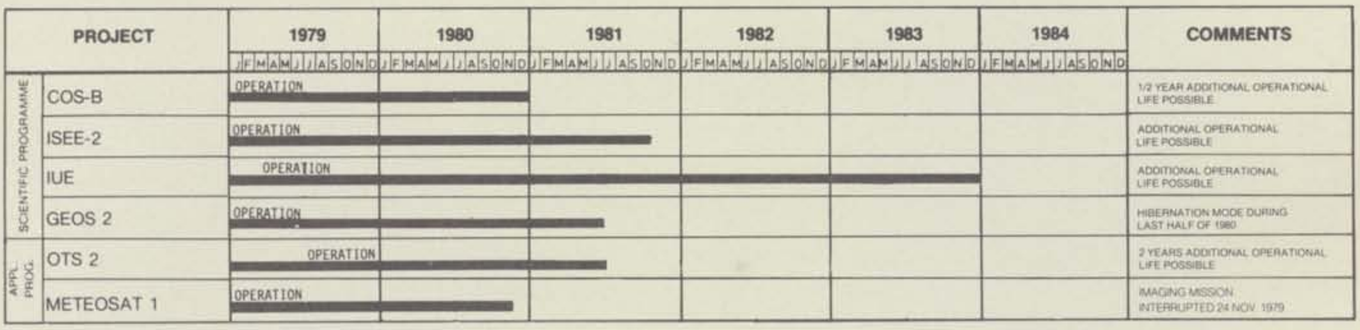
In addition, aside from its incapacity to even continue in fields in which Europe has had the lead, such as gamma-ray astronomy with Cos-B, it is hard to believe that in the present climate ESA could ever enter, of its own volition, the challenging but costly fields of infrared astronomy or planetary missions.

If no substantial increase in financial support is forthcoming, ESA will eventually only be in a position to undertake primary survey, exploratory and specialised missions in support, at best, of other agencies' major facilities. Europe could soon reach the point where it will be forced to renounce ambitions in certain scientific domains because, due to the sporadic nature of the support that can be offered to the sciences that have a dependence on space, those sciences will tend to decay and will no longer be in the situation of being able to propose first-rate space-science projects from which ESA can make its choice.

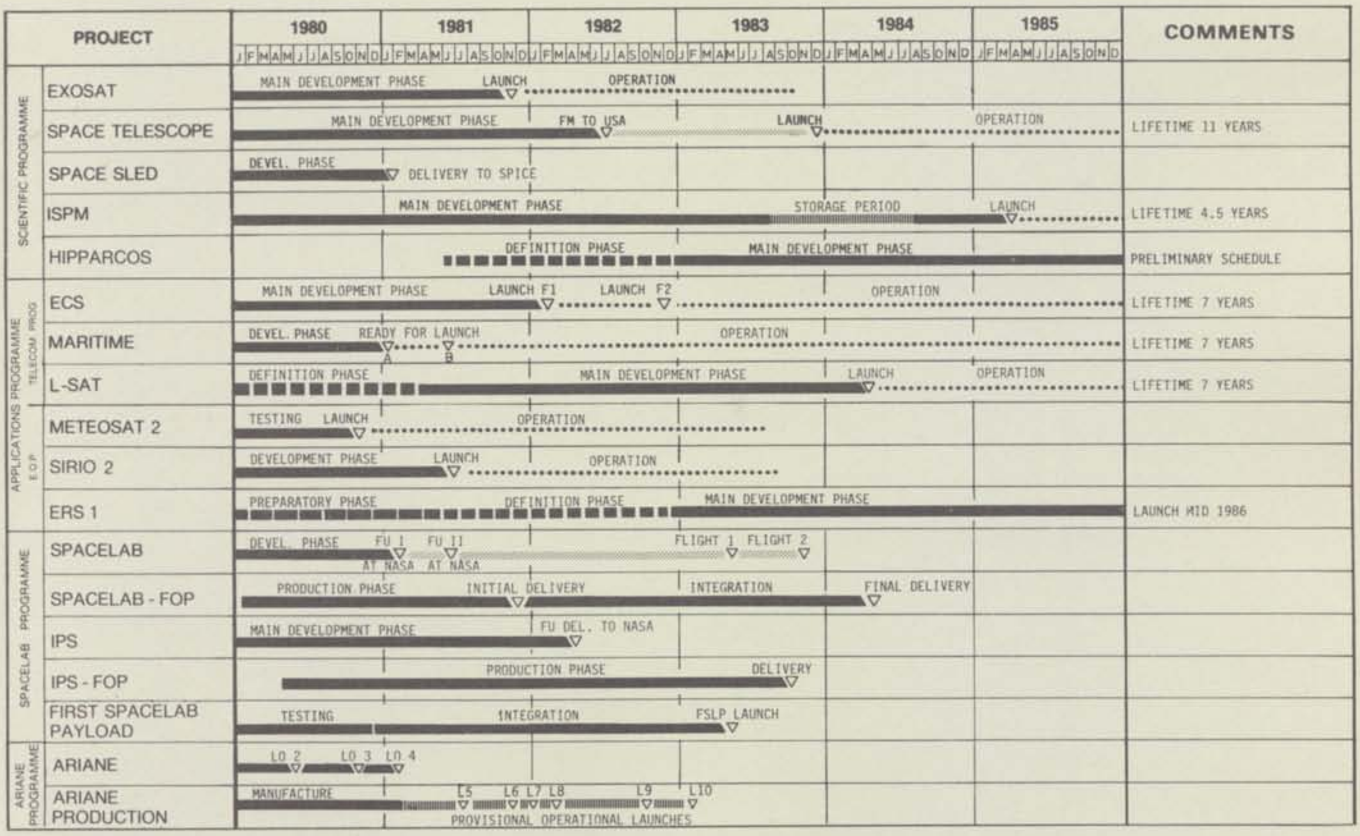
The criticality of the situation is well recognised within ESA and its Member States. All the elements touched on above have been, and continue to be, the subject of spirited discussions both internally and with the Delegations of Member States, in the context of appraisal of the future aims and programmes of the Agency. Much will depend on the outcome of the present discussions as to whether the ESA Science Programme will again be allowed to meet the scientific requirements of a vigorous and independent European scientific community and to resume its role as a rallying point for all the Agency's Member States, in accordance with the primary aim of the Agency's founders in establishing the scientific programme.

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

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status and bar chart valid per 1 June 1980.

Etat des projets et planning au 1er juin 1980.

Cos-B

Aucune modification importante n'est à signaler dans le fonctionnement de Cos-B depuis le dernier rapport. En avril, le gaz de la chambre à étincelles a été chassé et le plein a été refait. L'intervalle de 144 jours écoulé depuis la précédente opération de même nature était le plus long enregistré jusqu'ici. Il reste suffisamment de gaz pour procéder à une nouvelle chasse de gaz, de sorte que la poursuite des opérations au moins jusqu'à la fin de cette année reste techniquement faisable. Le soutien financier est assuré au moins jusqu'à fin août.

Le nouveau gaz a amélioré l'efficacité globale de la chambre à étincelles mais on constate un déséquilibre évident entre les performances des espaces interélectrodes successifs. Ce phénomène, qui n'affecte que partiellement la capacité de détection et de mesure des rayons gamma, a été parfaitement maîtrisé dans le passé et c'est la première fois qu'il se reproduit depuis trois ans. Les mesures nécessaires ont été prises pour obtenir les meilleures performances possibles.

Les récentes observations ont notamment porté sur une étude du radiopulsar PSR1822-09 associée à des mesures radio simultanées effectuées par la Division 'Radiophysique' du CSIRO (Australian Commonwealth Scientific and Industrial Research Organisation). Ces travaux s'effectuent dans le cadre de la coopération entre le CSIRO et le groupe Caravane – qui réunit les responsables des expériences Cos-B – et ont pour objet de détecter les rayons gamma émis par des radiopulsars sélectionnés et de rechercher de nouveaux radiopulsars dans les 'boîtes d'erreur' des sources de rayons gamma détectées par le satellite. La collaboration Caravane participe également à d'autres activités conjointes, et notamment à une recherche similaire effectuée par l'Observatoire radio du NAIC (National Astronomy and Ionospheric Centre) à Arecibo (Porto Rico). Une recherche de sources de rayons-X dans les 'boîtes d'erreur' de Cos-B est également entreprise, à titre d'observation 'hôte', par l'Observatoire Einstein.

Geos-2

Les opérations suivantes ont été exécutées au cours de la période couverte: manoeuvre d'inversion de l'axe de rotation le 18 mars, déplacement en longitude jusqu'au point d'intersection des équateurs géographique et géomagnétique (18 avril – 4 mai), demi-inversion en ce point et nouvelle manoeuvre de déplacement jusqu'à la longitude magnétique de la Scandinavie.

A la mi-avril, le signal de sortie selon l'axe Z du magnétomètre à noyau saturé a atteint la saturation. On ne dispose donc plus de données en provenance de cette expérience fondamentale. Les seules informations sur l'orientation magnétique dont on dispose dorénavant sont celles fournies par la sortie combinée du magnétomètre à bobine exploratrice et de l'expérience de résonance, et ce à intervalles de 11 minutes seulement par suite du fonctionnement peu fréquent de cette dernière.

A la suite d'une demande faite par la Délégation du Royaume-Uni au Comité du programme scientifique, et avec l'accord de la majorité des expérimentateurs, Geos-2 fonctionnera à plein temps jusqu'au 31 juillet 1980. Ce mois de prolongation en sus de la durée de vie opérationnelle financée sera possible en abrégeant de deux mois la période de fonctionnement à mi-temps envisagée en 1981. On projette maintenant de mettre Geos-2 en hibernation du 1er août 1980 au 28 février 1981 et de ne le remettre en activité que pour 4 mois, en liaison avec l'installation EISCAT, du 1er mars au 30 juin 1981. A l'occasion d'un symposium qui s'est déroulé à Bournemouth, les expérimentateurs Geos ont pu avoir avec les représentants de l'Association scientifique EISCAT une réunion à laquelle des plans préliminaires ont été dressés pour un travail commun des deux systèmes. (EISCAT est le sondeur radar européen à diffusion non cohérente utilisé pour suivre les mouvements propres aux couches supérieures de l'atmosphère).

ISEE

La mission est entrée dans la deuxième année d'opération simultanée des trois véhicules spatiaux et continue à se dérouler normalement et à fournir des résultats scientifiques détaillés.

Les véhicules spatiaux sont toujours en bonne condition. Les réserves de gaz pour les commandes sont suffisantes à bord pour 5 à 10 ans d'opérations au rythme actuel d'utilisation. La récupération des données est satisfaisante, elle dépasse la plupart du temps 65% pour les trois satellites simultanément. Depuis le dernier rapport, certains instruments ont posé des problèmes. En mars, l'instrument de Garching pour l'étude du plasma énergétique, sur ISEE-2, est tombé en panne après l'une des longues périodes d'éclipse. Sur ISEE-3, un détecteur d'électrons de l'instrument de Berkeley et l'élément 'ions' de l'instrument de Los Alamos pour l'étude du plasma du vent solaire sont également tombés en panne. La défaillance de ce dernier instrument représente une perte importante pour la mission, encore que certains des paramètres de base du vent solaire puissent être obtenus par l'élément 'électrons' de l'instrument consacré au plasma et également par l'expérience sur la composition du plasma embarquée sur le même véhicule spatial.

La NASA a l'intention d'exploiter les véhicules spatiaux ISEE jusqu'au lancement de la mission OPEN, si le budget et l'état des véhicules spatiaux s'y prêtent. On espère que l'ESA sera en mesure de supporter le coût modique de l'exploitation d'ISEE-2 aussi longtemps que les résultats scientifiques le justifieront.

IUE

Sur les 171 propositions de programmes d'observations au moyen d'IUE que l'ESA a reçues pour 1980–1981, le comité de sélection en a retenu 121. Le programme est actuellement complet jusqu'en août et en bonne voie pour le reste de l'année. Un nouvel appel aux propositions devrait être lancé à la mi-juin.

Au cours d'une réunion des trois organismes participant au projet (NASA, ESA, Science Research Council du Royaume-Uni) qui s'est tenue au Goddard Space Flight Center en mai, il a été pris acte des points suivants:

- *le système d'alimentation en hydrazine accuse un accroissement*

Cos-B

The performance of Cos-B has shown no major change since the last report. In April the spark chamber gas was flushed and replenished. The interval of 144 days since the previous such operation was the longest so far. There remains sufficient gas for one more flushing so operation at least until the end of this year continues to appear technically feasible. Financial support is assured at least until the end of August.

With the new gas, the overall efficiency of the spark chamber is increased, but an imbalance in the performance of alternate gaps is evident. Such a situation, which only fractionally affects the ability to detect and measure gamma rays, has been completely cured in the past and this is the first occurrence for over three years. The necessary action to obtain the best possible performance has been initiated.

Recent observations have included an investigation of the radio pulsar PSR1822-09 with simultaneous radio measurements being made by the Radiophysics Division of the Australian Commonwealth Scientific and Industrial Research Organisation. This work is part of a collaborative venture by CSIRO and the Caravane group of Cos-B experimenters, aimed at detecting gamma-rays from selected radio pulsars and at searching for new radio pulsars in the positional error boxes of gamma-ray sources detected by Cos-B. The Caravane Collaboration is also participating in other joint efforts, including a similar search by the NAIC radio observatory at Arecibo, Puerto Rico. A search for X-ray sources in the Cos-B error boxes is being undertaken as a guest observation on the Einstein Observatory.

Geos-2

The following operations were carried out during the reporting period: a spin-axis inversion manoeuvre on 18 March, a longitudinal shift to the intersection point of the geographic and the geomagnetic equators (18/4–4/5), a half inversion at this point and a further shift manoeuvre to the magnetic longitude of Scandinavia.

In mid-April, the Z-axis output of the fluxgate magnetometer drifted into saturation. No more data is therefore available from this rather fundamental experiment. Magnetic attitude information is now available only from the combined output of the search-coil magnetometer and the resonance experiment, and due to the infrequent operation of the latter, only at 11 min intervals.

Following a request from the UK delegation to the Science Programme Committee and with the agreement of the majority of the experimenters, Geos-2 will be operated on a 24 h per day basis until 31 July 1980. This extension by one month beyond the funded operational lifetime has been arranged at the expense of two months of operation on a 12 h per day basis in 1981. It is now proposed to hibernate Geos-2 from 1 August 1980 to 28 February 1981 and reactivate it for only four months in conjunction with EISCAT from 1 March through 30 June 1981. On the occasion of a conference in Bournemouth, a meeting between Geos experimenters and representatives from the EISCAT Scientific Association has taken place and preliminary plans for the joint operation of the two facilities have been established. (EISCAT is the European Incoherent Scatter radar used for monitoring motions of the upper atmosphere.)

ISEE

The mission continues to run smoothly and to provide comprehensive scientific output. The mission is now in its second year of overlapping operation of all three spacecraft.

The spacecrafts' health remains good. The on-board control gas supplies will be sufficient for 5-10 yr of operations at the present rate. The data coverage is satisfactory, exceeding 65% overlap for the three spacecraft most of the time. Since the last report, some instrument problems have occurred. In March, the Garching fast plasma instrument on ISEE-2 failed after one of the long eclipse periods. On ISEE-3, an electron sensor of the Berkeley instrument and the ion portion of the Los Alamos solar-wind plasma instrument have also failed. The latter is a significant loss to the mission, but some of the basic solar-wind parameters can be derived from the electron portion of the plasma instrument and from the plasma composition experiment on the same spacecraft.

NASA intends to operate the ISEE spacecraft until the launch of the OPEN mission, spacecraft health and budget permitting. It is hoped that ESA will be able to support the modest cost of the ISEE-2 operation as long as the science output justifies it.

IUE

Following the receipt by ESA of 171 proposals for observations with IUE during 1980/81 the selection committee accepted 121. Scheduling is currently complete up to August and well in hand for the rest of the year. A new solicitation of proposals should be circulated in mid-June.

At a three-agency meeting (NASA/ESA/UK Science Research Council) at Goddard Space Flight Center in May, it was reported or agreed that:

- there was a systematic increase with time of the temperature of the hydrazine system, which is now under study. The present rate of increase, however, will not cause any operational problems until the mid-1980s, when other factors will affect the technical lifetime of IUE;
- a programme of evaluation for the second long-wave camera will be pursued in the next six months with a view to offering users a choice of long-wave cameras eventually;
- the exchange of archived data from NASA to ESA (and SRC) continues to lag behind the exchange in the other direction, but it is hoped this situation will be improved in the next months.

The retrieval of archived data at Vilspa has been interrupted due to staffing problems. These problems will be solved with the hiring of one extra contract-worker in June or July.

Two highlights of the many results announced recently from IUE are:

- the discovery of molecular carbon dissociation bands in a white-dwarf star
- an observation of the double quasar supporting the gravitational lens hypothesis by showing that the flux ratio in the UV is the same as that in the radio and that the optical flux of one component is contaminated by the lens galaxy.

régulier de température, sur lequel une étude est actuellement en cours. A son rythme actuel, toutefois, cette élévation thermique n'entrainera aucun problème opérationnel avant le milieu des années 1980, époque à laquelle d'autres facteurs influeront sur la durée de vie technique d'IUE;

- *un programme d'évaluation portant sur la deuxième chambre à grande longueur d'onde sera poursuivi au cours des six prochains mois, en vue de parvenir à offrir un choix aux utilisateurs pour ce type d'instrument;*
- *l'échange de données archivées dans le sens NASA-ESA (et SRC) reste en retard par rapport à l'autre sens, mais on espère voir s'améliorer la situation au cours des prochains mois.*

La ressaisie des données archivées à Vilspa a dû être interrompue par suite de problèmes d'effectifs. Ceux-ci seront résolus avec l'engagement d'un employé contractuel supplémentaire en juin ou juillet.

Parmi les nombreux résultats des observations IUE récemment annoncés, deux méritent plus particulièrement d'être cités:

- *des bandes de dissociation du carbone moléculaire ont été découvertes dans une étoile naine blanche;*
- *une observation faite sur le quasar double est venue corroborer l'hypothèse de la lentille gravitationnelle en montrant que le rapport de flux dans l'ultraviolet est le même que dans la partie radioélectrique du spectre et que le flux optique d'un composant est altéré par l'effet de lentille de la galaxie.*

Exosat

Satellite

A la suite de la livraison début avril du matériel manquant pour le système de commande d'orientation et de correction d'orbite (AOCS), la configuration du modèle d'identification *a pu être portée aux normes de construction prévues, ce qui a permis de procéder normalement aux essais fonctionnels. Bien que des solutions de rechange aient permis d'éviter une interruption du programme du modèle d'identification au cours des premiers mois de cette année, ce programme n'en a pas moins enregistré un glissement supplémentaire d'au moins deux mois. Les travaux se poursuivent actuellement avec les essais fonctionnels de l'AOCS et la mise au point définitive des logiciels connexes de vérification et de bord. Quelques problèmes techniques mineurs ont été décelés et sont en cours de solution. Le contractant fait un effort supplémentaire pour mener à bien les essais du système intégré qui doivent prouver la capacité de fonctionnement du satellite en plusieurs modes d'opération. La pression est forte sur le programme car un 'créneau' déterminé doit être respecté pour les essais de bilan thermique qui doivent se dérouler au CNES à Toulouse en août-septembre, il faut en outre réduire au minimum les chevauchements avec le programme du modèle de vol.*

Le modèle mécanique *a commencé à subir une série d'essais de qualification et les résultats de ceux qui ont déjà été exécutés – les essais sous charges acoustiques et statiques – sont satisfaisants. Un problème de résonance entre le réseau solaire et le corps du satellite décelé au cours des essais en vibration à faible niveau nécessite une révision de la conception des interfaces réseau solaire-mécanismes.*

La production, et dans certains cas les essais, des unités de rechange et de vol sont en bonne voie. Le lancement en novembre 1981 paraît toujours possible, à condition que les problèmes posés actuellement par la production des unités de la charge utile et par les essais de qualification du lanceur se révèlent mineurs et n'aient pas d'incidence sur le calendrier du programme du modèle de vol, qui est déjà très serré.

Charge utile

La fabrication des équipements de vol se poursuit suivant un calendrier extrêmement serré, aggravé encore par un certain nombre de problèmes apparus au cours des essais. Une perte de résolution, qui affecte à la fois les détecteurs moyenne énergie et faible énergie, pose un problème extrêmement préoccupant dont on s'efforce très activement de déterminer la cause.

Une modification du banc propre du télescope moyenne énergie, portant notamment sur le support du miroir, a été introduite dans le modèle mécanique, afin de faciliter les mesures de stabilité du miroir.

La réalisation du compteur proportionnel à gaz à scintillation se poursuit conformément au calendrier.

Ariane + P07 (4ème étage)

L'échec du tir L02 a eu sur Exosat une incidence immédiate en ce sens qu'on ne dispose pas de chiffres de performances pour le dispositif de suppression de l'effet pogo du 2ème étage ni pour les niveaux de contamination. On espère obtenir un certain nombre de données concernant les couvertures de protection acoustique grâce aux 60 premières secondes du vol.

Un tir d'essai au sol de P07, le moteur du 4ème étage d'Ariane, a été effectué au banc d'essai d'Istres, fin mai, et a été couronné de succès.

Activités ESOC

L'IPC s'est prononcé pour l'achat d'une nouvelle antenne de 15 m pour Exosat, qui doit être installée à la station sol de Villafranca, près de Madrid. La fabrication, la mise en place et les essais de recette de cette antenne doivent en principe être terminés pour le mois d'août.

Un examen de la conception du logiciel de traitement des données a eu lieu à l'ESTEC en mai et les travaux de mise au point de ce logiciel s'effectuent de façon satisfaisante. Dans le même temps un accord est intervenu avec l'ESOC sur une meilleure formule pour la production des bandes de données finales, qui devrait se traduire par une meilleure qualité de service pour les utilisateurs.

Télescope spatial

Réseau solaire

Un accord complet s'est fait avec les contractants sur l'introduction, par ces derniers, du nouvel impératif de limitation, à un très faible niveau, du couple d'interaction entre le réseau solaire et le Télescope spatial; le Comité de la Politique industrielle a approuvé l'avenant modifiant en conséquence le contrat sur le réseau solaire. L'examen de conception préliminaire du nouveau mécanisme d'entraînement du réseau solaire a été mené à bonne fin. Les progrès concernant la réalisation du réseau solaire sont conformes au calendrier établi. Les modèles pour les essais d'endurance des différents composants mécaniques critiques ont été fabriqués et montés; ils sont maintenant prêts à être soumis aux essais d'endurance.

Exosat

Following late delivery of the attitude and orbit control subsystem (AOCS) hardware early in April, the engineering-model configuration could be brought to its intended build standard, allowing the functional tests to proceed as planned. Although work-around solutions had helped to avoid an interruption of the engineering-model programme during the first months of this year, an additional slippage of almost two months resulted. Functional testing of the AOCS and finalisation of the associated checkout and orbital operations (OBC) software is presently in progress. Some minor technical problems have been detected and are being remedied. Extra effort is being deployed by the contractor to complete the integrated system tests, to prove the performance capabilities of the satellite in various operating modes. The programme is under strong pressure, as a fixed time slot for the thermal balance test at CNES (Toulouse) in August/September has to be met and overlap with the flight-model programme has to be minimised.

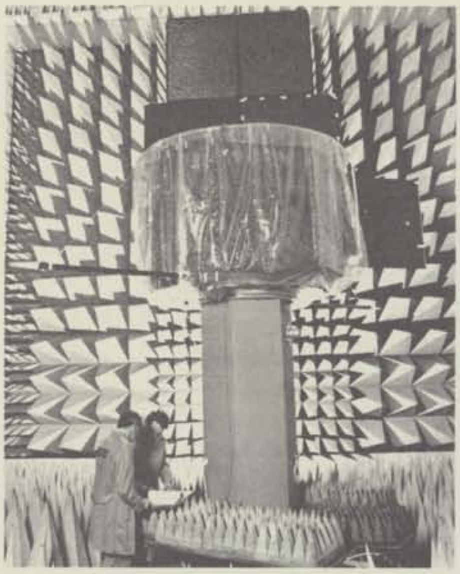
The mechanical model entered its qualification test sequence and satisfactory results can be reported for those tests already carried out (static-load and acoustic). A resonance problem between the solar array and main body of the spacecraft, detected during low-level vibration tests, calls for some redesign work on the solar-array-mechanisms interface.

Production, and in some cases testing, of spare and flight units is well under way. Launch in November 1981 still appears feasible, provided problems currently being experienced in the production of payload units and the launcher qualification test prove to be minor in nature and do not have an impact on the very tight flight-model programme.

Payload

Manufacture of flight units is proceeding within an extremely tight schedule, made worse by some problems exposed during testing. A drop in the resolution of both the medium- and low-energy detectors is causing most concern and is the subject of intense investigation.

A modification to the low-energy telescope clean bench, particularly at the mirror mounting, has been introduced on the mechanical model in order to facilitate easier measurement of mirror stability.



Exosat engineering model in the anechoic chamber at MBB, Ottobrunn

Modèle technologique d'Exosat dans la chambre anéchoique chez MBB, Ottobrunn

Production of the Gas Scintillation Proportional Counter remains on schedule.

Ariane + fourth stage

The immediate impact on Exosat of the L02 test-flight failure is the nonavailability of performance figures for the second-stage pogo-suppression device and contamination levels. Some data for the acoustic blankets are expected from the first minute of flight.

Ariane's fourth stage motor was successfully test-fired at the Istre test range at the end of May.

ESOC

A decision has been taken by the Agency's Industrial Policy Committee (IPC) in favour of procurement of a new 15 m antenna for Exosat, to be installed at the Villafranca (Madrid) ground station. Manufacture, installation and acceptance tests are scheduled to be completed by August.

A review of the data-processing software design was held in ESOC in May and development is proceeding satisfactorily. At the same time agreement with ESOC has been reached on an improved scheme for production of final data tapes, which should result in a better service to the users.

Space Telescope

Solar array

Complete agreement has been reached with the contractors on their introduction of a new requirement to control the interactive torque between the solar array and the Telescope at very low levels, and the Industrial Policy Committee has approved the associated rider to the solar-array contract. A successful Preliminary Design Review of the new solar-array drive mechanism has been held. Progress in the array's development has been as expected. The life-test models for various critical-mechanism components have been manufactured and assembled and are ready for testing.

Faint Object Camera (FOC) module

The complete structural thermal model has been assembled and is presently under test. The test programme, which comprises exposure to environmental qualification levels and thermal-balance/thermal-vacuum tests, is scheduled to finish by mid-August, three weeks later than originally planned. Tests to date, including the acoustic test, indicate satisfactory performance. The Interface Control Document for the scientific instruments and the optical telescope assembly and support systems module, has been signed off and is now under NASA configuration control. The Interface Control Document for the scientific instrument command and data-handling subsystem should be signed-off in June 1980.

Photon Detector Assembly (PDA)

Progress has been made towards solving the corona-discharge problem, corona-free operation of the intensifier section in vacuum having been achieved over a two-week period. However, a new problem has emerged in the form of a drift in the 500 M Ω resistors that distribute the high voltage to the various intensifier stages. A quality problem in manufacture, in combination with a potentially weak component design, is suspected. Several urgent parallel actions are under way to solve this problem.

Adjustment of the PDA schedule to recover the slippage incurred due to the corona problem is under investigation. It has been decided to divorce this particular problem from the PDA engineering-model programme for schedule reasons, and consequently the engineering model will not be operated in vacuum.

Module de la Chambre pour astres faibles (FOC)
Le modèle complet structure/thermique a été monté et les essais ont commencé. Le programme d'essais comprendra l'exposition du modèle aux niveaux requis pour la qualification aux conditions d'ambiance; le bilan thermique et les essais thermiques sous vide devraient s'achever à la mi-août, soit trois semaines après la date prévue initialement au calendrier. Les essais effectués jusqu'à présent, qui comprennent les essais acoustiques, indiquent un fonctionnement satisfaisant. Le document de contrôle des interfaces entre les instruments scientifiques et le télescope optique d'une part, et le module des systèmes de soutien d'autre part, a été signé; il a maintenant été passé au contrôle de configuration de la NASA. Le document de contrôle des interfaces avec le sous-système de commande des instruments scientifiques et de traitement des données doit être signé en juin.

Détecteur de photons (PDA)
Des progrès ont été accomplis dans la résolution des problèmes de décharges corona, la partie intensificateur ayant fonctionné sous vide, sans décharges corona, pendant deux semaines. Toutefois, un nouveau problème est apparu avec la dérive des résistances de 500 M Ω qui distribuent la haute tension aux divers étages de l'intensificateur. On pense qu'il est imputable à un problème de qualité chez le fabricant, joint à une conception potentiellement faible de ce composant. Plusieurs actions urgentes parallèles sont en cours pour résoudre cette question.

On étudie actuellement une réorganisation du calendrier du PDA pour rattraper le retard imputable aux problèmes des décharges corona. Il a été décidé de dissocier les problèmes d'effet corona du programme du modèle d'identification du PDA, pour des raisons de calendrier. En conséquence, ce modèle d'identification ne fonctionnera pas sous vide.

Activités NASA
Le dernier manisfeste en date concernant la Navette indique que le lancement du Télescope spatial sera assuré par le vol no. 16 de la Navette en janvier 1984. Le programme du Télescope continue de se dérouler, pour ce lancement, selon le calendrier et les progrès techniques sont conformes aux prévisions. Le programme n'a pas été affecté par les récentes réductions budgétaires de la NASA.

Spacelab

Recette du modèle d'identification
Le programme de développement du Spacelab a franchi une nouvelle étape importante en avril, marquée par la première partie de la recette du modèle d'identification. Une équipe ESA-NASA a vérifié que les matériels et logiciels Spacelab à livrer à la NASA avaient été réalisés et montés conformément à la documentation technique. Les points pour lesquels des écarts ont été relevés sont sans incidence sur le calendrier de livraison. Toutes les révisions nécessaires seront achevées avant la deuxième partie de la recette du modèle d'identification, qui couvrira les aspects 'système' et doit commencer en septembre 1980.

Poursuite du programme au-delà de son enveloppe financière initiale
Les formalités nécessaires au financement du programme Spacelab entre 120 et 140% de son enveloppe initiale ont été remplies par le Conseil directeur du programme.

Conformément à l'Arrangement initial, les contributions versées par les Etats participant au programme permettaient son financement avec une marge d'aléas de 20%. Des procédures de financement ont dû être définies pourla tranche 120%–140%; elles ont conduit à une nouvelle clé de répartition des contributions s'établissant comme suit:

Participants	Pourcentage
Allemagne	*64,40*
Autriche	*0,76*
Belgique	*5,07*
Danemark	*1,81*
Espagne	*3,38*
France	*12,07*
Italie	*1,00*
Pays-Bas	*2,53*
Royaume-Uni	*7,60*
Suisse	*1,00*

Par cette mesure, les Etats participants réaffirment unanimement leur volonté de mener le programme Spacelab à bonne fin.

La NASA commande un deuxième système de pointage d'instruments
Le 27 mai 1980, le Directeur général de l'ESA, M. E. Quistgaard, a signé un contrat avec la firme allemande Dornier System pour la production d'une unité de vol du système de pointage d'instruments (IPS) du Spacelab. La NASA a besoin de cet IPS supplémentaire pour le modèle de mission du Spacelab avec utilisation de l'IPS, et ceci a fait l'objet d'un avenant – signé le 23 mai par l'ESA et la NASA – au contrat de fourniture d'un second Spacelab. Cet équipement sera livré fin 1983. La NASA supportera le coût – environ 15 MUC – de la production de l'IPS par l'industrie européenne. Dornier System est assisté dans ce travail par d'autres firmes européennes, notamment MBB (Allemagne), Sodern (France), Matra (France), Contraves (Suisse) et Ferranti (Royaume-Uni).

Le système de pointage d'instruments est destiné à être monté sur le porte-instruments du Spacelab afin de permettre une précision de pointage de l'ordre de la seconde d'arc pour des expériences touchant à différentes disciplines scientifiques et d'applications comme l'astronomie, la physique solaire, l'astrophysique des hautes énergies et l'observation de la Terre. L'IPS peut porter des instruments scientifiques pesant de 200 à 2000 kg.

Le contrat signé le 27 mai complète ce contrat antérieur et porte de 117 à 132 MUC le total des travaux Spacelab exécutés sous contrat pour la NASA.

Traîneau spatial

Les essais en vibration du sous-système mécanique de vol ont été exécutés avec succès en avril 1980. Ce modèle a été renvoyé chez le contractant pour inspection et essai final ainsi que pour l'alignement des rails, avant sa livraison à l'ESTEC prévue pour juin 1980.

En avance sur le calendrier, l'examen de recette du modèle du sous-système mécanique destiné à la formation a eu lieu le 7 mai 1980. L'examen a donné toute satisfaction et la commission d'examen a simplement recommandé quelques améliorations mineures à apporter par le contractant. Ce modèle a été livré le 28 mai 1980 à l'ESTEC, où seront exécutés l'intégration du câblage électrique et d'autres préparatifs en vue de l'assemblage, de l'intégration et des essais au niveau système.

Le sous-système électrique subit le contrecoup de retards intervenus dans

NASA
The latest Shuttle manifest now shows the Space Telescope to be assigned a launch on Flight No. 16, in January 1984. The NASA Telescope programme continues to be on schedule for this launch and technical progress is nominal. The programme has not been affected by the recent NASA budgetary reductions.

Spacelab

Spacelab engineering-model acceptance

Another important milestone in the Spacelab development programme was satisfactorily achieved in April with completion of the first stage of engineering-model acceptance. An ESA/NASA team verified that Spacelab hardware and software to be delivered to NASA has been developed and assembled in accordance with the engineering documentation. The discrepancies identified do not affect the delivery schedule. All necessary revisions will be completed before the second part of engineering-model acceptance, covering systems aspects, begins in September 1980.

Continuation of the Spacelab programme beyond its initial financial envelope

The necessary formalities for ensuring the funding of the Spacelab programme to 140% of the originally envisaged envelope have been completed by the Spacelab Programme Board.

Under the initial Arrangement, the contributions paid by the States participating in the programme provided for its funding with a contingency margin of 20%. New funding procedures have had to be defined in respect of the 120 to 140% slice, leading to a new scale of contributions:

Participant	*Percentage*
Germany	64.40
Austria	0.76
Belgium	5.07
Denmark	1.81
Spain	3.38
France	12.07
Italy	1.00
Netherlands	2.53
United Kingdom	7.60
Switzerland	1.00

Through these measures, the participating States have unanimously reaffirmed their will to complete the Spacelab programme.

Second Spacelab instrument pointing system (IPS) ordered by NASA

On 27 May, the Director General of ESA, Mr. E. Quistgaard, signed a contract with Dornier System (Germany) for the production of a Spacelab IPS flight unit. This additional IPS is required by NASA for the Spacelab and IPS utilisation mission model, and is the subject of a rider, signed on 23 May by ESA and NASA, to the contract for the provision of a second Spacelab. It will be delivered at the end of 1983. NASA will bear the cost – approximately 15 MAU – of the production of the IPS by European industry. Dornier System is supported in this work by a number of other European companies, in particular MBB (Germany), Sodern (France), Matra (France), Contraves (Switzerland), and Ferranti (UK).

The instrument pointing system is designed for mounting on the Spacelab pallet in order to provide a pointing accuracy in the arc-second range for experiments in various scientific and application disciplines like astronomy, solar physics, high-energy astrophysics and earth observation. The IPS can carry scientific instruments weighing between 200 and 2000 kg.

The contract signed on 27 May complements the earlier follow-on production contract for a second Spacelab flight unit, signed earlier this year, and increases the total volume of Spacelab work being conducted under NASA contract from 117 MAU to 132 MAU.

Sled

Vibration tests on the flight model of the mechanical subsystem were completed successfully during April. This model has now been returned to the contractor for inspection, final testing and rail alignment prior to delivery to ESTEC, which is expected in June 1980.

The acceptance review of the training model of the mechanical subsystem took place on 7 May, ahead of schedule. The review was very successful and the board recommended only a few minor improvements to be implemented by the contractor. ESTEC took delivery of this model on 28 May, and the electrical cabling will now be integrated and further preparations made for system assembly, integration and test.

The electrical subsystem is suffering from delays in the procurement and delivery of electrical components. All components are now in the process of being supplied but a delay in the delivery of the subsystem to ESTEC cannot be avoided. This delay can be partially recovered by re-scheduling the system-level assembly, integration and test activities at ESTEC.

Studies and negotiations to define a new flight opportunity for Sled on a Spacelab flight later than First Spacelab Payload (FSLP) are being actively pursued and a decision is expected later this year.

Meteosat

Space segment

Further attempts to recover Meteosat-1 to full operational status have been unsuccessful, but the satellite is still supporting the data-collection mission.

Meteosat-2 successfully completed its last remaining environmental test on 23 May. The results of the subsequent satellite and ground-segment Flight Readiness Review (FRR) were very satisfactory.

The MAGE-1 apogee motor successfully underwent its first qualification firing on 22 May, but the back-up American motor (Aerojet) failed its firing test, possibly due to age (four years).

The launch date for Meteosat-2 (L03 launch) had been changed by Ariane from 23 September to 7 November 1980 prior to the L02 launcher failure. Since then, it has been further postponed to a launch window between December 1980 and February 1981.

Exploitation

Due to the Meteosat-1 failure, operations are presently restricted, as pointed out above, to the data-collection mission. The user service is limited to archived image data.

A considerable effort is being devoted to the preparation and improvement of the ground segment ready for Meteosat-2 operations.

l'approvisionnement et la livraison des composants électriques. Tous les composants sont maintenant en cours de fourniture mais la livraison du sous-système à l'ESTEC sera inévitablement retardée. Ce retard pourra être en partie rattrapé en remaniant le calendrier des activités d'assemblage, d'intégration et d'essai au niveau système à l'ESTEC.

Les études et négociations sont activement menées en vue de déterminer le nouveau vol du Spacelab sur lequel pourrait être embarqué le Traîneau spatial, après la FSLP, et une décision devrait être arrêtée plus tard dans l'année.

Météosat

Secteur spatial

Les nouvelles tentatives faites pour remettre Météosat-1 en état de fonctionner pleinement n'ont rien donné. Toutefois, le satellite continue à assurer sa mission de collecte de données.

Météosat-2 a terminé avec succès les derniers essais d'ambiance le 23 mai. Les résultats de l'examen de préparation au vol du satellite et du secteur sol sont très satisfaisants.

Le moteur d'apogée MAGE-1 a réussi son premier tir de qualification le 22 mai, mais le moteur américain de secours (Aerojet) a échoué à l'essai de tir, peut-être en raison de son âge (4 ans).

La date de lancement de Météosat-2 à bord du vol L03 avait été reportée du 23 septembre au 7 novembre 1980 par le Conseil directeur Ariane avant que se produise la défaillance du lanceur L02.

Depuis, elle a été de nouveau reportée à un créneau qui se situe entre décembre 1980 et février 1981.

Exploitation

Par suite de la panne de Météosat-1, les opérations se limitent à la mission de collecte des données. Le service assuré aux utilisateurs ne couvre que les données d'image archivées.

Un gros effort est consacré à la préparation et à l'amélioration du secteur sol pour les opérations Météosat-2.

Programme opérationnel Météosat

L'analyse de l'offre du Consortium COSMOS portant sur le secteur spatial est maintenant achevée, après que la SNIAS a répondu à un grand nombre des questions suscitées par l'offre initiale.

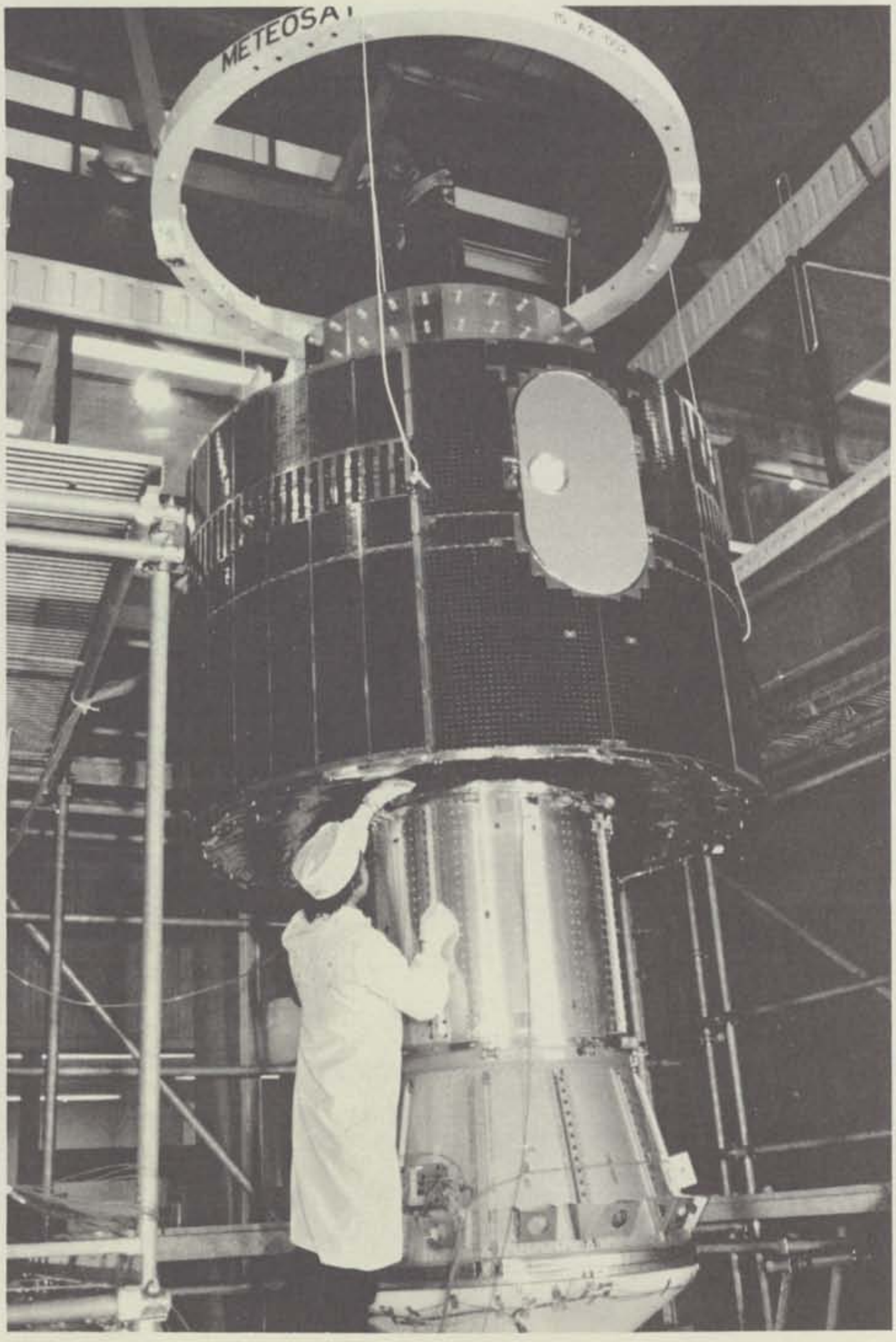
L'Agence élabore actuellement sa proposition aux utilisateurs, qui couvre l'ensemble du système Météosat (véhicules spatiaux, lanceurs et opérations au sol), et pense pouvoir la diffuser en juillet.

Sirio

La Revue intermédiaire de la conception a eu lieu en avril chez le contractant principal à Rome. Etant donné les bons résultats de cet examen, l'ESA a donné le feu vert pour l'assemblage du modèle d'intégration du satellite et pour le démarrage de la fabrication du modèle de vol.

Le financement nécessaire à la préparation de la phase d'exploitation est maintenant assuré.

Une étude concernant l'implantation des stations d'utilisateurs du système de



Derniers préparatifs de Météosat-2 pour le vol L02 d'Ariane

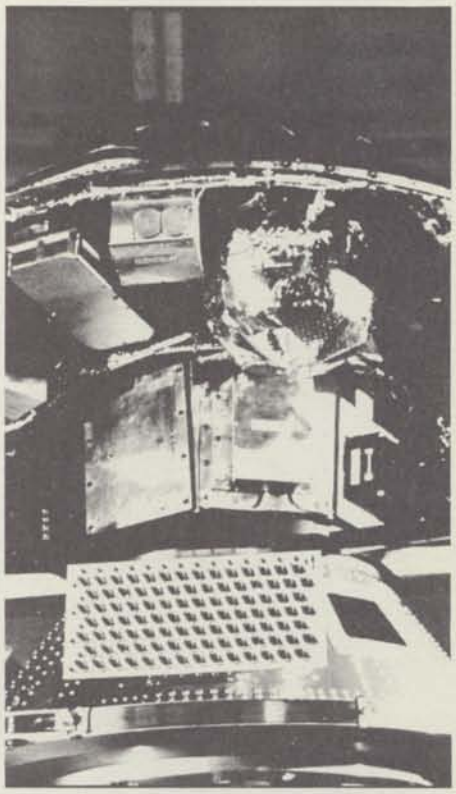
Meteosat-2 undergoing final preparations in readiness for launch on Ariane flight L02

Operational Meteosat programme
Analysis of the Cosmos Consortium's offer for the space segment has now been completed, following SNIAS's reply to a large number of questions on the original offer.

The ESA proposal to the users for the overall Meteosat system, comprising spacecraft, launchers and ground operations, is now being drafted and is expected to be issued in July.

Sirio

The Intermediate Design Review (IDR) was held at the prime contractor's facilities in Rome in April. Following successful conclusion of the Review, ESA gave the go-ahead for the assembly of the satellite integration model, and for the start of flight-model manufacture.
Funding has been obtained for preparation of the exploitation phase.



Sirio-2 satellite equipped with the LASSO experiment retroreflectors

Satellite Sirio-2 équipé de l'ensemble 'rétroréflecteurs' de l'expérience LASSO

A study of the deployment of the MDD (Meteosat data dissemination) user stations in Africa has been completed. The need for the MDD mission has been well demonstrated and two possible pilot concepts are at present being studied. Selection of the final concept will eventually be made, inter alia, in agreement with both the African countries concerned and the World Meteorological Organisation (WMO). As a consequence of the technical part of this pre-implementation study, some modifications in channel allocation and interstation protocol will be introduced to tune the system to operational needs.

A LASSO Working Group (LWG) has been set up to advise the Executive on all aspects of the LASSO experiment, particularly the definition and implementation of the demonstration programme.

As far as the support functions, and in particular satellite control, are concerned, the technical specifications have been agreed in a series of meetings with Telespazio, and it is anticipated that a contract will be signed in June 1980.

Remote Sensing

The content of the Remote Sensing Preparatory Programme (RSPP) has been slightly modified to take into account Canada's participation in the programme.

In the context of the system and payload studies, a contract for the study of an Ocean Colour Monitor has been awarded to SNIAS (France) with Marconi Space and Defence Systems (MSDS, UK) as subcontractor. The scatterometer and altimeter studies will start very soon.

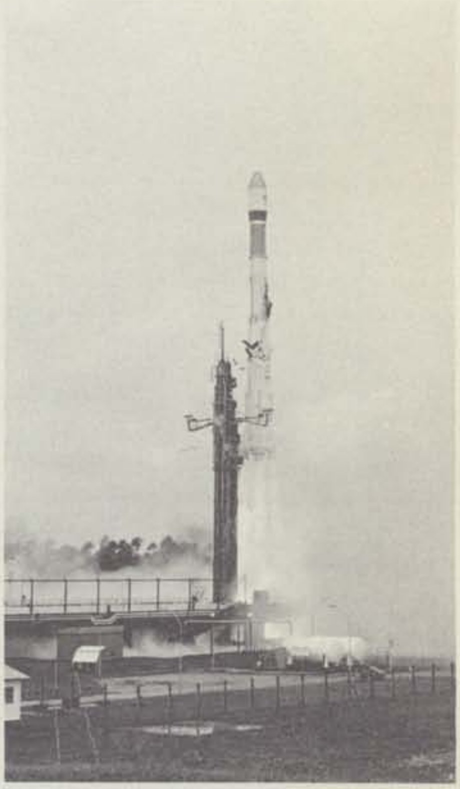
The preliminary programme proposal has been revised to take into account the reactions of the Delegations obtained at the February meeting of the Remote Sensing Programme Board. The proposal was first presented to the Board in May and is now being finalised for the Board's next meeting (4 July). The programme is expected to be approved at that meeting, which will permit a detailed definition phase (B1) to be completed by the end of 1981. At that time, the final payload configuration and the industrial consortium for the development will be selected.

Ariane

L02 launch
Disappointment was in store for those who attended the Ariane L02 launch on 23 May 1980 at the Guiana Space Centre (Kourou, French Guiana). After a countdown interrupted by minor incidents and a weather-induced holding period, launch finally took place at 14.29.39 (UT). After a normal light-up of the four L 140 engines of the first stage, irregular combustion occurred in engine D after the first few seconds of flight. The sequence of events was as follows:

H0 + 3.3 s:
Launcher lift-off.

H0 + 4.4 s:
All four engines function nominally up to this instant.



Lift-off of Ariane L02 on 23 May 1980 at the Guiana Space Centre

Décollage d'Ariane L02 le 23 mai 1980 au Centre spatial guyanais

H0 + 4.4 s to H0 + 6 s:
Chamber pressure in engine D begins to fluctuate by ±4 bar, finally oscillating with an amplitude of ±11 bar at a frequency of more than 1000 Hz. Mean chamber pressure remains nominal.

H0 + 6 s to H0 + 28.3 s:
Engine D once again nominal

H0 + 28.3 s to H0 + 28.45 s:
Recurrence of chamber-pressure

distribution des données météorologiques (MDD) en Afrique a été menée à bien. La nécessité de la mission MDD a été parfaitement démontrée et deux concepts pilote possibles sont actuellement à l'étude. Le choix du concept définitif sera arrêté en temps voulu et en accord avec les pays africains intéressés et l'Organisation météorologique mondiale. Sur la base des éléments techniques de cette étude de mise en oeuvre, certaines modifications seront apportées aux allocations de canaux et au protocole inter-stations afin de mieux répondre aux besoins opérationnels.

Un Groupe de travail sur l'expérience LASSO a été constitué en vue de conseiller l'Exécutif sur tous les aspects de cette expérience, en particulier pour la définition et la mise en oeuvre du programme de démonstration.

En ce qui concerne les fonctions de soutien, et en particulier le contrôle du satellite, les spécifications techniques ont été convenues au cours d'une série de réunions avec Telespazio, et l'on prévoit qu'un contrat sera signé en juin 1980.

Télédétection

Le contenu du Programme préparatoire de télédétection a été légèrement modifié pour tenir compte de la participation du Canada au programme.

En ce qui concerne les études sur le système et les charges utiles, un contrat pour l'étude d'un imageur couleur des océans a été attribué à la SNIAS (avec MSDS comme sous-traitant). Les études relatives au diffusiomètre et à l'altimètre vont commencer très prochainement.

La proposition de programme préliminaire a été révisée eu égard aux réactions manifestées par les délégations lors de la réunion de février du Conseil directeur du Programme de Télédétection. La proposition a ensuite été présentée au Conseil directeur en mai et on y met actuellement la dernière main pour la représenter à sa prochaine réunion (4 juillet). On pense que le programme sera approuvé à cette réunion, ce qui permettra de mener à bien une phase de définition détaillée (B1) pour la fin de 1981. A ce moment, la configuration définitive des charges utiles et le consortium industriel chargé du développement pourront être sélectionnés.

Ariane

Lancement L02

Déception au Centre spatial guyanais de Kourou (Guyane française) pour les témoins du lancement d'Ariane L02. Après une chronologie interrompue pour des événements mineurs et un arrêt météo, le lancement a été effectué le 23 mai 1980 à 14 h 29 mn 39 s (TU). Après un allumage normal des quatre moteurs L 140 du 1er étage, des anomalies de combustion sur le moteur D ont fait leur apparition dès les premières secondes du vol. Le déroulement des événements se présente comme suit:

H0 + 3,3 s:
Décollage du lanceur.

H0 + 4,4 s:
Jusqu'à cet instant, fonctionnement nominal des quatre moteurs.

H0 + 4,4 s jusqu'à H0 + 6 s:
Apparition d'anomalies d'amplitude de plus ou moins 4 bars sur la pression au foyer du moteur D, se transformant en oscillation de plus ou moins 11 bars à une fréquence supérieure à 1000 Hz. La valeur moyenne de la pression au foyer reste nominale.

H0 + 6 s à H0 + 28,3 s:
Le moteur D est à nouveau nominal.

H0 + 28,3 s à H0 + 28,45 s:
Nouvelle apparition d'oscillation de pression au foyer de plus ou moins 7 bars sur le moteur D, se traduisant de la même façon que précédemment sur les films.

H0 + 28,45 s à H0 + 63,8 s:
La pression du moteur D est à nouveau nominale, une mesure de température dans la baie de propulsion montre une élévation linéaire de 24°C à 56°C.

H0 + 63,8 s:
La température indiquée précédemment monte brutalement à 100°C, simultanément la pression au foyer du moteur D chute brutalement à 10 bars. Le lanceur reçoit un fort couple en roulis.

H0 + 63,8 s à H0 + 104 s:
Le pilotage réussit à maintenir le lanceur dans le plan de la trajectoire nominale. La vitesse de roulis atteint 60° par seconde.

Récupération du moteur D d'Ariane à 5 km au sud des Iles du Salut (Guyane française). Sorti de l'eau le 16 juin, ce moteur subit actuellement une inspection approfondie à la SEP à Vernon (France).

Recovery of the suspect Ariane 'D' engine on 16 June from the sea 5 km south of the Iles du Salut, French Guiana. This engine is now undergoing thorough inspection at SEP, Vernon (France) oscillation of ±7 bar in engine D, confirmed on film.

H0 + 28.45 s to H0 + 63.8 s:
Pressure in engine D nominal once more. A temperature sensor on the propulsion bay records a linear rise from +24° to 56°C.

H0 + 63.8 s:
Temperature in question rises sharply to 100°C, and the chamber pressure in engine D falls simultaneously to 10 bar. The vehicle experiences a powerful roll torque.

H0 + 63.8 s to H0 + 104 s:
The flight- control system succeeds in maintaining the launcher in the nominal trajectory plane. The roll rate reaches 60° per second.

H0 + 104 s:
Fall in chamber pressures in engines A and B, hitherto completely nominal. Engine C continues to function nominally.

H0 + 108 s:
Fall in chamber pressure in engine C and destruction of launcher, probably initiated by the breaking of a structural connection, as a result of the considerable general stresses, activating the self-destruct system fitted to each tank.

A number of theories attributing the irregularity either to the engine or to the environment have been put forward. The initial cause of the malfunction of engine D is still to be determined, by thorough study of the various recordings and films available and a comparison with the data collected during the first and fully successful Ariane flight, in December 1979.

In addition, a search has been undertaken with a view to recovering the wreckage of the launcher from the sea, particularly the first-stage propulsion bay, examination of which might provide valuable information.

The L02 failure does not call the continuation of the programme into question. When the cause of the engine failure has been identified and the necessary corrective actions taken, the programme authorities will conduct the other two planned qualification firings. Six Ariane vehicles are currently being manufactured – within the framework of the launcher promotion series – for the placing in orbit of the satellites Marecs-B/Sirio-2, Intelsat-V, Exosat, ECS and Telecom 1A (see article 'First Clients for the Ariane Operational Phase', ESA Bulletin No. 22, pages 66–69).

ISPM

Major interest in ISPM during recent months has tended to centre not so much on technical aspects of the spacecraft as on when, and whether, the launch will take place. In the NASA 1981 budget launch was delayed by approximately two years to April 1985 and more recently there have been moves within the US Congress to abandon the project completely. At the time of writing the issue is still open and, pending resolution, work is continuing both in the USA and Europe based on the 1985 launch schedule.

One of the consequences of the changed launch date is that the ESA and NASA spacecraft will now be launched independently on two separate Shuttles. Although this gives some relief to the weight situation, this gain is partially offset by the relatively long (40 d) launch window required, largely in order to refurbish the pad facilities at Eastern Test Range following the first launch. Investigations are currently under way to determine whether this window can be reduced, since a narrower one could substantially improve the scientific mission.

On the European side, spacecraft development is progressing normally. There have recently been reviews of all the individual subsystems, culminating in a formal review of the overall spacecraft before a joint ESA–NASA board on 24 and 25 June. No major difficulties have been identified although, as is usual at the present stage of a project, shortcomings in some areas are apparent. In close cooperation with the contractors and the experimenters, a revised development schedule to accommodate the 1985 launch has been prepared. In this the total development time allocated to the spacecraft has been increased by about ten months, following which a storage period of some fifteen months is foreseen prior to the launch campaign.

Liaison with scientific groups providing the experiments and with our colleagues in Jet Propulsion Laboratory in the USA, who are responsible for the US spacecraft, continues to be close and friendly. Such interface problems as occur are treated promptly and straightforwardly with mutual understanding of difficulties. There is no reason to doubt that the delayed launch will be as successful both technically and scientifically as that originally foreseen for 1983.

Hipparcos

At its meeting on 4 and 5 March 1980, the Science Programme Committee (SPC) selected the astrometry satellite 'Hipparcos' as the new scientific project of ESA (see ESA Bulletin No. 22, page 75). The instrument payload will form part of the project work, which means that the Agency has responsibility for the management of the payload development. The Agency will not be financially responsible for the detailed definition of the observing programme, nor for the data-reduction activities.

The space-astrometry mission Hipparcos is intended to measure with unprecedented accuracy the trigonometric parallaxes, proper motions and positions of over 100 000 selected stars, most of them brighter than magnitude 10. The expected average inaccuracy is in the range 1–2 marcs (0″.001–0″.002) for the parallaxes and in each coordinate of the positions and proper motions per year.

Such an order of magnitude improvement in precision and amount of data, compared with the existing and foreseeable situation with ground-based observatories, can only be achieved with a dedicated astrometric instrument operating in space and taking advantage of zero gravity, full-sky visibility, constant thermal environment and absence of refracting atmosphere.

The final outcome of the mission will be a catalogue documenting the five astrometric parameters of the 100 000 stars, distributed approximately uniformly over the whole sky.

Current plans are aimed at starting the industrial development programme (Phase-B) in 1981 with a view to launching the Hipparcos spacecraft on an Ariane vehicle in late 1985 or 1986

H0 + 104 s:
Chute des pressions aux foyers des moteurs A et B, qui étaient parfaitement nominaux depuis le début du vol. Le fonctionnement du moteur C reste nominal.

H0 + 108 s:
Chute de pression au foyer du moteur C et destruction du lanceur, celle-ci étant vraisemblablement provoquée par la cassure au niveau d'une liaison de structure, due à des efforts généraux importants qui ont déclenché le système de destruction auto-commandé monté sur chaque réservoir.

Un certain nombre d'hypothèses situant l'origine de l'anomalie soit au niveau du moteur, soit dans son environnement ont pu être avancées aussitôt après le tir. Reste à identifier la cause initiale qui a conduit au mauvais fonctionnement du moteur D, grâce à une investigation approfondie des différents enregistrements et films disponibles et une comparaison avec les données recueillies lors du premier tir d'Ariane en décembre 1979.

De plus, des recherches ont été entreprises pour récupérer en mer les débris du lanceur, notamment la baie de propulsion du 1er étage, dont l'examen est susceptible d'apporter des éléments d'information intéressants.

Cet échec ne remet pas en cause la suite du programme. Après identification de l'origine de la défaillance du moteur en cause et apport des remèdes nécessaires, les responsables du programme procèderont aux deux autres tirs de qualification. Six lanceurs Ariane sont actuellement en cours de fabrication dans le cadre de la série de promotion pour mettre en orbite les satellites Marecs-B, Sirio-2, Intelsat-V, Exosat, ECS et Telecom-1A. (Voir article 'First Clients for the Ariane Operational Phase', Bulletin ESA *No. 22, pages 66–69.)*

ISPM

Au cours des derniers mois, l'intérêt pour l'ISPM a moins porté sur les aspects techniques du satellite que sur le point de savoir s'il serait lancé et à quelle date. Dans le budget 1981 de la NASA, le lancement a été retardé d'environ deux ans, jusqu'à avril 1985, et l'on a noté, au Congrès américain, une tendance à abandonner complètement le projet. A l'heure où nous écrivons, la question est toujours pendante et, en attendant qu'elle soit résolue, les travaux devront se poursuivre, tant aux Etats-Unis qu'en Europe, sur la base d'un lancement en 1985.

L'une des conséquences du changement de la date de lancement est que les satellites de l'ESA et de la NASA seront maintenant lancés séparément par deux Navettes distinctes. Bien que cela améliore quelque peu la situation concernant la masse, cet avantage se trouve partiellement compensé par l'étendue relativement grande (40 jours) du créneau de lancement qui est nécessaire, en grande partie, pour pouvoir remettre en état les installations de l'aire de lancement sur l'Eastern Test Range après le premier lancement. Des études sont en cours pour déterminer si ce créneau pourrait être réduit car un créneau plus étroit pourrait améliorer notablement la mission scientifique.

La réalisation du satellite progresse normalement au sein de l'équipe européenne. Des examens ont eu lieu récemment pour tous les sous-systèmes individuels; ils ont abouti à un examen officiel de l'ensemble du satellite avant que se tienne une réunion conjointe de la Commission mixte ESA/NASA les 24–25 juin. Aucune difficulté majeure n'a été identifiée bien que, comme il est fréquent à ce stade d'un projet, des insuffisances existent dans certains domaines. Un calendrier de réalisation révisé pour tenir compte du lancement en 1985 a été préparé en étroite collaboration avec les contractants et les expérimentateurs. Dans celui-ci, la durée totale de réalisation du satellite a été augmentée d'environ 10 mois, qui sera suivie d'une période de magasinage de quelque 15 mois avant la campagne de lancement.

La liaison avec les groupes scientifiques qui fournissent les équipements d'expériences et avec nos collègues responsables du satellite américain, au Jet Propulsion Laboratory, demeure étroite et amicale. Les problèmes qui apparaissent sont traités promptement et directement dans un esprit de compréhension mutuelle des difficultés. Il n'y a pas de raison de douter que le lancement retardé ne soit techniquement et scientifiquement aussi réussi que celui qui était initialement prévu pour 1983.

Hipparcos

A sa réunion des 4 et 5 mars 1980, le Comité du Programme scientifique (SPC) a choisi comme prochain projet scientifique de l'ESA le satellite d'astrométrie Hipparcos. Les instruments constituant la charge utile feront partie du projet, ce qui signifie que l'Agence a la responsabilité de gérer la réalisation de la charge utile. L'Agence ne sera pas financièrement responsable de la définition détaillée du programme d'observation ni des activités de dépouillement des données.

La mission d'astrométrie spatiale Hipparcos a pour but de mesurer, avec une précision sans précédent, la parallaxe trigonométrique, le mouvement propre et la position de plus de 100 000 étoiles choisies, dont la brillance, pour la plupart d'entre elles, est supérieure à la magnitude 10. L'erreur moyenne escomptée est de l'ordre de 1–2 millièmes de seconde d'arc (0",001–0",002) pour les parallaxes et pour chacune des coordonnées de la position et du mouvement propre par an.

Un progrès d'une telle ampleur, en matière de précision et de volume des données, comparativement à la situation actuelle et prochaine des observatoires terrestres, ne peut être accompli qu'avec un instrument astronomique spécialisé fonctionnant dans l'espace et tirant profit de l'impesanteur, de la visibilité de tout le ciel, d'une ambiance thermique constante et de l'absence d'atmosphère réfractante.

Le produit de la mission sera un catalogue contenant les cinq paramètres atmosphériques des 100 000 étoiles mentionnées, réparties de façon approximativement uniforme dans l'ensemble du ciel.

Selon les plans actuels, le programme de développement (Phase B) devrait démarrer dans l'industrie en 1981 et le lancement du satellite Hipparcos par Ariane devrait avoir lieu à la fin de 1985 ou en 1986.

Microgravity Research in the Space Environment

H.S. Wolff, Chairman of ESA Life Sciences Working Group
Y. Malmejac, Chairman of ESA Materials Science Working Group

So far the great majority of the scientific research carried out in orbit has been in astronomy, astrophysics, and earth observation. This was only to be expected, since for these sciences the opportunity to work in space conditions represents a natural extension of a field of action that has been growing steadily for many years. They want to make observations without the hindrance of the earth's atmosphere, or to be able to observe planets from close quarters, or to observe the earth's surface from a distance.

Now two further groups of scientists are claiming a right to research facilities in orbit – materials scientists and life scientists. They do so for quite a different reason; they have no particular desire to escape from the earth's surface, but they see great scientific opportunities to be gained from the absence of gravity.

It is not easy for the materials scientists and life scientists to establish a right to orbital research opportunities in the face of counter-claims by physical scientists, because there is no established body of knowledge for them to appeal to. While both physical and biological processes have been investigated in hyper-gravity ($g > 1$), there is no appreciable existing knowledge of the behaviour of physical and biological systems at hypo-gravity ($g < 1$), and more specifically at effective gravity levels close to zero ($g < 0.001$). The space-science 'establishment' is only now beginning to appreciate fully the challenge posed by the sudden availability of prolonged micro-gravity for experimentation and the impossibility of their having acquired any previous experience.

The case for micro-gravity research

In laboratory experiments it is often possible to simplify the investigation of the influence of a particular substance or effect by performing the experiment not only at different concentrations or levels of the effect, but also by removing the effect altogether or at least reducing it to a very low level. The one effect for which this course is not possible is gravity, and consequently whole scientific disciplines have built up their body of knowledge with gravity as an ever-present modulator of the results of all investigations.

It is possible to carry out experiments at increased levels of gravity, but it does not follow that results thus obtained will allow extrapolation to very low gravity, any more than the effects exhibited by systems at higher than room temperatures can be used to predict what is likely to happen at temperatures close to absolute zero. A case can therefore be made for a scientific exploitation of the 'tool' of micro-gravity which would not only expose the role that gravity plays as a modulator of other influences, but might also expose hitherto unknown effects that only occur at low gravity. This latter expectation has been confirmed to some extent by the work already carried out.

Clearly, micro-gravity experimentation is going to be expensive, and decisions as to when to employ it must be viewed in relation to the probability of a scientific return. Two different philosophies can be applied here.

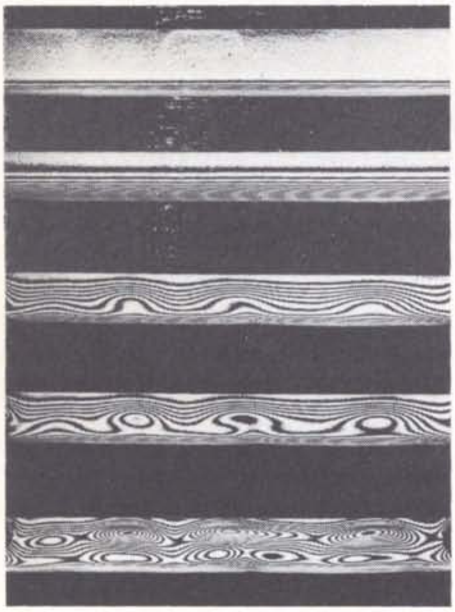
Previous work based on short-term micro-gravity exposure on nonorbital rockets and long-term exposure on NASA and Soviet missions has demonstrated the existence of a number of phenomena that cannot readily be explained in terrestrial terms. These phenomena could provide a base for further research.

In addition, in the biological field adaptive processes take place in response to the removal of gravity through mechanisms that are still largely unknown.

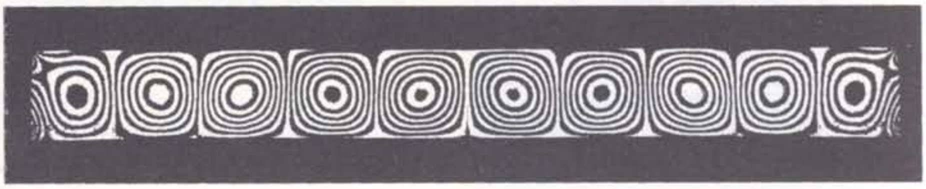
Moreover, the all-pervading presence of gravity in all terrestrial scientific research makes it reasonable to assume that its removal is bound to lead to unexpected results. A crude analogy might be a situation in which all physics and biology to date have been conducted at atmospheric pressure and room temperature, and one was trying to

Figure 1 – Interferograms of time-dependent convection currents within a rectangular box. Such experiments in earth-based laboratories constitute a preparatory step for the design of future experiments to be conducted in space on the influence of transient phenomena

(a) Unsteady convection. Rayleigh number increasing top to bottom
(b) Steady convection



(a)



(b)

forecast the benefits that might accrue from the construction of a vacuum pump and a low-temperature facility.

Principles of experiment selection

It is possible to think of a very large number of experiments in which the virtual removal of gravity will produce an effect. It is very much more difficult to design an experiment in which the connection between the reduction in gravity and the observed effect is sufficiently direct to identify the actual point in the system where gravity acts, and to quantify the effect. This requires the identification of the simplest possible systems in which the effect can be expected, and the design of experiment hardware which, while also exhibiting effects due to the reduction of gravitv, will not allow these to introduce artifacts into the experiment itself.

For a number of quite understandable reasons the majority of experiments performed so far have not met the above criteria. In the life sciences, most of the observations and experiments have been concerned primarily with assessing the effects of space flight on man himself, in order to identify potential risks. Such experiments were not intended to, and are probably incapable of, yielding insights into fundamental mechanisms.

In the materials-sciences field, again understandably, the emphasis has been on immediate technological exploitation of the micro-gravity environment, and not the use of micro-gravity as a tool for scientific investigation.

Nevertheless, it would be a mistake to dismiss the past work as being of little service to science; what it did do was to gather experience of how to do experiments; it has laid the foundations for the design of hardware, and it has highlighted some intriguing scientific problems.

Benefits of a materials-sciences programme

From the work that has already been done, it is readily apparent that the low-gravity environment offers the materials scientist a number of well-demonstrated experimental approaches by which long-standing problems can be attacked:

The absence of gravity-induced convection as a result of the absence of buoyancy forces in nonuniform fluids. The absence of convective flow makes it possible to suppress all its various associated secondary effects, such as alteration of heat transfer and solute redistribution, resulting in more ideal transport processes. It also leads to a better understanding of the other convection-driving forces – interfacial tensions, volume expansions, g-jitter and electric and magnetic fields (Fig. 1).

The absence of settling of suspended particles or fluid inclusions. This potential advantage, which also stems from the suppression of buoyancy phenomena, is useful for numerous scientific and technological purposes, in electrophoresis, composite materials, immiscible fluid phases, etc.

The absence of hydrostatic pressure, which modifies all nucleation processes of gases within liquids, and their equilibrium shapes.

The absence of interface distortion (gas/liquid and liquid/liquid), which leads to increased knowledge of interfacial equilibria.

The reduction of local density gradients in fluids near the gas/liquid critical point. The observation of critical phenomena in liquids is strongly affected by gravitational forces, because the response of the density to a very small pressure change becomes very large. In addition, clusters of molecules, engaged in thermal fluctuations, become so large near the critical conditions that the correlation distance for density fluctuations is of the same order as the distance required to detect differences in hydrostatic pressure, under normal gravity conditions. Under micro-gravity conditions, this coupling problem is removed.

The possibility of levitating isolated samples. There are a number of property measurements and basic processes for which it is advantageous to isolate specimens from container walls. It may be possible in this way to obtain specimens with unique chemical and physical properties (Fig. 2).

The possibility of testing experimentally the assumptions of theoretical models of such processes as solidification and

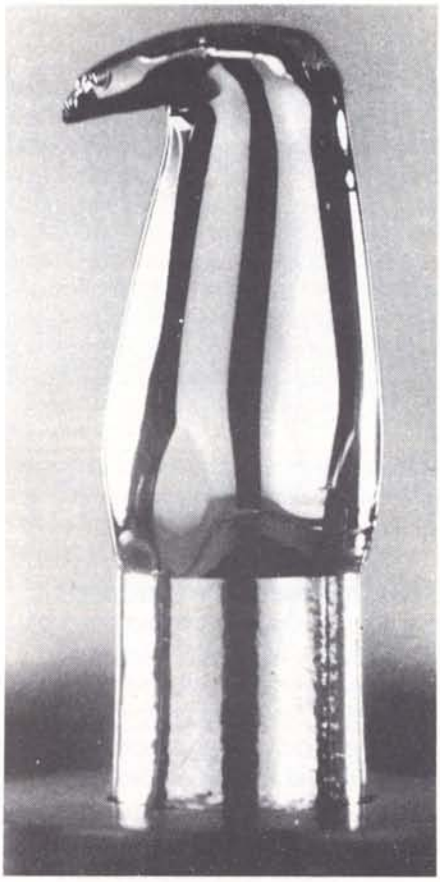


Figure 2 – Example of a homogeneously doped simple crystal (indium antimonide) grown using containerless techniques (photo courtesy of R.S. Snyder, NASA)

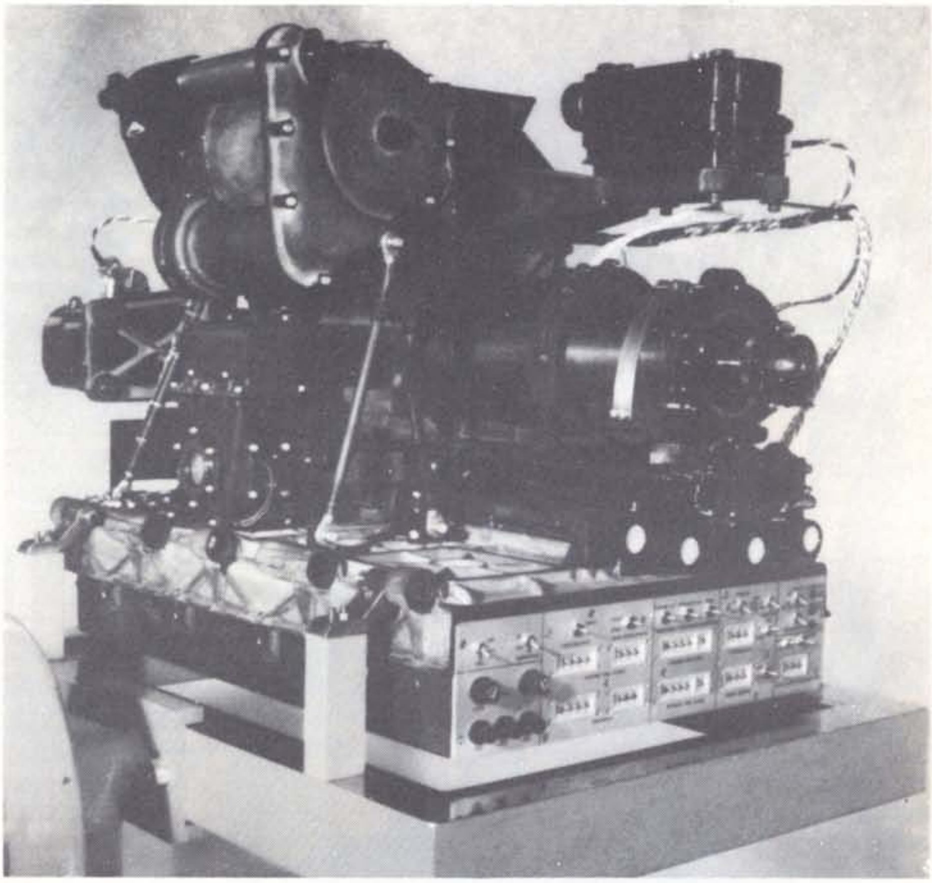


Figure 3 – The Fluid Physics Module, to be carried on the first Spacelab flight, is designed for fundamental investigations of fluid dynamics problems under microgravity conditions

combustion, that couple transformation and transport phenomena and unavoidably generate both density gradients and density-gradient-driven convection. Density gradients are complicated in that they never permit total stable stratification against buoyancy-driven natural convection under the earth's gravity. Natural convection tends to interfere with planar, spherical or other simple symmetries in those experiments by which basic physical theory can be tested and directed most incisively. This is particularly important when, as is common for complex nonlinear phenomena, theory predicts that a system may behave in more than one way. Careful experiments in low gravity can therefore advance our scientific understanding of two of the most universal physical processes (Fig. 3).

The importance of these seven major advantages afforded by micro-gravity is still greater when one considers that a great parallel exists in classical earth-based processes to the particular problems that have been highlighted here as being more amenable to solution through space experimentation.

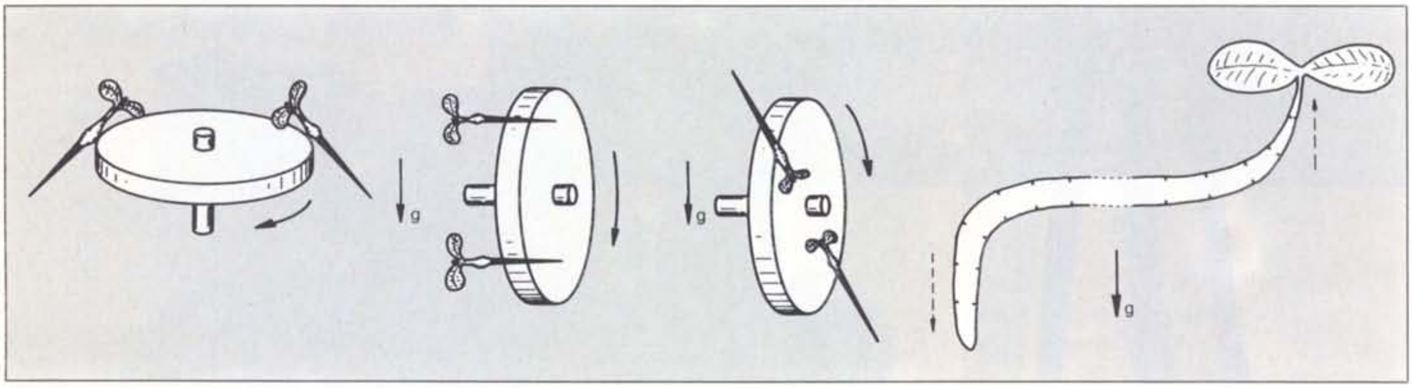
Benefits of a life-science programme

To the biologist, micro-gravity offers not only new methods of investigating problems already recognised, but a whole new area of research which has hitherto hardly been considered. Living things have evolved within the limits of the particular physical conditions found on the surface of the earth. Most of these are variable, within limits, and much understanding of living organisms has been obtained by studying the effects of varying these conditions.

Gravity, however, is invariable, and biology has built up its body of knowledge with gravity as an ever-present modulator of all investigations (Fig. 4). That it has had profound effects is obvious; the whole structure and functioning of higher plants and animals has evolved in relation to it – whether to combat it, e.g. by skeletal or vascular structures, or to use it, e.g. by position-sensing mechanisms. But how it operates at the much more fundamental levels of the individual cell and its organelles is almost totally unknown.

Investigations of gravity at this level represent a completely new field for biological research. The possible results are of course quite unpredictable; but it seems reasonable to assume that they would cast light not only on the effects of gravity itself, but also on those of many other factors whose influences have so far been obscured or complicated by gravity.

Figure 4 – Classical experiments conducted in 1806 (by Knight) with seedlings on rotating wheels showed that shoots and roots grow at different angles with respect to the imposed centrifugal force. If any part of a plant is displaced from its preferred orientation with respect to the gravity vector, a growth response is evoked which restores that element to its original posture.



Effects at cellular level

Gravitational forces within the cell must be extremely small, probably of the order of those producing Brownian movement. However, this does not mean that they are negligible; the fact that certain bacteria respond to the earth's magnetic field demonstrates that a steady unchanging force will generally override those that are random and fluctuating. Gravity must thus operate as a constant bias on the movement of components within cells, and a number of active intracellular transport processes may have developed in response to the need to counteract sedimentation. Similarly the exchange of materials between the cell and its environment must be substantially influenced by micro-convection.

The gravity vector seems likely to be used by single-celled organisms for orientation purposes, and it would be useful to study the way it interrelates with other factors such as chemotaxis, temperature and illumination. It must also play a large part in interactions between cells, particularly in the building-up of cell aggregates.

Effects on development

In the development of multicellular organisms, apparently similar cells differentiate into highly diverse forms according to their position in the embryo; it seems likely that gravity plays a part in determining which particular developmental path each pluri-potent cell will take. Of special interest would be its influence on the development of cells destined to become part of gravity-sensing systems.

Many cells of both plants and animals are markedly polarised in relation to the structure of the whole organism. This polarity seems to be hormonally controlled, but it would be of great interest to know whether gravity also is involved, if only by determining the distribution of the hormone.

It would also be interesting to know whether the change in the amount of gravity experienced by the foetus on leaving egg or uterus acts as trigger for any of the many developmental changes occurring at this time.

The processing of gravity vector information

The use of the gravity vector as an aid to orientation is a large subject in itself, embracing both the perception and the processing of the stimulus. Nothing is known about the threshold values below which gravity is not perceived, in terms either of the magnitude of the stimulus or of its duration.

In plants both perception and processing are very imperfectly understood. In animals, up to and including man, the integration of information about gravity with that from other stimuli, and with in-built motor patterns, provides an enormous field of interest.

A further possibility to be explored is that the perception of slow cyclic changes in gravity may act as a component of biological clocks.

Adaptive processes to micro-gravity

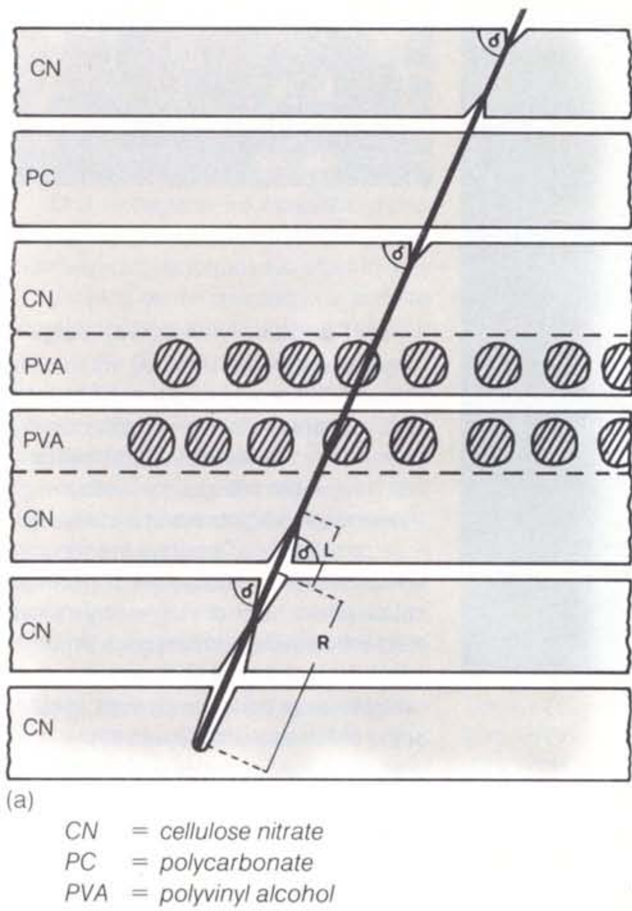
Finally there is a group of processes of adaptation to the absence of gravity whose study could well illuminate the normally-occurring process. In the absence of gravity, bone becomes demineralised and muscle proteins are broken down faster than they are built up. The cardiovascular system has to function differently in the presence of different hydrostatic forces. All these phenomena occur to some extent in prolonged bed-rest, and are thus of clinical importance. But micro-gravity has already been shown to produce rather different effects, presumably because of the elimination of effects of gravity on the individual components of the body as well as its effects on the body as a whole.

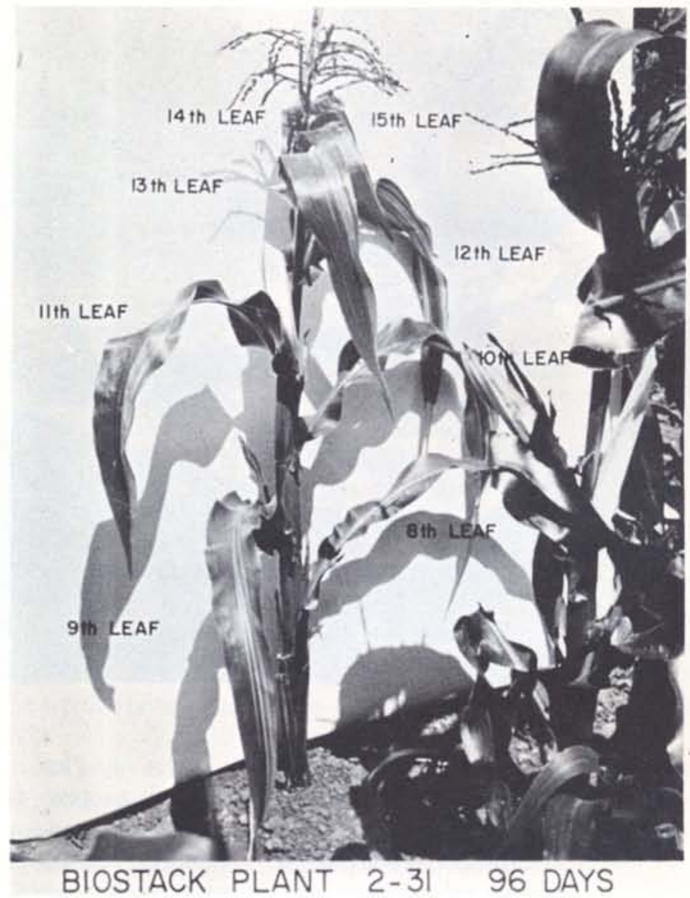
Study of radiation responses

The study of the interaction of cosmic-ray particles with living matter is another area of research made possible by Spacelab. It is of interest for four reasons. It will increase our insight into the fundamental aspects of the biological effects of ionising radiation on cells, tissues and organisms, such as mutation, developmental alterations, tumour induction and cell death. It will improve our insight into the radiation hazards to man on earth from both natural and artificial radiation sources. It will increase our understanding of the natural repair

Figure 5a – 'Biostack' experiments on Apollo-16 and 17 and the Apollo-Soyuz Test Project (ASTP) have already demonstrated that high-energy cosmic radiation can damage or even destroy biological cells. Plant seeds, bacterial spores and animal eggs were sandwiched between nuclear track detectors in these experiments.

Figure 5b – Zea maize plants grown from seeds exposed to high-energy cosmic particles on Apollo flights developed yellowed stripes in their leaves through radiation damage (photo courtesy of Prof. H. Bücker)





mechanisms for radiation damage, as well as being of help in the development of anti-radiation drugs and procedures. Lastly, it will assist the evaluation of the radiation hazards to man during prolonged space missions, in terms of both their immediate and longer-term effects.

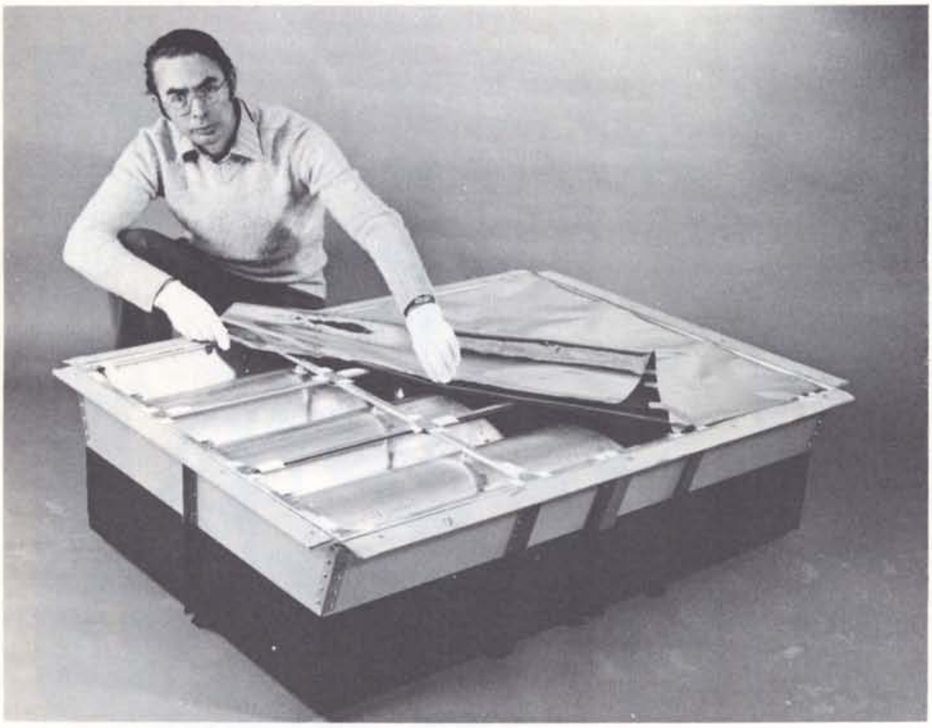
While a considerable part of this work can be conducted with particles generated using earth-based accelerators, the full spectrum of HZE particles is difficult to produce simultaneously. There is already evidence that space-flight factors such as weightlessness may enhance the biological effects of radiation, and the mechanisms of this could cast much light on the functioning of the genetic apparatus (Figs. 5a & b).

Establishment of an integrated European micro-gravity programme

The Spacelab FSLP (first Spacelab payload) mission in 1983 will represent the first opportunity of access to a micro-gravity environment for many European experimenters, and an excellent opportunity to capitalise on past, largely American, experience in defining the best objectives for future experiments and the best means of achieving them. The scene will then be set for the development of second and further generations of experiments, provided a number of conditions that will determine whether micro-gravity science is to become a new discipline in the European context are met.

Experience in other scientific fields has already demonstrated the value of an interdisciplinary approach, and the fact that separate outlines have been presented here for the materials and life-sciences domains does not mean that these activities have nothing in common except the space environment in general and the micro-gravity conditions in particular. There are many areas of shared interest, ranging from the significance of micro-convection, through the behaviour of nonsedimenting suspensions, nucleation, crystallisation and analogous organisational phenomena in liquids, the properties of liquid/gas and liquid/liquid and liquid/solid interfaces undisturbed by gravitational influences, to the identification of as yet unknown effects that only occur below some particular gravity threshold.

Figure 6 – The Long-Duration Exposure Facility (LDEF) to be used for future extended-period materials- and life-sciences experiments in space



The foundation of the European Low Gravity Research Association (ELGRA) is already an indicator that a new scientific community is developing in which the traditional boundaries between the physical and biological disciplines may be less sharply delineated than hitherto, and the challenge of the opportunities for research presented by the availability of the space environment should lead to still greater co-operation between scientists of very different backgrounds.

Facilities available

Spacelab is intended to provide conditions in which experiments in a wide variety of scientific disciplines can be carried out. The pressure, temperature and atmospheric conditions of the cabin will be maintained at levels in which people can comfortably work, and a small group of scientists will oversee the experiments. They will be chosen from disciplines appropriate to the particular experiments being flown, and given special training in the techniques needed.

The apparatus required will be embodied in special racks for materials science and for the life sciences. They will be selfcontained and removable, and will be carried only on flights concerned with the particular discipline.

Radiobiological experiments that require no intervention will also be carried outside the pressurised cabin, on the pallets, where exposure to radiation will be less affected by masking due to the walls of Spacelab.

It is envisaged that at later stages in the space programme materials- and life-sciences experiments may be carried on LDEF (Long Duration Exposure Facility) flights, put into orbit by the Space Shuttle and left there for substantial periods, or on unmanned free-flying satellites launched by Ariane. Either of these options would obviously greatly facilitate the long-term experiments required to answer many biological questions.

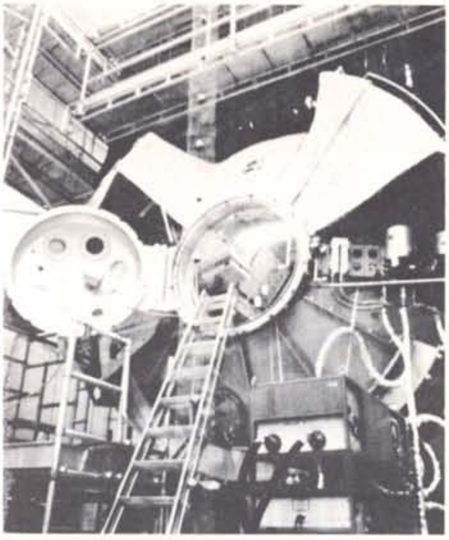
Calls for proposals

To exploit the possibilities of micro-gravity, whether in materials or life sciences, calls for scientists with an unusual combination of skills. They need considerable experimental ingenuity if they are to devise protocols that are feasible within the limited facilities available in Spacelab, they need a broad scientific knowledge if they are to choose the most suitable subjects and processes for investigation, and above all they need the imagination to step outside conventional gravity-limited science and perceive where gravity is likely to be producing important effects.

Such scientists are unlikely at the moment to be particularly interested in gravity, for interest is stimulated only by questions that have some possibility of being answered. The Materials Science and Life Sciences Working Groups have therefore circulated their Calls for Proposals very widely, conscious that only a tiny minority of scientists is likely to respond. However, it is already clear that this minority includes some people with original ideas. Some of the experiments already proposed pose genuinely interesting questions, so that by the time future flights are planned a much larger scientific public should be awake to the possibilities of low-gravity research.

Conclusion

There is at present a much-quoted belief that funding for micro-gravity research on either a national or on an ESA level can only be considered in response to an adequate volume of high-quality demand from the scientific community. However, by its very nature, space research, with its infrequent flight opportunities for experiments and long lead times, requires at the very least an advance guarantee of a series of opportunities if outstanding scientists are to be attracted. Ideally, therefore, ESA would like to be in a position to offer these necessary stimuli to those life and materials scientists who have plans for space-based micro-gravity research, and especially to create flight opportunities and provide basic re-flyable, common-user facilities.



The Spacelab Production Programme

J. Marchal, Spacelab Programme Directorate, ESA, Paris

An agreement signed in August 1973 between the Government of the United States of America and certain European governments*, members of the European Space Research Organisation, for a cooperative programme 'concerning development, procurement and use of a space laboratory in conjunction with the Space Shuttle system' has formed the basis for long-term cooperation between the USA and Europe in an area that was new to the latter, namely manned space flights, which are the inevitable extension of the European space effort.

This agreement laid down the principle, inter alia, of the procurement by the United States, according to its operational needs, of Spacelabs, components and spares in addition to the initial delivery to the USA free-of-charge of the first Spacelab flight unit developed in Europe.

The Memorandum of Understanding (MOU) concluded in the same period between NASA and ESRO/ESA and constituting the practical implementation of the governmental agreement, stipulated that NASA would place an initial procurement order for at least one further Spacelab, no later than two years before the delivery of the first.

* Germany, Belgium, Denmark, Spain, France, Italy, Netherlands, United Kingdom, Switzerland, and subsequently Austria.

These provisions have not remained a dead letter: they were given concrete form in late January 1980 with the signature of the procurement contracts between NASA and ESA on the one hand, and ESA and European industry, represented by ERNO (Germany), the Spacelab prime contractor, on the other. In early May final negotiations were in progress for the placing, before 25 May, of two similar contracts relating to the instrument pointing system (IPS), for which Dornier System (Germany) is the prime contractor (see 'In Brief', page 67).

Between August 1973 and January 1980 many things have happened in the context of what NASA officially calls 'follow-on procurement' and what we in Europe call 'follow-on production', a difference of little consequence since everyone involved talks about 'FOP'. The initial texts expressing statements of intent represented just the first step; the fact is that these intentions could never have been fulfilled without the patience, goodwill, and above all, the enormous amount of hard work put in by all those who have been associated since with the variety of problems that have arisen at every level. It is worth reflecting on some of these problems and the solutions adopted, not least as a lesson for any similar project that may be undertaken in the future.

As early as 1974 NASA, quite legitimately, enquired with ESA about the cost of FOP, so as to have some yardstick for budgetary purposes. At least two estimates were subsequently supplied, but they were not, and indeed could not be, 'official proposals' because the contract and technical requirements had not been defined at that time. The list of equipment and documentation had not been accurately drawn up and the spares had not been clearly identified. Spacelab was in a development phase where the rate at which technical modifications were being introduced (due to Orbiter interface requirements, needs expressed by the users, modifications to the original design and other technical problems) was very high. It was therefore very difficult to distill from the development costs, which moreover had been very much underestimated at the time, those recurring costs associated with the subsequent production of hardware whose final configuration was still far from frozen. These premature estimates eventually turned out to be much too low and this in itself led to difficulties when a firm price was formally established in reply to an official Request for Proposal.

When a start was made on FOP in 1976, two factors immediately became clear to the partners:

- NASA had no experience in placing major procurement contracts outside its national industry
- ESRO, by now ESA, had never produced space systems for third parties.

These novel features inevitably raised major problems of principle. The Agency was obliged to think very carefully about its role and policy in the matter, especially as similar situations were foreseeable in the future. What system should be adopted? Should NASA be asked to go

Figure 1 – Signature, in January 1980, of the ESA contract with European industry for the production of a second Spacelab

photo ch. laurentin

directly to European industry or should ESA act as an agent? In the latter case, there would be the question of whether or not to apply the Agency principle of 'no profit, no loss'.

In the case of FOP, NASA could hardly be displeased at the thought of having its European partner looking after calls for tender, handling negotiations, and supervising the industrial work to be carried out in no less than nine countries on the other side of the Atlantic. ESA, for its part, found it rather awkward to have its Spacelab development contract being performed by its contractors (mostly on a cost-reimbursement basis) in parallel with a production contract for the same equipment (on a fixed-price basis) placed by another customer.

In the event, the principle of a system of 'cascade' contracts had to be accepted; that is a NASA/ESA contract would cover, in addition to the industrial element, the actual internal cost of ESA managing its contracts with industry. Both contracts had to be drawn up in such a way that ESA, while not making a profit should neither run the risk of accruing losses.

In this new framework, which was full of potential snares and had still to be applied in detail, two practical problems immediately arose. Firstly, since ESA was now, practically and legally, a NASA 'contractor', the latter tended to apply, by force of habit, the 'general clauses and conditions' that a whole series of laws, rules and traditions obliged it to introduce into its contracts. These clauses may be perfectly reasonable when applied to local American industry, but they can sometimes be difficult for an organisation like ESA to either apply or accept; for example, questions relating to audit and to commercial relations with certain countries. Though the negotiation process may have appeared slow, in the final analysis it must be said that NASA made every effort to obtain the maximum number of 'waivers' from the authorities concerned regarding the clauses that ESA found it difficult to accept.

The second problem that was very soon identified was that NASA's plan of annual payment appropriations would not be sufficient to cover the requirements of European industry's payments schedule. This could be attributed to two causes:

- initial underestimation of the cost of FOP
- NASA's difficulty in obtaining the fresh funds that were absolutely essential to cover the increased needs for Shuttle development.

This matter was subsequently resolved but the initial difficulties arising out of this general situation in which the two Agencies found themselves were probably at the root, in mid-1977, of a concept that brought about a temporary diversion from the original plan for FOP.

Where, by whom and how the idea was spawned no one really knows, but the concept of a compensatory agreement – a 'barter' instead of a procurement – must have looked very attractive judging from the way it quickly gained favour on both sides of the Atlantic. ESA would pay for the construction of the second Spacelab and in return NASA would donate the equivalent value , agreed in advance, in Space Shuttle utilisation flights. There would be no exchange of funds, hence removing NASA's budgetary problems; NASA's contract rules would no longer apply to ESA, and there would be a more flexible Memorandum of Understanding; last but not least, ESA and its contractors would have greater freedom as regards contract conditions and planning.

However, the idea was not followed up. Though no one could deny the virtues of this type of compensatory agreement between the two Agencies, which generally speaking would remove the cumbersome elements of contract-type relations, in the event the terms of the exchange were not considered valid by the European States, whose plans at the time did not extend to the utilisation of four complete Shuttle flights. In mid-1978, therefore, the contract system was revived.

NASA's procurement terms as set out in the 1973 Memorandum of Understanding were very general: its agreement was required on the specifications and delivery schedule; the price was to be considered by NASA as 'reasonable'. However, these perfectly legitimate pre-conditions led to a

Figure 2 – Spacelab-1 in the final stages of preparation at ERNO (Bremen) for delivery to NASA

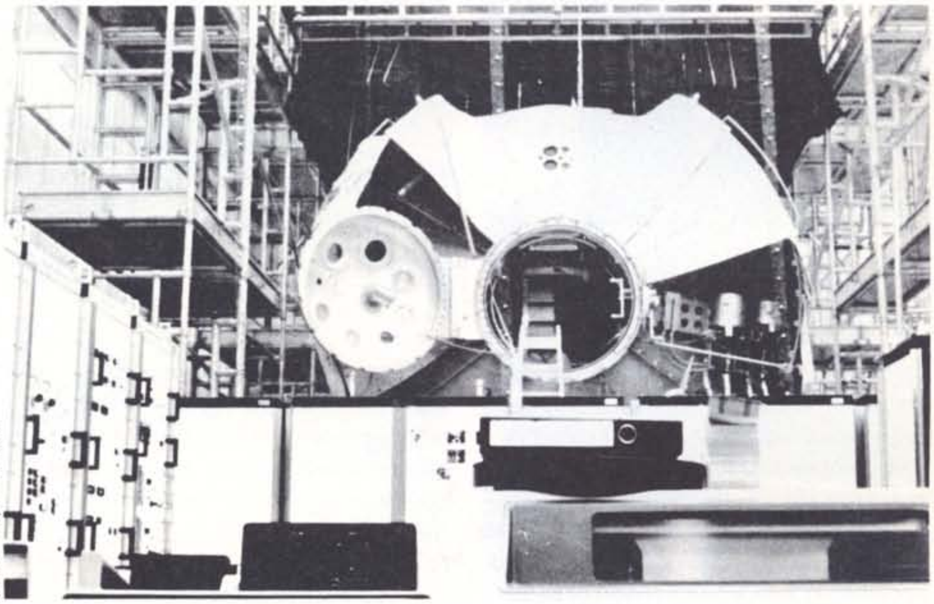


photo m.-p. hubrecht

need to resolve a number of specific questions.

As regards specifications, NASA wanted to procure a second Spacelab identical to the first, to be delivered by ESA in 1981. At the time of placing the follow-on contract, however, the configuration of the first Spacelab was not 100% frozen. Fixed margins had therefore to be included in the fixed-price contracts and hence involved protracted negotiations.

Among other things, NASA imposed a presentation of the specifications, broken down according to 'contract end-items'. This breakdown was not the same as that established for the Spacelab development phase, which was related more to the firms' production. A vast amount of documentation was affected by this constraint. In addition, NASA asked for *all* drawings, a requirement that involved difficulties of availability, cohesion and language, particularly for documents at the lowest technical levels. In addition, it raised delicate industrial-property problems.

As regards schedules, it was necessary to reconcile NASA's mission-model requirements and Europe's desire to extend Spacelab development activities by production under optimum conditions without costly gaps or undesirable overlaps.

In reality, as a result of the easing of the NASA timetable due to the build-up of delays in Shuttle development and with the Spacelab itself, by force of circumstance the NASA/ESA FOP contract was finally signed after tough three-sided negotiations, at the correct point in time, in January 1980, for a figure of 117.1 MAU (mid-1979 prices).

ESA's contract with industry (Fig. 1) is a traditional Agency fixed-price contract (with minor exceptions for American subcontractors who, in spite of direct intervention by NASA, are working on a cost-reimbursement basis) with an escalation clause. Particular attention was given to ensuring that its clauses were compatible with those in the NASA/ESA contract, to avoid ESA finding itself later in a disadvantageous legal, technical or financial position.

The work breakdown is roughly the same as for the Spacelab development contract (Fig. 2) and the equipment will be delivered, after integration by ERNO, in 14 batches, spread over the period from October 1981 to April 1984.

The NASA/ESA contract covers the industrial costs and it also provides for reimbursement of ESA's management costs. It is established in the national currencies of the participating firms, and NASA is obliged to settle the invoices in each of these currencies, a procedure with which it has hitherto been unfamiliar. NASA is also responsible for the financial implications of any variations in exchange rates in relation to the dollar.

The problem of the lack of NASA budget appropriations in 1980 and 1981 referred to earlier has now been resolved via a loan, with a ceiling of 110 million DM, made to ESA by a banking consortium (bank charges to be borne by NASA). The ESA Council has guaranteed the loans to be taken out in 1980 and NASA, which in principle does not have the equivalent of our contract authority, has made special arrangements with the US Congress to take over this guarantee in 1981, from October onwards, the beginning of its fiscal year.

It now remains for ERNO to divide up its own industrial contract within its consortium, and it is to be hoped that this phase will be easier on the staff of the two Agencies and industry than the efforts needed to bring the contract into being! Be this as it may, NASA already has the satisfaction of having fully lived up to its obligations expressed in 1973, while for Europe the very fact that it has concluded a deal of this magnitude with the United States for a space system should be a source of pride and should seriously encourage the continuation of its efforts 'per ardua ad astra'.

Domestic Television – by Satellite, Cable and/or Optical Fibre?

P. Jeppesen, Electromagnetics Institute, Technical University of Denmark, Lyngby

The intention of this article is to discuss the prospects for and merits of satellite television broadcasting either direct to private homes or to community antennas feeding fibre-optic/cable TV (CATV) networks, and its integration with other domestic services. It is concerned specifically with a comparison of semi-direct systems broadcasting to small or medium-sized earth stations feeding CATV networks and direct-to-home systems feeding small private earth stations and the question of whether optical fibres can increase the competitiveness of CATV networks coupled to satellite earth stations.

The geostationary satellite is an ideal means of broadcasting television programmes to an unlimited number of receiving earth stations. Satellite broadcasting can be divided naturally into three categories:

(i) Programme distribution to conventional broadcast stations; this service is implemented in most existing communications satellite systems, but may indeed be termed 'conventional', and is actually outside the scope of this paper.

(ii) Semi-direct broadcasting to small or medium-sized earth stations feeding CATV networks; this service is widely used in the United States and Canada, although the networks are normally based on coaxial cables rather than optical fibres.

(iii) Direct-to-home broadcasting to very small, private earth stations; this service is not yet available, but experiments are in progress in several countries.

Direct-to-home broadcasting

The prospects for the development of direct-to-home television broadcasting from especially powerful satellites were considerably strengthened by the successful conclusion of the 1977 World Administrative Radio Conference (WARC) in Geneva, where it was agreed to limit each country's allocation of space slots and frequency channels to four or five television programmes. Several countries now have plans to introduce direct television broadcasting from satellites in the first half of the 1980s, and various experiments with very small earth stations have been going on for some time.

The Canadian experiments

The Canadian Communications Technology Satellite (CTS), also called 'Hermes', was launched on 17 January 1976 as a joint venture by the Canadian Department of Communications and NASA (Fig. 1). It was the first satellite in orbit to have a 14/12 GHz communications capability (14 GHz uplink and 12 GHz downlink), and it has been used to conduct a variety of communications experiments, including television broadcasting. Although Hermes was designed for a two-year mission, it is now well into its fourth year of operation. For one of its two 85 MHz radio-frequency channels, a travelling wave tube with a nominal output power of 200 W provides, in combination with the transmitting antenna, a total effective isotropic radiated power (EIRP) of 59.5 dBW. This is at least ten times the output of previous communications satellites and is characteristic of the power levels required for a television broadcasting service from space.

TV receive-only (TVRO) ground terminals from several manufacturers have been tested. Using antenna diameters in the 1.2–1.6 m range, a television channel has been received with a signal-to-noise ratio of about 50 dB, giving very satisfactory picture quality. A 0.6 m diameter terminal with a signal-to-noise ratio of about 43 dB has also been tested; this latter terminal should be of interest for direct-to-home reception, because its projected total cost, including indoor demodulating unit, is of the order of \$500–\$700. Some repointing of the receiving antennas was necessary to maintain optimum performance, but

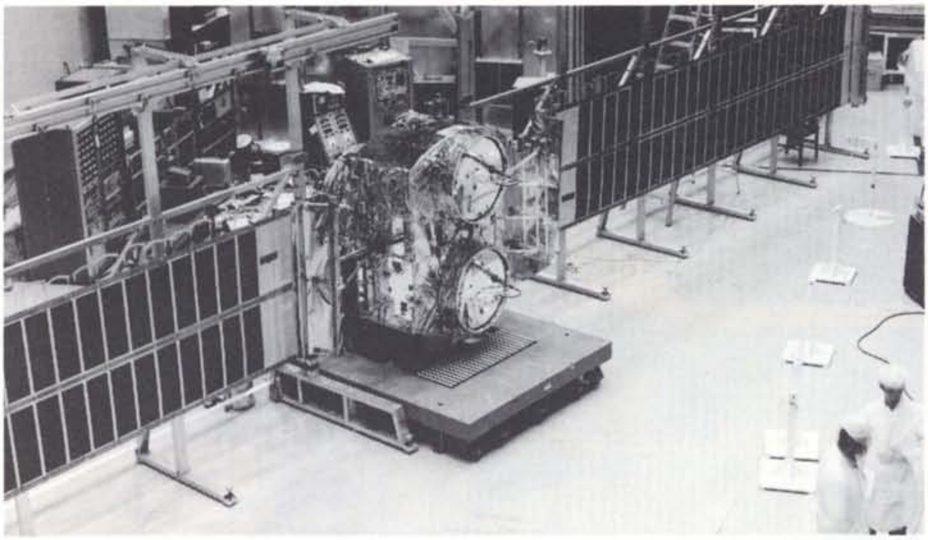


Figure 1 – The Canadian Communications Technology Satellite (CTS)

Figure 2 – Three-metre diameter antenna typical of the type used for OTS reception demonstrations

consumers seemed content to accept slightly degraded picture quality and forgo the realignment exercise. The Canadian experiments have clearly demonstrated the technical ability of satellite systems to transmit high-quality television reliably to domestic users both in cities and in very remote regions.

The Japanese experiments

The Japanese medium-scale Broadcasting Satellite for Experimental Purposes (BSE) was launched from Cape Canaveral on 8 April 1978. The aim of this project is to perform a three-year technical evaluation of a 12 GHz satellite broadcasting system. The geostationary satellite is capable of transmitting two colour-television signals with a radio-frequency power of 100 W, corresponding to an EIRP of 56 dBW. The satellite antenna's radiation pattern is designed to provide a high-quality service throughout Japan. It is anticipated that a colour-television signal with a 45 dB signal-to-noise ratio can be received with a rainfall attenuation margin of 2 dB (corresponding to 99.9% of the time) when earth stations with 1.0–1.6 m antenna diameters are used on the mainland, and 2.5–4.5 m diameter antennas on the surrounding islands.

To evaluate the feasibility of direct-to-home broadcasting, various kinds of antenna and receiver configurations were designed to determine the best compromise between cost and performance. The experiments have investigated picture-quality variations as a function of weather conditions, snow, rain, temperature, wind, ice deposits on antenna and feeder, along with the disturbing influences of nearby mountains, woods, trees, buildings, railways, aircraft and intervening glass windows. In their first year of operation the BSE experiments have proved the feasibility of direct-to-home television broadcasting by satellite for Japan also.

The BSE programme includes a number of novel features, such as transmission experiments with high-definition television requiring 20 MHz of bandwidth, and differential pulse code modulation (DPCM) television transmission at 64 Mbit/s.

Experiments in the USA

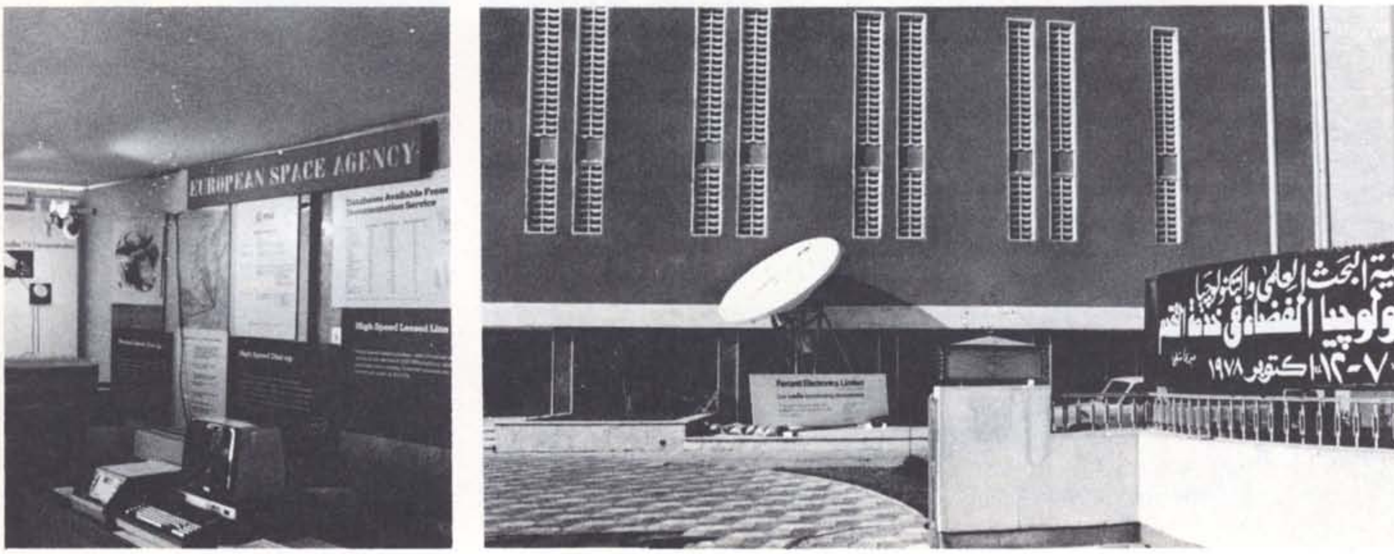
Experiments with CTS/Hermes are also being carried out in the USA, one series called 'Terminals of Tomorrow' being conducted by the US Federal Communications Commission (FCC). The terminals are very similar to those in use in Japan, with antenna diameters in the 0.6–1.6 m range. A particular objective of this programme is to evaluate reception quality under typical, rather than optimum, conditions, including adverse locations, nonoptimum equipment adjustment, reception outside the primary coverage area, attenuation due to rain, etc.

The FCC has just removed the need for a licence for an antenna to receive television directly via satellite, and Comsat General is considering developing a system to provide direct broadcasting of several simultaneous channels to millions of American homes. This recent development in the USA has taken place despite the fact that the official American viewpoint was not in concert with the 1977 WARC plan.

The European experiments

Television broadcasting experiments in Europe have been conducted with the Orbital Test Satellite (OTS-2), ESA's first communications satellite in orbit, launched on 11 May 1978. OTS is not designed specifically for direct

Figure 3 – Demonstration of television transmission via OTS during the 1978 Space Technology Conference in Cairo



broadcasting, but its 120 MHz bandwidth transponder, transmitting at 11.6 GHz, delivers a 20 W output. Successful television reception with signal-to-noise ratios of around 40 dB has been demonstrated with 3 m diameter antennas (Figs. 2, 3).

OTS is intended as the precursor of the European Communications Satellites (ECS), the first of which will be launched in 1981. It is planned to install 12 repeaters on ECS, each equipped with 20 W travelling-wave-tube amplifiers (TWTAs), similar to those on OTS. Two repeaters will be used for the transmission of two television channels but, as suggested by the choice of 20 W travelling wave tubes, ECS is not intended to be powerful enough for direct home reception with a small receiver.

Several European countries are now planning the near-term introduction of direct satellite-broadcast systems and ESA, having pointed out the degree of commonality between the majority of television-satellite platforms, has advocated the idea of a coordinated European development programme.

Germany decided in 1979 to implement direct-to-home satellite television broadcasting, and a satellite for experimental use is scheduled to be launched in 1983, but some delay can be expected. It will handle three channels, each carrying one television signal and two sound signals. The power stages use 260 W tubes with an efficiency of 43%, providing the maximum EIRP of 65.6 dBW permitted by the 1977 WARC plan. Some 10 000 domestic television receivers will be suitably equipped at the beginning of the experimental phase. The second satellite for this system is scheduled for launch in 1985, at which time the operational phase could start.

France has also decided to undertake a direct-broadcast project and Luxemburg, and perhaps also Monaco, may wish to pursue their tradition of 'peripheral transmission' on a much greater scale with the aid of satellites.

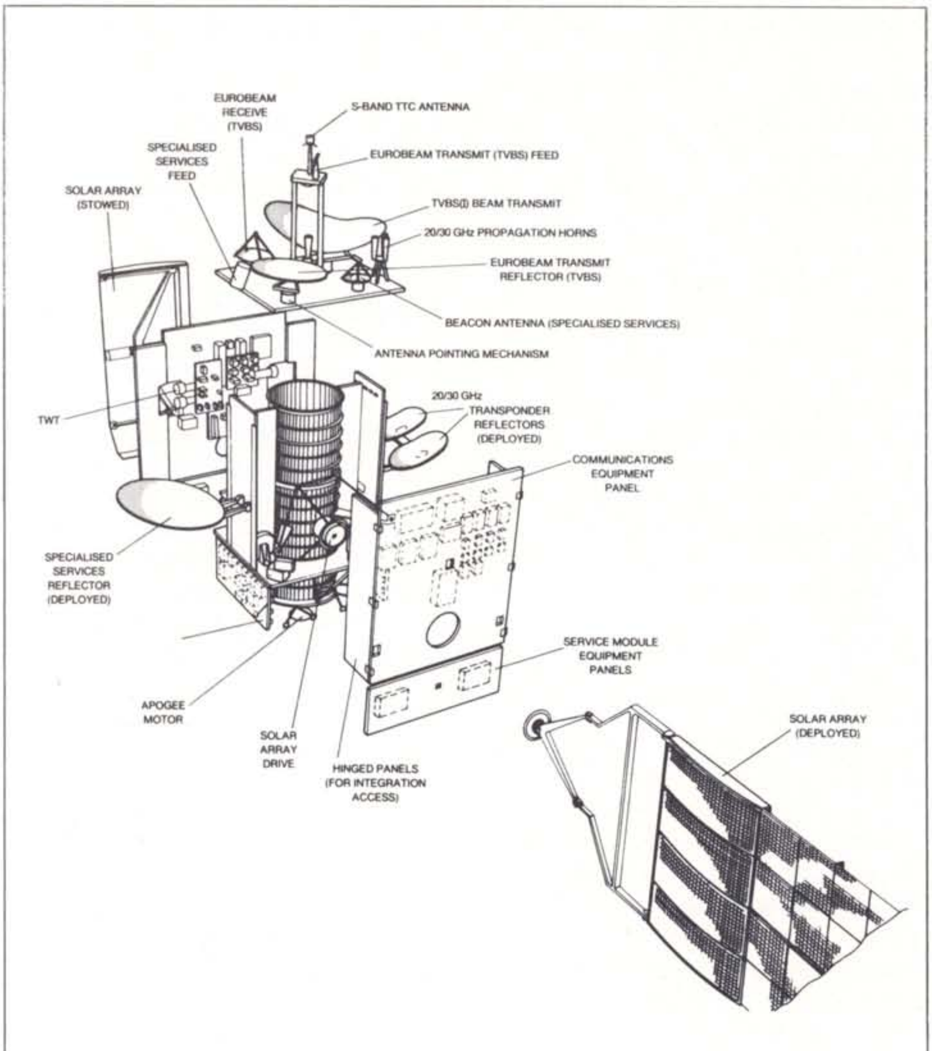
At the European level ESA is preparing L-Sat (Fig. 4). So far nine countries, Austria, Belgium, Denmark, Italy, Netherlands, Spain, Switzerland, United Kingdom and Canada, have acceded to this programme. The satellite will carry several different payloads, one of which will be for a direct-broadcast mission. Two channels will be installed, both with a power output of 350 W, for European broadcasting.

The Nordic countries have elaborate plans for their own satellite, the so-called 'Nordsat', but no decision on its actual deployment has yet been taken. In Denmark, satellite coverage can be expected from 1983 and earlier from the forthcoming German and French satellites. Later Nordsat or other television satellites may appear, and some ten satellite television channels are expected to be available around 1990. Prompted by this prospect, Aalborg University Centre has undertaken a research and development project aimed at producing a low-cost 12 GHz receiver provided with a frequency-synthesis accessory for demodulating forty television programmes – the maximum number possible in Denmark, corresponding to full implementation of the 1977 WARC agreement.

Experiments in India

The Indian national satellite Insat-I is currently being prepared for launch in 1981. It is a multipurpose system for domestic telecommunication, meteorology and television broadcasting.

Figure 4 – Exploded view of ESA's L-Sat telecommunications spacecraft, now being developed for a planned 1984 launch



In addition to national networking of terrestrial television transmitters, the latter component also encompasses television broadcasting to augmented community receivers in rural and remote areas, for which this kind of approach is economically more attractive. The system is designed to provide, over a seven-year satellite in-orbit lifetime, two 36 MHz television channels in the 5.855–5.935 MHz range for the earth-to-satellite link, and in the 2.555–2.635 MHz range for the satellite-to-earth link. The end-of-life EIRP is 42 dBW over the primary coverage area. Reception of these two channels with a 43 dB signal-to-noise ratio can be achieved with a 3.6 m diameter, low-cost chicken-mesh antenna, with a receiver noise figure below 4.5 dB. The Indian Government has yet to take investment decisions concerning radio and television utilisation facilities, but Insat-I should contribute significantly to the establishment of a broadcasting infrastructure in India.

Typical characteristics of the existing or planned television satellites discussed above are summarised in Table 1.

Table 1 – Typical characteristics of existing or planned television satellites broadcasting to receivers with antenna diameters of less than 3 m

System	Satellite mass, kg	Launch date	Uplink/ downlink frequencies GHz	Number of possible TV channels	TWTA output power per channel, W	EIRP dBW
CTS	350	17 01 76	14/12	1	200	59.5
BSE		08 04 78	14/12	2	100	56
OTS	324	11 05 78	14/11	1	20	
Insat-1		early 81	6/2.5	2		42
German TV-Sat	950	early 83	18/12	3 (– 5)	260	65.6
French TV-Sat			18/12	4	350	
L-Sat	1200	1984	18/12	2	350	64

Advantages and disadvantages of direct television broadcasting

The advantages of direct-to-home television broadcasting are:

(i) complete and large-area coverage from the start of operations
(ii) easy access to remote areas
(iii) advantageous in countries that do not yet have a ground-based broadcasting infrastructure
(iv) possible international copyright problems tend to be less acute
(v) no excavation for cable installation is needed.

Disadvantages may be summarised as:

(i) private receivers may need converters to adapt them to the various countries' television systems
(ii) specially powerful satellites are needed

(iii) in populous areas the many private antennas may be undesirable from an environmental point of view
(iv) the system is susceptible to jamming
(v) two-way communication is not possible
(vi) exclusive distribution to pay-television customers requires coded transmission, and individual decoders add significantly to the cost of private receivers.

The two last points are part and parcel of the overall problem that direct-to-home television broadcasting is incompatible with the concept of an integrated network, an aspect that will be discussed in greater detail later in the article.

Semi-direct broadcasting
Semi-direct television broadcasting from satellites to a number of earth stations, with 4–10 m antenna diameters, linked to CATV networks, was initiated with the Canadian Telesat system. This kind of broadcasting has now established itself as a very successful service, notably in the USA and Canada, and it will probably catch on in many other countries with the future proliferation of television satellites (Canada is also now planning for 'direct' television).

CATV in the USA
In the USA, CATV distributed on coaxial cables is responsible for much of the current growth in satellite communications. With satellites CATV can offer programmes that viewers cannot otherwise receive, and a virtual explosion is taking place in this field. Until 1976 the minimum diameter permitted by the FCC for CATV receive-only satellite earth stations was 9 m. In December 1976 the FCC reduced the permissible diameter to 4.5 m, significantly reducing the cost of a television receive-only earth station. The history of and projected growth of more than 5% per month for CATV earth stations indicate that there will be approximately 2700 earth stations in operation by January 1981, providing a CATV service to about 20 million homes.

A major factor in the exceptional growth in CATV is pay-television, via which comparatively new films, sport events and shows – all without interruption by commercials – are distributed to paying customers. About one-third of all CATV subscribers also take pay-television, and this percentage goes up to 75% for new systems. Even the most optimistic proponents of pay-television via satellite completely underestimated the number of CATV systems that would invest in receive-only earth stations, which typically cost $25 000 each. It is nevertheless a fact that many smaller systems (3500 subscribers or less) have found it profitable to make this capital investment in order to get the added income that pay-television generates.

CATV in Europe
In countries of modest area and in which television programmes from neighbouring countries can be received, CATV is already offered to a large percentage of the population. A prime example is Belgium, where the developmental trend is particularly interesting because it seems to be leading towards the installation of a unified cable distribution network covering the whole country.

Holland also has a high degree of CATV coverage, but there the existing mosaic of independent local cable networks is likely to be preserved for some time to come. This is also believed to be the case in Denmark, where about one million people, one fifth of the population, are already connected to many small and quite separate community installations.

Switzerland and Austria are other examples of CATV-oriented countries, but with the interesting feature that there is country-wide distribution of foreign programmes to CATV inputs via microwave links installed by the national PTTs.

It is also perhaps worth mentioning that the Deutsche Bundespost is contemplating a nationwide CATV network for a minimum of 12 television channels and 24 FM stereophonic sound signals. This concept involves trunk lines some 1000 km long to serve as a supplement to the radio links used at present.

Fibre-optic CATV networks
So far CATV networks have been based on the use of coaxial cables in a 'tree' structure, a technology that can provide efficient, low-cost simultaneous distribution of a large number of television programmes. Using VSB-FDM techniques, 20–30 programmes can easily be handled, and a US company has recently increased cable capacity from 35 to 52 channels by expanding the 300 MHz transmission band to 400 MHz.

The advent of optical-fibre communications has prompted intense research and development aimed at establishing new and more powerful CATV networks. It has quickly become clear that digital fibre-optic television transmission is technically and economically superior to analogue coaxial techniques on the main and medium trunk sections. In the subscriber loops the situation is more complex, the key element here being that optical-fibre communication systems can only handle a few simultaneous television channels on one fibre, at least when VSB-FDM techniques are used. This is primarily due to the presence of nonlinearities in the optical sources, but various noise problems can also be troublesome. These problems are being studied extensively at the TU Denmark Electromagnetics Institute.

One attractive way of getting around the problem is to use local exchange units from which the individual subscriber can select the programme he wants, so that only one television channel has to be transmitted at any one time. A star-shaped subscriber network results, instead of the conventional tree structure used with coaxial cables.

The need for the local exchange unit may appear to be a complication, but it does in fact provide the key to future flexibility, allowing a choice of an almost unlimited number of television and stereo sound channels to be offered. If the exchange units were co-located with local telephone switchboards or concentrators, telephone traffic could also be transmitted on the same network. The network could also be further expanded to include data transmission, two-way video, videophones, etc., as needs dictate. The result is a so-called 'integrated network' and field trials with such systems are already underway in several countries. Before reviewing a few such systems, it should perhaps be mentioned that the idea of integrating telephone and television transmissions – as opposed to switching – on a common network is a controversial one, as it challenges current regulatory and commercial practices in many countries.

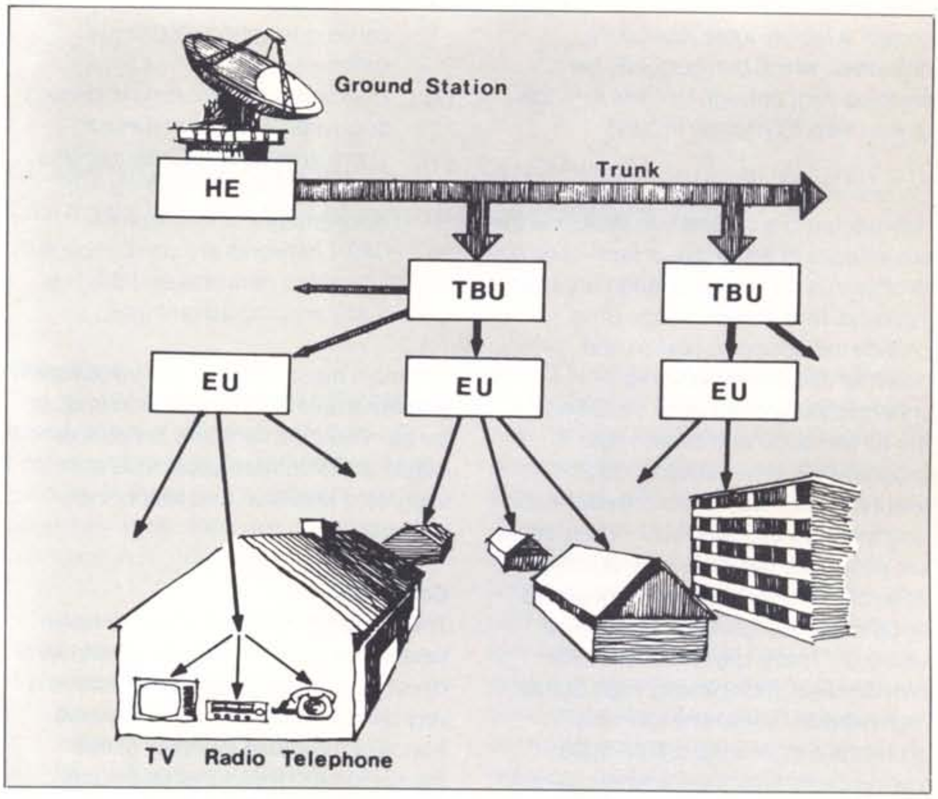


Figure 5 – Satellite television-broadcast reception by an integrated network consisting of trunks, trunk branching units (TBU), exchange units (EU) and subscriber lines

The first medium-scale fibre-optic network to be put into service was the so-called 'HiOVIS' system in Higashi Ikoma, a suburb of Osaka, Japan. The system connects 158 homes, with two fibres for simple two-way analogue intensity-modulated television transmission and associated sound and signalling channels. The subscribers are connected to a local exchange unit provided with a video switch, giving access to network and local television, video cassettes, a photographic library, etc. It is the largest network in operation today involving interactive video systems in private homes. The system is heavily government sponsored; it does not constitute an economically viable service at this moment, but a second-generation system to serve between 3000 and 5000 homes has nevertheless already been proposed.

Several fibre-optic television systems are planned in Canada, and a few are due to go into service shortly, including the Manitoba system, where a single fibre will carry two television channels, data and telephone traffic to individual homes.

The French PTT has recently announced plans to install a fibre-optic network in 1983, carrying broadband services, including videophone, to between 2000 and 3000 homes in Biarritz. Little information has been released as yet but it is believed that there is no technical reason why CATV could not be included.

In Denmark, the Jutland Telephone Company and the Electromagnetics Institute at Lyngby are planning an all-digital fibre-optic integrated network (Fig. 5). From the CATV head, 140 or 280 Mbit/s trunks will be used to carry off-the-air television and FM mono and stereo sound channels to trunk branching units. In initial and very recent experiments Jutland Telephone has transmitted 140 Mbit/s unrepeatered over 15 km using 0.85 μm devices. From the branching units the channels will be carried to local exchange units where telephony and data services can be coupled in. Each exchange unit is planned to serve 200 to 500 subscribers, each of whom will be provided with one downstream and one upstream fibre. The downstream fibre will carry 140 Mbit/s signals encompassing one TV-channel, all available audio and data services, and one-way telephony. The upstream fibre will provide the return path for telephony, for data, and for service-selection signals. Subscribers who need two simultaneous television channels will be provided with an extra fibre. The system offers the choice of 16 television and 22 stereo radio programmes. The 140 Mbit/s bit rate (139.264 Mbit/s to be precise) has been chosen for reasons of compatibility with the European pulse-code-modulated (PCM) telephony hierarchy. Future developments in fibre-optic directional couplers and wavelength-division multiplexers may make it attractive to incorporate the return path in the downstream fibre, rendering the upstream fibre unnecessary. At the moment the project is facing some regulatory difficulties, which can hopefully be resolved early enough to allow field trials to start with 200 homes in 1983.

Compared with a conventional CATV network using a coaxial tree structure, the advantages of an all digital fibre-optic star structure using local exchange units are threefold. First, the exchange units provide the access to flexible and powerful integrated networks encompassing all services, including off-the-air television and stereo radio programmes, pay-television, data telephony, two-way video communication, videophones, etc. Secondly, optical fibres are potentially inexpensive and provide large capacity over long, unrepeatered distances, particularly on trunk-route sections. Thirdly, digital transmission provides easy multiplexing, high quality, high reliability, avoids nonlinearity problems with analogue fibre-optic transmission, and takes advantage of future low-cost digital large-scale integrated (LSI) circuits, which will also provide efficient television-encoding in the future.

Short-term disadvantages are higher costs, although this situation should change after the mid-1980s, and powering of the telephone. The latter problem could be solved by including wires in the subscriber cable, by batteries or by light powering.

Advantages and disadvantages of CATV networks

Compared to direct-to-home satellite television broadcasting, CATV networks – especially in the form of integrated networks – coupled to satellite earth stations provide the following advantages:

(i) The costs of reception antennas, receivers and conversion electronics are shared between many subscribers and the equipment can therefore be of a higher quality and complexity.
(ii) Leased transponders on normal communications satellites also carrying telephone traffic are sufficient.
(iii) Environmental problems in densely populated areas are relieved.
(iv) There are larger systems margins and hence fewer problems with electromagnetic interference.
(v) CATV networks are compatible with integrated networks and this has many ensuing advantages.

The main disadvantages are troublesome and expensive cable installation and, as far as integrated networks are concerned, regulatory difficulties associated with integrated television and telephone transmission.

Conclusion

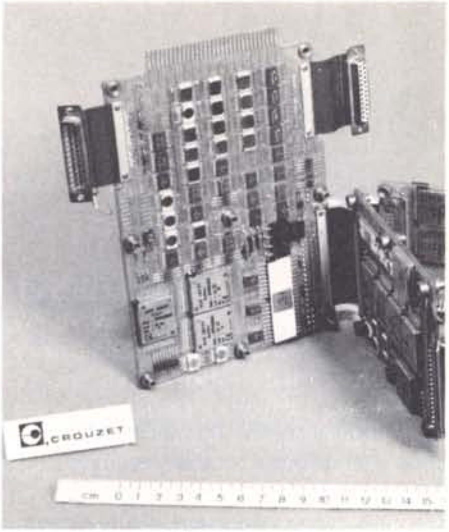
The future mix between direct-to-home satellite television broadcasting and semi-direct broadcasting via CATV systems is very difficult to predict, as it will evolve from a complicated interplay of free market forces, governmental cultural policies and telecommunications regulations, all of which are subject to change and differ from one country to the next. In the USA, for example, a number of scenarios depending on future regulations have already been studied, ranging from almost chaotic direct satellite television broadcasting, to nation-wide fibre-optic networks operated by telephone companies.

In Europe there are presently no plans for semi-direct satellite broadcasting for feeding CATV networks. Any broadcast satellite designed for direct reception can, however, provide programmes for CATV over a much wider coverage area.

From an economic point of view, it seems safe to predict that in more densely populated areas CATV networks will offer a better service at a lower cost, with fewer environmental problems and with greater versatility, especially in the case of integrated networks. In sparsely populated areas, individual reception will be economically more attractive, but with more limited quality and versatility. The economic cross-over point is very difficult to identify in general terms, but estimates based on Danish conditions indicate that CATV or community systems provided with satellite earth stations will be cheaper for the subscriber when at least 100 to 200 neighbouring homes share the cost.

Hence in Denmark, and in many other countries also, a balanced deployment of direct and semi-direct satellite television broadcasting seems a reasonable expectation, the optimum mix being determined primarily by economic considerations. However, such a rational development may not occur unless unusually strong governmental regulations are enforced. The question of timing, for example, could have a strong impact on how things actually develop, because the service that becomes established first in a particular area is likely to preclude any competing alternative for a long time to come.

As to the future role of optical fibres in CATV networks, it seems certain that they will become attractive, both technically and economically, in trunk sections, while in the subscriber network – especially in urban areas – further development is needed to establish their economic viability. As far as terrestrial television distribution between cities is concerned, a comparison must be made between radio links and optical-fibre trunk routing. This question is beyond the scope of this article, but in the light of the rapid progress being made in long-distance optical-fibre communication, a nationwide fibre network could well turn out to be an attractive proposition, particularly in countries of modest geographical extent.



The Modular Attitude and Orbit Control System – A Step towards Greater Cost-Effectiveness in Spacecraft Control

G. Mehwald, C.J. Reimers, A.J. Sarnecki, Attitude and Orbit Control Division, ESTEC, Noordwijk, Netherlands*

Present-generation Attitude and Orbit Control Systems (AOCS) are characterised by high and steadily increasing cost, long development cycles and considerable hardware development risk, deficiencies that can largely be attributed to the present customised method of equipment development and to the absence of a coherent AOCS design philosophy. The Modular Attitude and Orbit Control System (MACS) concept is intended to overcome these drawbacks by emphasising systematisation and standardisation, while at the same time circumventing unacceptable design constraints.

* Now with ESTEC Systems Engineering Department.

Objectives

The general aim of increasing the cost-effectiveness of future attitude and orbit control systems can be formulated more precisely in terms of a number of specific objectives. Essentially, one is seeking a reduction in:

- hardware/software development problems and timescales
- manufacturing costs
- procurement complexity
- product-assurance effort
- integration and test effort, and
- management effort

while at the same time striving to improve AOCS performance potential in terms of:

- control law complexity and flexibility
- accuracy
- reliability
- mass
- power consumption.

Due regard must of course be paid to constraints inherent in the European space scene, such as the relatively small spacecraft production programme, the industrial structure and the resulting industrial policy.

Approaches to a cost-effective solution

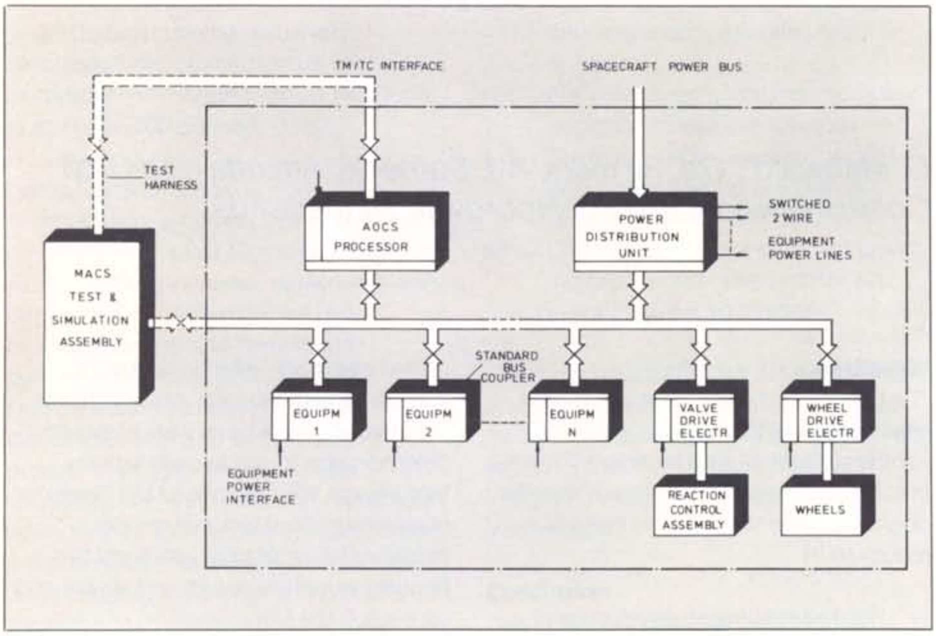
So far, there have been two main approaches followed in order to reduce satellite design and manufacturing costs, the 'Service Platform Spacecraft' approach and the 'Subsystem Modular Spacecraft' approach. However, the exclusive application of either concept to the European space programme would not be very practical.

A third approach, which may be called the 'Equipment Modular Approach' has now become feasible in view of recent developments in modern electronics technology. With advanced LSI (large-scale integration) technology, the implementation of logic functions has become extremely cheap and simple and as a result the miniaturisation of these functions has ceased to be a major design driver when conceiving spacecraft subsystems. This has opened up a completely new perspective in that practically all levels of 'electronic intelligence' can now be decentralised, allowing largely autonomous subsystems and self-contained assemblies to be implemented. As a result, functional and hardware interfaces can be considerably simplified and standardised, with fundamental consequences in terms of re-usability of hardware and ease of spacecraft development, manufacture, integration, test and management.

A problem with modern electronics technologies is still the qualification and quality-assurance philosophies for space application, which have not kept pace with the technologies themselves. There is visible progress, however, and reasonable solutions are being identified.

It is perhaps worth mentioning that the 'Equipment Modular Approach' is not mutually exclusive as far as the two earlier mentioned approaches are concerned, particularly the 'Service Platform' concept. It is equally well suited for combination with or use within them.

Figure 1 – Block diagram of a typical Modular Attitude and Orbit Control System (MACS)



Composition and application of the MACS concept

A tentative MACS concept taking advantage of the latest technological achievements has evolved as a synthesis of several ESA and non-ESA studies and developments. It can be considered as the baseline for further improvement and consolidation activities, aimed at the final definition of a well-balanced AOCS design approach.

MACS is structured around a dedicated digital processor to provide all the necessary spacecraft control algorithms and AOCS monitoring and management functions in as autonomous a manner as possible (Fig. 1). Adaptation to mission-specific requirements is achieved via software at the processor level and by selection of appropriate equipment – mainly sensors and actuators – at subsystem level. The processor and all equipment are characterised by systematised performance and software requirements, and in particular feature an identical and simple interface standard. It is not the intention to standardise detailed hardware designs; this would only hamper technical progress by preventing further improvements on the basis of new technologies, and moreover create the danger of setting up undesirable monopolies.

Communication between the AOCS processor and the other AOCS equipment is to be via a standard data bus with standard interfaces, adequately supporting all AOCS needs. However, the decentralisation aspect is to be kept prominent even within the AOCS so that, where appropriate, specific processing will be performed in the individual equipment items.

All equipment items are to be supplied with one standard voltage and individual power conditioners will provide all internally required voltages. Power switching will be performed in an AOCS switching unit. This also provides for power conversion if necessary, since it has not been possible so far to define a general spacecraft power standard.

Interfacing with telemetry/telecommand (TM/TC) or the spacecraft on-board data handling (OBDH) system will be via the AOCS processor. Telemetry data collection and telecommand distribution within the AOCS will be handled by this processor using the AOCS internal data bus.

Redundancy provisions are foreseen to cope with different reliability requirements, with redundancy switching and system reconfiguration controlled autonomously by the AOCS processor as far as practicable.

The system will be designed to comply with both existing and foreseen standards, in particular those for EMC, so as to cover the broadest range of applications with least expense.

In system development, test and checkout, use will be made of a standard test processor, which can simulate, stimulate and monitor any of the AOCS equipment utilising the AOCS bus and the TM/TC interface of the AOCS processor. This permits high-confidence testing and simulation even when the subsystem is not fully assembled or integrated. For complete functional and/or dynamic tests, the usual stimulators and motion systems can still be used.

Programme of work

Future activities on MACS are intended to lead to a consolidation of the tentative concept presented here and to its final and comprehensive elaboration and verification. In order to ensure that a well-balanced design approach is arrived at and to achieve the widest possible acceptance, the participation of as many AOCS industrial contractors as practicable in the intended work programme will be sought. The planned programme will comprise three phases of subsystem-level activity and two equipment level activities.

Implementation of a fully MACS-configured attitude and orbit control system on board European spacecraft will be possible from 1984 onwards, but many of the intermediate results of the programme will be suitable for use earlier in conventionally configured attitude and orbit control systems.

In Brief

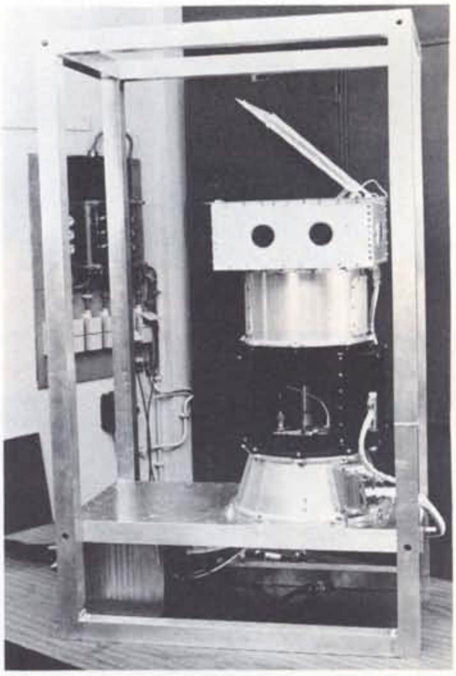
ESA Space Science Department Experiment on First Spacelab Flight

ESA and NASA have recently confirmed the selection of 37 scientific experiments to be carried out on the first flight of Spacelab, scheduled for launch aboard the Space Shuttle in mid 1983. The experiments, 24 of which are sponsored by and are the responsibility of the European Space Agency, fall into five broad categories: atmospheric physics and earth observations, space plasma physics, materials sciences and technology, astronomy and solar physics and the life sciences.

One of the instruments in the astronomy category is an X-ray astronomy experiment being developed by the Physics Institutes of the Universities of Milan and Palermo, the Mullard Space Science Laboratory of University College London, and the High-Energy Astrophysics Division of ESA Space Science Department. The heart of the instrument, designed for X-ray observations in the 2–80 keV energy range, is a gas-scintillation proportional counter (GSPC) pioneered by the High-Energy Astrophysics Division. The use of this counter will allow the study of not only the continuum X-ray emission from cosmic objects, but also spectral lines and absorption features over a wide energy range, with high efficiency and with high time resolution. No existing instrumentation can achieve the performance of the GSPC over such a broad bandwidth and in such detail.

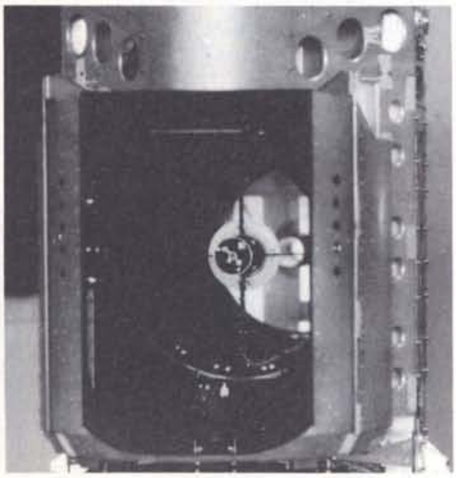
The flight hardware for the experiment and the computer-based ground checkout equipment arrived in ESTEC (Noordwijk) at the beginning of June for the commencement of interface and environmental testing. Dr R D Andresen of ESA Space Science Department is the principal investigator for this novel Spacelab astronomical experiment.

The X-ray astronomy experiment to be flown on Spacelab (below) and its associated computer-based checkout equipment (above)



The three European payload specialists. From left to right: Wubbo Ockels, Ulf Merbold and Claude Nicollier

The infrared grill spectrometer to be carried on the first Spacelab flight



Spacelab Crew Training in France

The three European and two American payload specialists and the two American mission specialists from whom the crew for the first Spacelab flight will be chosen visited the Office National d'Etudes et de Recherches Aerospatiales (ONERA) at Châtillon-sous-Bagneux, in France, for three days at the end of May to familiarise themselves with the details of one of the experiments that they will be carrying on that first flight. This experiment, jointly designed and prepared by the Institut d'Aéronomie Spatiale de Belgique and ONERA, will use an infrared grill spectrometer, invented at ONERA, to analyse the chemical composition of the stratosphere and thereby to monitor the effect of man's activities on its evolution. In the course of their training session the seven visitors participated in a ground-based simulation of the experiment operations they will have to perform during the Spacelab flight.

In addition to the Shuttle Commander and Co-Pilot, the first Spacelab crew will be comprised of two payload specialists – one American and one European – whose task it will be to carry out the on-board experiments, and two mission specialists who will be responsible for the interface between Shuttle and Spacelab. The five payload-specialist candidates training at Châtillon-sous-Bagneux were:
Ulf Merbold (Germany)
Claude Nicollier (Switzerland)
Wubbo Ockels (Netherlands)
Michael Lampton (USA)
Bryon Lichtenberg (USA)

The two mission specialists present were Owen Garriott and Robert Parker, both Americans.

Second Spacelab Instrument Pointing System (IPS) Ordered by NASA

The Agency's new Director General, Mr E. Quistgaard, signed a contract on 27 May with Dornier System (Germany) for the production of a second Spacelab instrument pointing system (IPS) flight unit. This additional IPS, which is a major Spacelab subsystem, is needed by NASA

Shaking hands, on the left Dr. Ulke, Technical Director of Dornier System, and on the right Mr. E. Quistgaard, ESA's Director General for the Spacelab and IPS utilisation mission model, and is the subject of a rider signed on 23 May by ESA and NASA to the contract for the provision of a second Spacelab. This latter contract was converted by ESA last January into a contract with European industry (see ESA Bulletin No. 22, page 72).

The contract signed on 27 May complements the earlier follow-on production contract and increases the total volume of Spacelab work under NASA contract from 117 MAU* to 132 MAU. NASA will bear the cost – approximately $20 million – of the IPS's production by European industry.

The IPS is a three-gimbal device which will be mounted on a Spacelab pallet in the payload bay of the Space Shuttle to provide a highly accurate pointing capability for scientific instruments that require greater accuracy and stability than can be provided by the Shuttle itself. The IPS has the ability to lock onto and accurately track scientific targets such as stars, solar flares, or specific points of interest on the earth's surface, unaffected by slight changes in Shuttle attitude.

It is the number of currently planned experiments demanding such accurate pointing that required that this second unit be purchased to supplement the first IPS, which forms part of the basic Spacelab equipment being furnished by ESA.

* 1 AU = ± 1.25 $US

The Economic Effects of Space and Other Advanced Technologies

Innovation policy, cost-effectiveness of research, competitiveness and advanced technology, and innovation and employment were the main themes debated by international experts at a Colloquium with the above title held in Strasbourg from 28 to 30 April 1980, and organised jointly by the European Space Agency and the Bureau of Theoretical and Applied Economics of the Louis Pasteur University of Strasbourg, under the aegis of the Parliamentary Assembly of the Council of Europe. It was attended by nearly three hundred participants, mainly economists, industrialists, scientists, government representatives and journalists, drawn from 24 countries.

In welcoming the participants, Mr C Hanin, Chairman of the European Joint Committee for Scientific Cooperation of the Parliamentary Assembly of the Council of Europe, noted the Colloquium as being 'concerned with one of the major issues of our time, the interplay between science and society, and more especially between advanced technology, that of space in particular, and economic growth'.

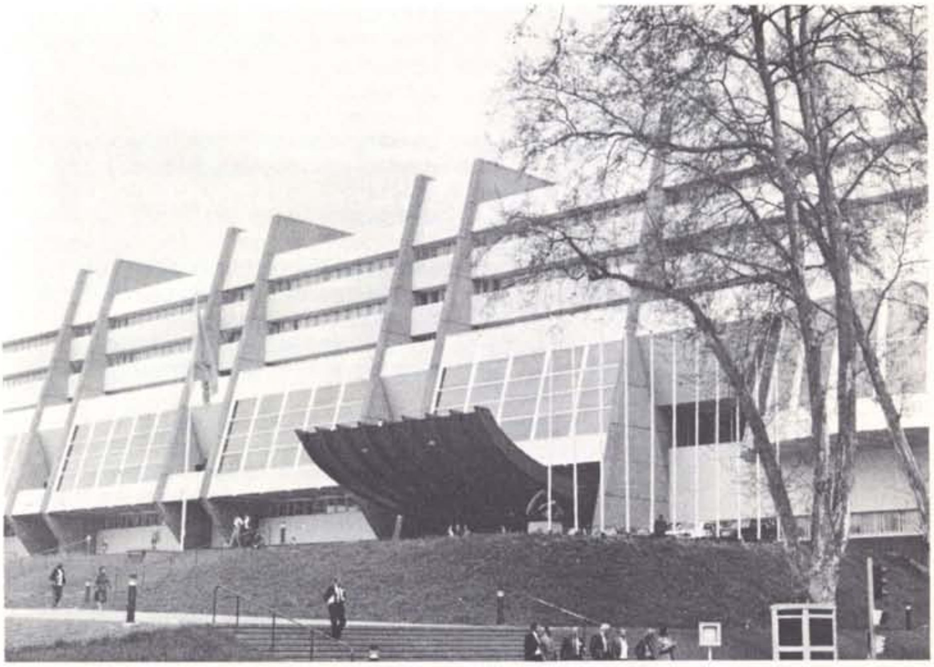
One of the Colloquium's major features were the discussions on the induced effects of innovation, covering not only its technical and organisational impacts, but also the social implications.

Four members of the Parliamentary Assembly of the Council of Europe were present and took part in the discussions:

- Mr J Valleix, Vice-Chairman
- Mr D Atkinson, rapporteur of the Plenary Commission for Science and Technology
- Mr J van Waterschoot, rapporteur of the Commission for Economic Questions and Development, and
- Mr J Wilhelm, rapporteur for European Space Policy of the Commission for Science and Technology.

In the light of the interesting results of the Colloquium, Mr van Waterschoot proposed that a public European parliamentary hearing should now be organised to evaluate the socio-economic spin-off of advanced technologies, as an aid to policy decision-making.

The Proceedings of the Strasbourg Colloquium, which include both the formal presentations and a transcript of the discussions, are available from ESA Scientific and Technical Publications Branch as Special Publication SP-151.



The seat of the Council of Europe Parliamentary Assembly in Strasbourg

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table on page 78 and using the Order Form on page 79

ESA Journal

The following papers were published in ESA Journal Vol 4 No 2:

NEAR-UNSTABLE SUPERGIANTS
DE JAGER C

HOW LARGE IS LARGE – REFLECTIONS ON FUTURE LARGE TELECOMMUNICATIONS SATELLITES
VANDENKERCKHOVE J A

PROSPECTS FOR USING SOLAR ENERGY TO POWER MATERIALS-SCIENCE FURNACES IN SPACE
HUTH U & BADER M

GEOSTATIONARY-ORBIT DETERMINATION BY SINGLE-GROUND-STATION TRACKING
SOOP M

STUDY OF HYBRID POWER STRUCTURES FOR SATELLITE APPLICATION
BOETTI A, JOHANSEN E, KORNUM J & OLESEN S

Scientific and Technical Memoranda

ESA STM-212 THEORETICAL EVALUATION OF A GROUNDING CONFIGURATION FOR AN INDIUM-OXIDE COATED THERMAL-CONTROL MATERIAL. (JAN 1980)
BOSMA, S.J. PRICE CODE: C1

ESA STM-216 USER'S GUIDE FOR A COMPUTER SIMULATION PROGRAM FOR MULTI-RIGID-BODY SYSTEMS. (FEB 1980)
BOLAND, PH. PRICE CODE C1

Contractor Reports

ESA CR(P)-1284 ON-BOARD SAR PROCESSOR DEFINITION - FINAL REPORT. (OCT 1979)
MARCONI, UK

ESA CR(P)-1286 ETUDE ET DEVELOPPEMENT D'UN ELEMENT D'ANTENNE RESEAU A GUIDES A FENTES - RAPPORT FINAL. (NOV 1979)
THOMSON-CSF, FRANCE

ESA CR(P)-1290 REPORT ON THE ADVANCED POWER SYSTEM CONFIGURATION STUDY. (JUN 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1291 A STUDY OF INCREASED RELIABILITY AND LIFETIMES FOR FUTURE COMMUNICATIONS SATELLITES. (1) SUMMARY REPORT. (2) FINAL REPORT. (OCT 1979)
GENERAL TECHNOLOGY SYSTEMS LTD., UK

ESA CR(P)-1293 PRE-PHASE A STUDY - AUTOMATIC SPACE PROCESSING EQUIPMENT (ASPE). VOLUME 1: TECHNICAL SUMMARY. VOLUME 3: TECHNICAL APPENDIX. (OCT 1979)
ERNO, GERMANY

ESA CR(P)-1294 ETUDE DES TECHNIQUES DE COULEUR POUR LE TRAITEMENT DES DONNEES IMAGES ET EXPERIMENTALES. (OCT 1979)
AEROSPATIALE, FRANCE

ESA CR(P)-1295 GYRO NOISE MEASUREMENT AND ANALYSIS. (SEP 1979)
NLR, NETHERLANDS

ESA CR(P)-1296 FINAL REPORT ON THE IMPROVEMENT OF MINIATURE PYROTECHNIC DEVICES FOR SPACE APPLICATION. (UNDATED)
NOBEL, UK

ESA CR(P)-1297 STUDY AND DEVELOPMENT OF COMPUTER PROGRAM FOR ANALYSIS OF SAR PLANAR ARRAY ANTENNAS - FINAL REPORT. (MAY 1979)
TICRA APS, DENMARK

ESA CR(P)-1298 A STUDY OF SPECTRUM EFFICIENT MODULATION TECHNIQUES FOR DIGITAL SATELLITE COMMUNICATIONS - FINAL REPORT. (JUN 1979)
MARCONI, UK

ESA CR(P)-1300 USE OF INTEGRATED OPTICS FOR ANALOG DATA SIGNAL CONDITIONING ABOARD SPACECRAFT - FINAL REPORT. (SEP 1979)
THOMSON-CSF, FRANCE

ESA CR(P)-1301 PROSPECTIVE STUDY ON THE UTILISATION OF SOLAR ENERGY FOR THE OPERATION OF SPACELAB MATERIAL SCIENCE FURNACES - FINAL REPORT. (DEC 1979)
SEP, FRANCE

ESA CR(P)-1302 DEVELOPPEMENT D'UNE BIBLIOTHEQUE DE MODELES THERMIQUES-APPLICATION A LA SIMULATION DYNAMIQUE DU CONTROLE THERMIQUES DES BOUCLES DE FLUIDES DE SPACELAB - RAPPORT FINAL (OCT 1979)
UNIV. DE POITIERS, FRANCE

ESA CR(P)-1304 EVALUATION OF TITANIUM BOLTS COATED WITH IVADIZE ALUMINIUM AND KALGARD 2240C IN TORQUE TENSION TESTS. (NOV 1979)
SPS LABORATORIES, IRELAND

ESA CR(P)-1305 DEVELOPMENT AND TESTING OF CLEANING PROCEDURES AND FEEDING SYSTEMS FOR A FIELD EMISSION THRUSTER MODEL - FINAL REPORT. (MAY 1979)
FULMER RESEARCH INSTITUTE, UK

ESA CR(P)-1303 STUDY AND DEVELOPMENT OF PRINTED CIRCUIT ELEMENT FOR SAR ARRAY ANTENNAS-FINAL REPORT (OCT 1979)
IEC, SPAIN

ESA CR(P)-1306 VANNE BISTABLE A VERROUILLAGE - RAPPORT FINAL. (JUL 1979)
AEROSAPTIALE, FRANCE

ESA CR(P)-1307 FIELD EMISSION ELECTRIC PROPULSION ION OPTICS OF DOUBLE EDGED EMITTERS - FINAL REPORT. (DEC 1978)
CULHAM LABORATORY, UK

ESA CR(P)-1308 TREND ANALYSIS - SPACE COMMUNICATIONS SYSTEM TECHNOLOGY - PHASE I FINAL REPORT: DEFINITION OF USER NEEDS. (DEC 1979)
ARTHUR D. LITTLE, FRANCE

ESA CR(P)-1309 SUB-ARC-SECOND SENSOR CALIBRATION - FINAL REPORT. (NOV 1978)
OSSERVATORIO ASTRONOMICO DI TRIESTE, ITALY

ESA CR(P)-1310 ESTL PROGRESS REPORT FOR 1978. (SEP 1979)
ESTL/UKAEA, UK

ESA CR(P)-1311 APPLICATION OF FINITE-ELEMENT METHODS TO THE ANALYSIS OF CRACKS - FINAL REPORT. (DEC 1979)
NLR, NETHERLANDS

ESA CR(P)-1312 LIFE TESTS OF THE TELECOMMUNICATIONS SATELLITE HEAT PIPES - FINAL REPORT (JAN 1979)
IKE, UNIV, STUTTGART, GERMANY

ESA CR(P)-1313 RAPPORT FINAL SUR UN COMPLEMENT D'ETUDE CONCERNANT LA FAISABILITE D'UN SYSTEME DE RADIODIFFUSION SONORE A MODULATION DE FREQUENCE PAR SATELLITE (DEC 1979)
THOMSON-CSF, FRANCE

ESA CR(P)-1314 PROSPECTIVE STUDY ON THE UTILISATION OF SOLAR ENERGY FOR THE OPERATION OF SPACELAB MATERIAL SCIENCE FURNACES - FINAL REPORT. (OCT 1979)
DORNIER SYSTEM, GERMANY

ESA CR(P)-1315 PALLET-ONLY CONFIGURATION IMPROVEMENT STUDY (RIDER) - FINAL REPORT. (NOV 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1316 COMET HALLEY PROBE STUDY - STUDY ON USE OF ISEE-B PLATFORM AS PROBE FOR ESA/NASA COMETARY MISSION - FINAL REPORT. (OCT 1979)
DORNIER SYSTEM, GERMANY

ESA CR(P)-1317 EVALUATION OF RADIATION EFFECTS IN THE MA328 CCD IMAGE SENSOR - FINAL REPORT. (JAN 1980)
SIRA INST., UK

ESA CR(P)-1318 HIPPARCOS PAYLOAD STUDY - FINAL REPORT. (JAN 1980)
MATRA, FRANCE

ESA CR(P)-1319 HIGH PERFORMANCE VCHP DIODE BEHAVIOUR - FINAL REPORT. (DEC 1979)
SABCA, BELGIUM

ESA CR(P)-1320 DYNAMIC SS/TDMA. (FEB 1980)
CSELT, ITALY

ESA CR(P)-1321 HIGH PERFORMANCE VCHP LIFE TEST - FINAL REPORT (DEC 1979)
SABCA, BELGIUM

ESA CR(P)-1322 ASSEMBLY AND TESTING OF A CATALYTIC HYDRAZINE GAS GENERATOR - FINAL REPORT. (FEB 1980)
ERNO, GERMANY

ESA CR(P)-1323 DEVELOPMENT OF SMALL CRYOGENIC HEAT PIPES - PHASE 1 REPORT. (DEC 1979)
SABCA, BELGIUM

ESA CR(P)-1324 MULTI-USER TDMA AND SS-TDMA (FEB 1980)
CSELT, ITALY

ESA CR(X)-1278 STUDY ON MODELLING OF AIRDRAG EFFECTS ON ORBIT AND ATTITUDE PREDICTION FINAL REPORT PART I: THE CALCULATION OF CONVEX BODY AERODYNAMICS IN FREE MOLECULAR FLOW USING A PLANE ELEMENT SURFACE APPROXIMATION/SURVEY ON THEORY AND METHODS/DESCRIPTION OF A FORTRAN PROGRAM PACKAGE. PART II: AERODYNAMICS FOR BASIC SHAPES AND COMPOSITE SURFACE ELEMENTS IN FREE MOLECULAR FLOW. PART III: WIND TUNNEL EXPERIMENTS AND APPROXIMATE THEORY ON THE DRAG OF THE TD1A SATELLITE. (AUG 1979)
DFVLR, GERMANY

ESA CR(X)-1289 DESIGN AND TECHNOLOGY STUDY OF SOLAR ARRAYS FOR SHUTTLE-LAUNCHED MISSIONS - FINAL REPORT. (OCT 1979)
AEROSPATIALE, FRANCE

ESA CR(X)-1292 STUDY OF THE REQUIRED GROUND OPERATIONS FOR EXPERIMENT 1ES021 AND DEFINITION OF THE RELEVANT PROCEDURES - FINAL REPORT. (MAY 1979)
ERNO, GERMANY

ESA CR(X)-1299 SYNCHRONISATION, CODING AND MODULATION SCHEMES FOR THE ESA TELECOMMAND TELEMETRY AND TRACKING STANDARDS - FINAL REPORT. VOLUME 1: SUMMARY AND INTRODUCTION. VOLUME 2: TELECOMMAND STRUCTURE AND CODING. VOLUME 3: TELEMETRY SYNCHRONISATION AND CODING. VOLUME 4: TELEMETRY/RANGING INTERFERENCE. VOLUME 5: FRAME SYNCHRONISER IMPLEMENTATION. (JAN 1979)
SAAB-SCANIA, SWEDEN

Technical Translations

TT-480 A STUDY ON PILOT/OBSERVER INTERACTION IN ALIGNING A HELICOPTER WITH A TARGET (JAN 1980)
DANNEBERG E, DFVLR, GERMANY

TT-544 INFLUENCE OF GRAVITY OF CHEMICAL VAPOR DEPOSITION PROCESSES (JAN 1980)
WAHL G, NICKL J, JUST W, BUNDESMIN FUER FORSCH U TECHNOL, GERMANY

TT-548 THERMODYNAMIC AND PHENOMENOLOGICAL DESCRIPTION OF CYCLIC CISCOPLASTICITY WITH DAMAGE (MAY 1979)
CHABOCHE J-L, ONERA, FRANCE

TT-550 INFLUENCE OF AGING TREATMENTS ON MECHANICAL PROPERTIES OF TA6V (APRIL 1979)
LOUBRADOU M, ONERA, FRANCE

TT-551 MODELIZATION OF THE INFLUENCE OF AN ACCELERATION ON THE FREQUENCY OF QUARTZ RESONATORS (MAY 1979)
JANIAUD D, ONERA, FRANCE

TT-552 CALCULATION OF HETERODYNE DETECTION WITH FOCUSSED RADIATION (JULY 1979)
MALOTA F, DFVLR, GERMANY

TT-553 NOISE GENERATION BY JET-ENGINE EXHAUST DEFLECTION (JULY 1979)
GEHLHAR B, DOBRZYNSKI W, FUHRKEN B, DFVLR, GERMANY

TT-555 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1978-5 (JULY 1979)
ONERA, FRANCE

TT-558 ANALYSIS OF CALCULATED THREE-DIMENSIONAL INVISCID FLOW FIELDS WITH EMBEDDED SHOCK WAVES (PRESENTATION OF A FIELD SOLUTION) PART 1 (JULY 1979)
WEILAND C, THIES H-J, DFVLR, GERMANY

TT-559 FEASIBILITY STUDY OF A SPACELAB-SUBSATELLITE (FEB 1980)
PULS J, ECKSTEIN M, LIEBING L, PUCH K, NAEHLE R, PIENING M, MANSKI D, SCHMIDT H, PIETRASS A, BOETTCHER R, DFVLR, GERMANY

TT-561 LA RECHERCHE AEROSPATIALE - BIMONTHLY BULLETIN, 1978-4 (JUNE 1979)
ONERA, FRANCE

TT-562 DEVELOPMENT OF ULTRASONIC TRANSDUCERS FOR MEASURING LIQUID FLOWRATES AT HIGH TEMPERATURE AND HIGH PRESSURE (JUNE 1979)
DEOM A, ONERA, FRANCE

TT-563 OPTICAL MEASUREMENTS IN FLOW, APPLICATIONS TO WIND TUNNELS AND ENGINE TEST STANDS (JUNE 1979)
BOUIS X, ONERA, FRANCE

TT-564 CONSTRUCTION PROBLEMS FOR HIGH REYNOLDS NUMBER WIND TUNNEL MODELS (JUNE 1979)
BAZIN M, ONERA, FRANCE

TT-572 NONLINEAR PROGRAMMING. FOUNDATIONS, TECHNIQUES, EXAMPLES (FEB 1980)
KRAFT D, DFVLR, GERMANY

TT-579 FORMATION OF PROMPT NITROGEN OXIDES DURING COMBUSTION OF HYDROCARBONS (FEB 1980)
AVEZARD N, ONERA, FRANCE

TT-580 INFLUENCE OF TURBULENCE ON HYDROCARBON COMBUSTION IN A STIRRED COMBUSTOR (JULY 1979)
BONNIOT C, ONERA, FRANCE

TT-585 THEORETICAL ESTIMATION OF NONLINEAR LONGITUDINAL CHARACTERISTICS OF WINGS WITH SMALL AND MODERATE ASPECT RATIO BY THE VORTEX LATTICE METHOD IN INCOMPRESSIBLE FLOW (JAN 1980)
SCHROEDER W, DFVLR, GERMANY

TT-587 CONTRIBUTIONS TO THE SYMPOSIUM 'COMPUTER SCIENCE IN SPACE FLIGHT', 19 JANUARY 1978, OBERPFAFFENHOFEN (FEB 1980)
KURAU A (ED), DFVLR, GERMANY

TT-591 INVESTIGATION OF THE SOLIDIFICATION BEHAVIOUR OF ELECTRON BEAM WELDS UNDER MICROGRAVITATIONAL CONDITIONS (JAN 1980)
BOGS H, HESSE P, SAHM P, BUNDESMIN FORSCH U TECHNOL, GERMANY

TT-592 FLOW PHENOMENA IN GRAVITATIONLESS MELTING ZONES IN THE PRESENCE OF ELECTROMAGNETIC FIELDS (JAN 1980)
CHUNG-HWANG CHUN, BUNDESMIN FUER FORSCH U TECHNOL, GERMANY

TT-593 COMPUTATION OF THE RADIATION CHARACTERISTIC OF ANTENNAS ON COMPLICATED STRUCTURES IN THE HIGH FREQUENCY CASE. PRINCPLE OF THE GEOMETRICAL THEORY OF DIFFRACTION (MAY 1979)
SCHROTT A, DFVLR, GERMANY

TT-594 FIELD COMPUTATION BY THE GEOMETRICAL THEORY OF DIFFRACTION (MAY 1979)
SCHROTT A, DFVLR, GERMANY

TT-595 RAY TRACING AND APPLICATION OF THE GEOMETRICAL THEORY OF DIFFRACTION FOR CALCULATING THE SCATTERED FIELDS OF COMPLICATED STRUCTURES (MAY 1979)
SCHROTT A, DFLVR, GERMANY

TT-596 SOLUTION OF ELECTROMAGNETIC BOUNDARY VALUE PROBLEMS OF COMPLICATED STRUCTURES - THEORY OF THE INTEGRAL EQUATION METHOD (MAY 1979)
STEIN V, DFVLR, GERMANY

TT-597 NUMERICAL SOLUTIONS OF THE ELECTRIC AND MAGNETIC FIELD INTEGRAL EQUATIONS (MAY 1979)
STEIN V, DFVLR, GERMANY

TT-598 COMPUTATION OF THE ELECTRODYNAMIC BEHAVIOR OF COMPLICATED STRUCTURES BY MEANS OF THE INTEGRAL EQUATION METHOD - APPLICATIONS (MAY 1979)
STEIN V, DFVLR, GERMANY

TT-600 ORDERING EFFECTS IN TRANSITION METAL ALLOYS IN RELATION TO THEIR ELECTRONIC STRUCTURE (JAN 1980)
TREGLIA G, ONERA, FRANCE

TT-604 DIGITAL PREFILTERING OF CORRELATED MEASUREMENT NOISE USING REGRESSION LINES (JAN 1980)
FRORIEP R, DFVLR, GERMANY

TT-609 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN 1979-3 (JAN 1980)
ONERA, FRANCE

TT-610 FLUTTER INSTABILITIES IN AN ANNULAR CASCADE WITH SUPERSONIC RELATIVE FLOW (FEB 1980)
SALAUN P, ONERA, FRANCE

TT-612 LA RECHERCHE AEROSPATIALE - BIMONTHLY BULLETIN 1979-4 (JAN 1980)
ONERA, FRANCE

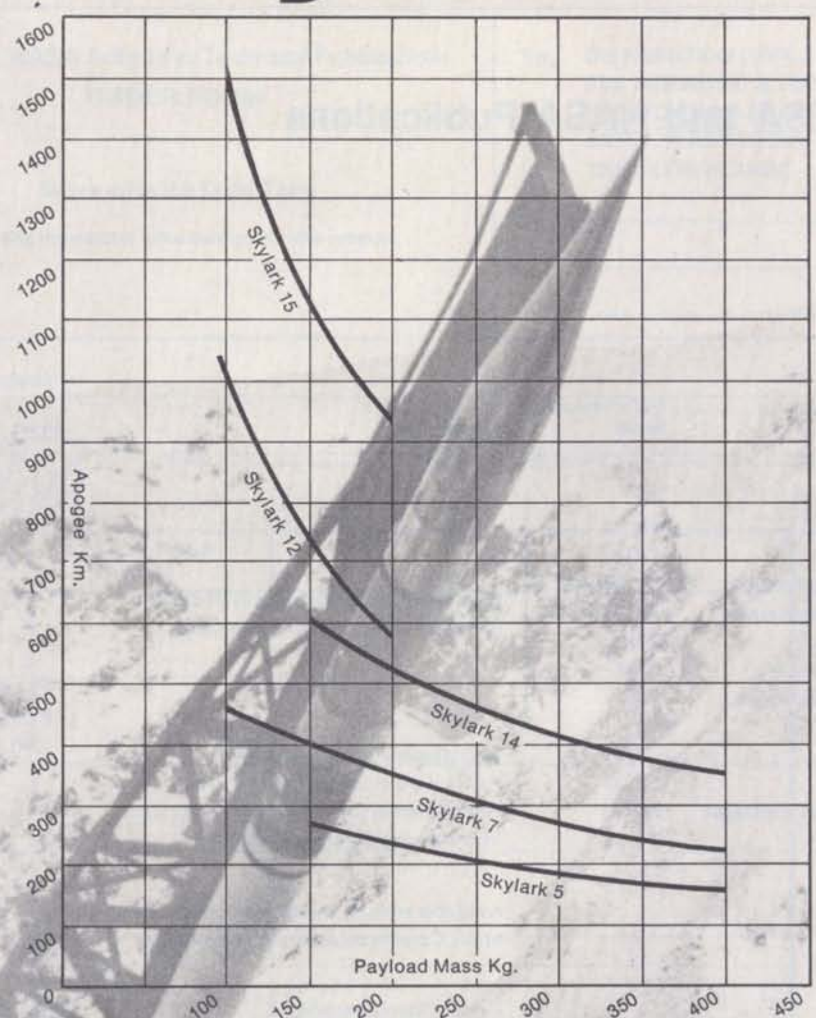
TT-614 DEFINITION OF A TWO LEVEL CONTROL SYSTEM FOR NONLINEAR AIRCRAFT MOTION (FEB 1980)
KIRSZENBLAT A, ONERA, FRANCE

Advertiser index

For all advertising information contact

La Presse Technique SA
3 rue du Vieux-Billard
P.O. Box 108
CH-1211, Geneva 4
Switzerland
Phone: (022) 219226 Tlx: 28456 ptsa ch

Skylark...



the *immediately available* platform for zero-gravity and other experiments in space

Skylark upper-atmosphere research rockets have proved their dependability and versatility in some 400 launchings over 20 years. Today – long before Space Shuttle capacity can be available – they are enabling scientists in the Federal Republic of Germany, Sweden and elsewhere to carry out experiments under microgravity conditions and test the practical value of future research. Skylark payload/altitude options range from 100 to 400 kgs payload and from 150 to 1,500 kms altitude, with up to 10 minutes' useable time for microgravity experiments and up to 20 minutes for research in extra-terrestrial physics.

For more detailed information, please complete the coupon.

To: Marketing Manager,
British Aerospace Dynamics Group, Filton House,
Bristol BS99 7AR, England

BRITISH AEROSPACE
unequalled in its range of aerospace programmes
DYNAMICS GROUP

Please send details of SKYLARK research rockets.
Name
Organisation
Position
Address
Nature of research

Availability of ESA and NASA Publications

Publications	Series	Available as	From
Special Publications	SP	Hard (printed) copy as long as stocks last; thereafter in microfiche or photocopy	ESA Scientific and Technical Publications Branch, ESTEC, 2200 AG Noordwijk, Netherlands
Brochures	BR		
Tribology series	TRIB		
Scientific Reports, Notes and Memoranda	SR, SN, SM		
Technical Reports, Notes and Memoranda	TR, TN, TM		
Scientific and Technical Reports	STR		
Scientific and Technical Memoranda	STM		
Procedures, Standards and Specifications	PSS		
Contractor Reports	CR		
	CR(P)	Microfiche or photocopy only	
	CR(X)	Restricted distribution; not for sale	
Electronics Component Databank Catalogue	ECDB	Hard (printed) copy as long as stocks last	
Technical Translations	TT	Microfiche or photocopy only	
Periodicals			
ESA Bulletin		Available without charge as a regular issue	
ESA Journal		or back numbers (as long as stocks last)	
Public relations material		General literature, posters, photographs, films, etc.	ESA Public Relations Service 8-10 rue Mario-Nikis, 75738 Paris 15, France

Printed documents Number of pages	Code	Price	Photocopy Number of pages	Price*	Microfiche Number per title	Price*
001—100	E1	FF 55	001—025	FF 70	1 or 2	FF 20
101—200	E2	FF 80	026—050	FF 100	3 or more	FF 40
201—350	E3	FF 125	051—075	FF 130		
over 350	E4	FF 160	076—100	FF 150	* Postage:	
			101—125	FF 170	Photocopy	FF 15 per title
001—100	C1	FF 55	126—175	FF 190	Microfiche	FF 6 per title
101—200	C2	FF 80	176—200	FF 210		
201—350	C3	FF 125	201—225	FF 230		
over 350	C4	FF 160	226—250	FF 270		
			over 250	FF 20 per 25 pages extra		

1 Photocopies will be supplied if the orginal document is out of print, unless microfiche is specified.
2 These charges apply to Member States, Austria, Canada and Norway. A 20 per cent surcharge will be levied on orders from 'other states'.
3 These prices are subject to change without prior notice.

N.B. FOR HARD-COPY CHARGES, SEE FACING PAGE

ESA and NASA Scientific/Technical Publications
ORDER FORM

Before using this Order Form

read the important information on the reverse.

To: DISTRIBUTION OFFICE
ESA SCIENTIFIC & TECHNICAL
PUBLICATIONS BRANCH
ESTEC, POSTBUS 299, 2200 AG NOORDWIJK
THE NETHERLANDS

From: ______________________________

____

____

PLEASE SUPPLY:

Customer's Ref ______________________________

Date ______________________ Signature ______________________________

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

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

MAILING LABEL (Print or type carefully)

Customer's Ref ______________________

ESA Order No.

To Name or Function ______________________________

Organisation ______________________________

Street Address ______________________________

Town, Province, Postal Code ______________________________

Country ______________________________

INFORMATION

1. Use this form for your order.

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

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

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

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

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

EXECUTION OF ORDER

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

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

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

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

SUPPLIES OF THIS ORDER FORM ARE AVAILABLE FROM ESA SCIENTIFIC AND TECHNICAL PUBLICATIONS BRANCH AT THE ADDRESS SHOWN OVERLEAF

european space agency
agence spatiale européenne

member states	**etats membres**
belgium	allemagne
denmark	belgique
france	danemark
germany	espagne
italy	france
netherlands	italie
spain	pays bas
sweden	royaume-uni
switzerland	suède
united kingdom	suisse