european space agency

esa bulletin

agence spatiale européenne

number 59

august 1989

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 Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an Associate Member of the Agency. Canada is a Cooperating State.

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

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

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

The Directorate of the Agency consists of the Director General; the Inspector General; the Director of Scientific Programmes; the Director of the Earth Observation and Microgravity Programme; the Director of the Telecommunications Programme; the Director of Space Transportation Systems; the Director of the Space Station and Platforms Programme; the Director of ESTEC; the Director of Operations and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr H. Grage.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellite 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; de l'Inspecteur général; du Directeur des Programmes scientifiques; du Directeur des Programmes d'Observation de la Terre et de Microgravité; du Directeur du Programme de Télécommunications; du Directeur des Systèmes de Transport spatial; du Directeur du Programme Station spatiale et Plates-formes; du Directeur de l'ESTEC, du Directeur des Opérations et du Directeur de l'Administration.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie

Président du Conseil: M H. Grage.

Directeur général: Prof. R. Lüst.

esa bulletin

no. 59 august 1989

contents/sommaire

Front cover: 87th Meeting of the ESA Council in session at ESTEC (see page 90)

Editorial/Circulation Office
ESA Publications Division
c/o ESTEC, Noordwijk, The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Assistant Editor
Regina Sliwa

Layout
Carel Haakman

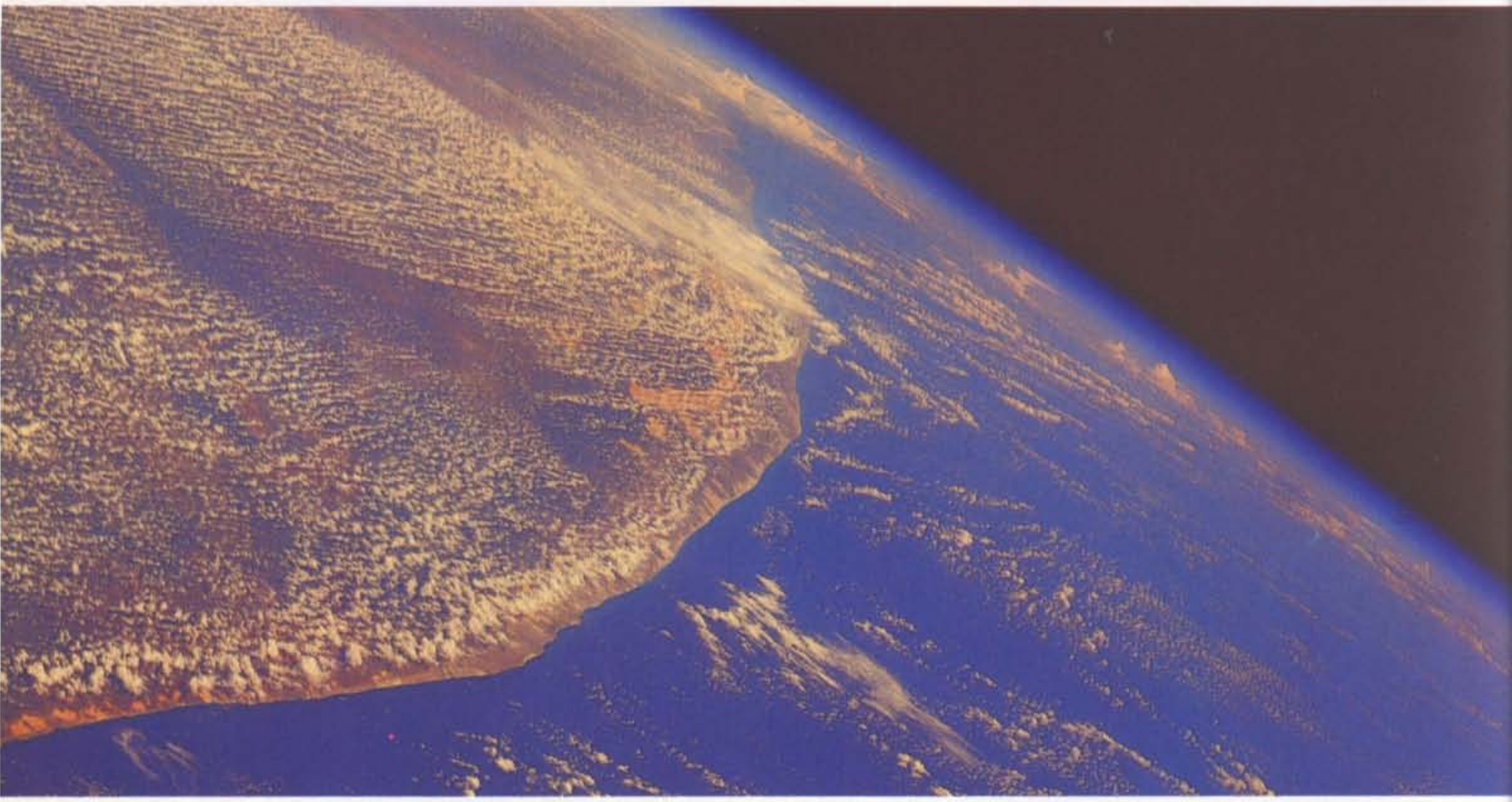
Montage
Keith Briddon

Advertising
Brigitte Kaldeich

Printed in The Netherlands
ISSN 0376-4265

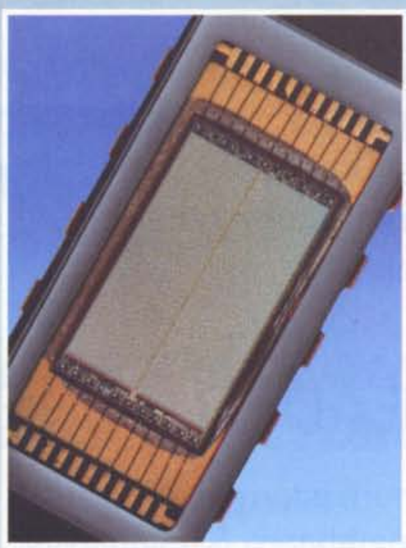
european space agency
agence spatiale européenne

Optical fibre cable production at the ANT plant in the Rhine valley.



RADIATION HARD FACT

High Performance Static Memories



Marconi have now introduced a new family of static RAM's to complement their already extensive range of 1K, 4K and 16K memories. The lead members are the MA9167, 16K x 1 and the MA9187, 64K x 1 static RAM's developed using new design techniques, whilst maintaining the proven stability of 6-transistor memory cells, in Marconi's 1.5μm double-layer-metal Silicon on Sapphire process. The Silicon on Sapphire eliminates the risk of latch-up and is the only commercially available technology that offers uncompromising performance in all aspects of hostile radiation environments.

The family is available in most leading package styles including dual-in-line, flatpack and leadless chip carrier, giving flexibility of design applications.

The totally integrated radiation hard solution from

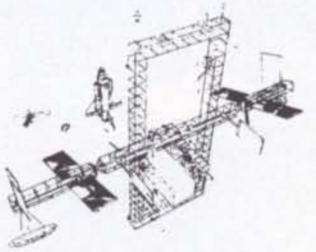
Marconi
Electronic Devices

Marconi Electronic Devices Ltd.
Integrated Circuit Division,
Doddington Road,
Lincoln LN6 3LF England.
Tel: 0522 500500 Telex: 56380
Fax: 0522 500550

Marconi Circuit Technology Corp.,
45 Davids Drive, Hauppauge,
New York 11788 U.S.A.
Tel: 516 231 7710
Telex: 275801
Fax: 516 231 7923

Marconi Electronic Devices,
2 Rue Henri-Bergson,
92600, Asnieres, France
Tel: (1) 4080 54 00
Telex: 612850
Fax: (1) 4733 11 31

Marconi Elektronik
Landsberger Strasse 65
8034, Germering, West Germany
Tel: 089 849 36 0
Telex: 5212642
Fax: 089 841 91 42




ISO

The European Long-Term Space Plan: A Basis for Autonomy and Cooperation*

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

The European Space Agency constitutes one of the best demonstrations that Europe can act as an entity with both a clear political will and a consistent policy. This has been confirmed both by the nature of the European space programmes conducted so far, and by the successful completion of the projects within these programmes. The clear political will that Europe should embark on further projects in space was demonstrated again eighteen months ago with the decision to endorse a European Long-Term Space Plan, taken at the Ministerial Conference in The Hague.

The basis for this Long-Term Plan was laid down in a Resolution at the preceding Ministerial Conference in Rome, referring to: 'expansion of Europe's autonomous capability and Europe's competitiveness in all sectors of space activities'.

This Conference today is devoted to space transportation, which forms an important part of space activities in general. However, it should be obvious to everybody that the development of space-transportation vehicles should not be pursued for its own sake, but rather to provide the necessary means for going into space, and for being present there to the benefit of mankind.

It is thus important for Europe, perhaps even more than for any single nation, to have an overall space plan at its disposal the main elements of which are user programmes. Space-transportation systems cannot determine this plan's contents, despite the public's fascination with launchers and launches.

It is also important for an understanding of the European Long-Term Space Plan to outline some boundary conditions for European space activities in general, and the responses to them. This will constitute the first part of my presentation. I would then like to describe briefly the aims and contents of the Long-Term Plan, both of which are probably already quite familiar to many in this audience. I will close by reporting on the present status of the Long-Term Plan's execution and discussing some topical questions.

*Opening Lecture, Second European Aerospace Conference EAC '89, Bonn-Bad Godesberg, W. Germany, May 1989

Boundary conditions and cornerstones for European space activities
When considering the activities of the European Space Agency in general, it is important to be aware of three boundary conditions that are common to all of its programmes:

1. Europe is still a patchwork of nations. The motivations and interests of these nations in conquering space are different.

2. ESA's Member States are not capable of making a financial commitment to space comparable to that of the two major space powers, whether measured in absolute figures, by expenditure per capita, or expressed as a proportion of gross national product (GNP).

3. European cooperation in space has to guarantee appropriate participation by all its Member-State industries in the realisation of the various programmes.

The last twenty-five years have shown that it is possible, with these constraints, to conduct European space activities successfully, even if one might have wished from time to time to be free of such impositions. The response to these European boundary conditions has been the establishment, in the course of the last fifteen years, of three general guidelines:

1. Firstly, a flexible general structure, with the existence of both mandatory and optional programmes, which allows each Member State to tailor its financial commitment according to national priorities and

financial capabilities. This structure also avoids the need for unanimous decisions on each new programme.

2. The rather limited funding, when compared with that of the major space powers, necessitates concentration on those space activities that seem most promising. Despite this obligation, Europe has succeeded in the past in covering all the important sectors, as a glance at the different user programmes demonstrates:

Thanks to the strict selection procedure employed, the ESA Science Programme has been able to keep pace with the Americans not just in broad terms, but also in terms of the achievements of every single satellite launched. Giotto, which transmitted the first image of a comet's nucleus to Earth, is a good example in this respect.

Through its Meteosat Programme, ESA has now provided four meteorological satellites, the latest of which was launched in January and is just becoming fully operational. Meteosat data are highly appreciated by meteorological services the world over. ESA's remote-sensing satellite ERS-1, due for launch next year, will make use of a synthetic-aperture radar that will allow the remote sensing of ocean and land surfaces even during bad weather conditions.

ESA's ECS telecommunications satellites, now being operated by Eutelsat, form an indispensable part of the European telecommunications scene. The same is true of the Marecs satellites, leased to Inmarsat, which provide telephony links to ships and platforms at sea.

The development of Spacelab not only provided Europe with experience with manned spaceflight, but also constitutes a sound basis for further use of the microgravity environment.

The Ariane launcher has demonstrated the feasibility of profitable investment in space activities, having already launched 40 satellites and attracted firm orders for 35 more launches, worth 2.1 billion ECU. Following ESA's usual policy, marketing of Ariane has been delegated, after the vehicle's successful development and qualification, to a dedicated organisation, in this case a private enterprise, Arianespace.

3. The third element is ESA's industrial policy. More than 90% of the income from the Agency's Member States is spent on projects with European industry; more than 40% of all contracts are placed with small- and medium-sized companies. In spite of these constraints, it has been possible to maintain healthy competition and to execute our programmes within the initial financial envelopes and time schedules.

Aims and contents of the Long-Term Plan

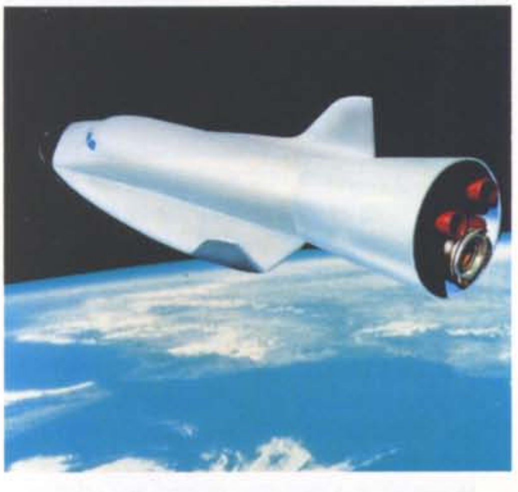
It is the aim of the Long-Term Plan to make the widest possible use of space on the basis of Europe's past achievements. Whenever necessary, Europe's autonomous capability in space will be expanded: not for its own sake, but rather not to be dependent on critical elements from outside Europe, and in order to become a competent partner for international cooperation. Europe will cooperate whenever possible with its oldest partner, the United States, but also with the Soviet Union, Japan and the other space nations.

Within these goals, the competitiveness of European industry has to be maintained or improved in all relevant sectors of space activity.

The general guidelines underlying the formulation of the various programmes have been:
- completeness of the entire Long-Term Plan
- coherence between the different programmes
- balance between the user programmes and in-orbit and ground infrastructure.

Completeness means that the Long-Term Plan will promote all relevant sectors that make sensible use of space, namely:
- space science
- research and technological developments under microgravity conditions
- Earth observation
- telecommunications.

The Long-Term Plan also includes investment for the infrastructure needed, both in space and on the ground, to support these user programmes. The in-orbit infrastructure consists of:
- the Ariane-5 launcher
- manned space laboratories
- the Hermes spaceplane
- an orbital communications system.



The ground infrastructure involves:
- expansion of the European Space Operations Centre (ESOC)
- a Control Centre for the manned laboratories
- a Hermes Control Centre
- a Data-Relay Satellite (DRS) Control Centre
- an Astronaut Training Centre.

It was agreed at the Ministerial Council in The Hague to embark on all of these programmes. ESA, supported by its Member States, together with European industry, has since fully prepared itself for carrying out the tasks laid down in this Plan.

Present status of the Long-Term Plan's execution

I would now like to report briefly on where we stand in terms of the execution of the Long-Term Plan, eighteen months after its endorsement. I cannot cover all of our current activities here, but will rather pick out the most important items and address some problems that I think could eventually arise.

1. The Science Programme within the Long-Term Plan is called Horizon-2000. It consists in the first instance of four so-called 'Cornerstone Missions', which have been designed to embrace a balanced set of modern space-science disciplines in the areas of astrophysics and solar-system exploration.

   The bids for the design phase, the so-called 'Phase-B', for the first of these missions, the Solar-Terrestrial Science Programme (STSP), have already been received and this phase should start in October. The mission, involving the Soho and the Cluster satellites, is devoted to the investigation of solar-terrestrial relationships, and will be carried out in cooperation with the USA, the USSR and Japan. The other three Cornerstone missions, covering astronomy observations in the far-infrared and X-ray regions, as well as the return to Earth of cometary samples, are in various stages of definition. It is planned to launch Soho/Cluster in 1995, the X-ray mission in 1998, and the last two Cornerstones will follow in 2003—2005.

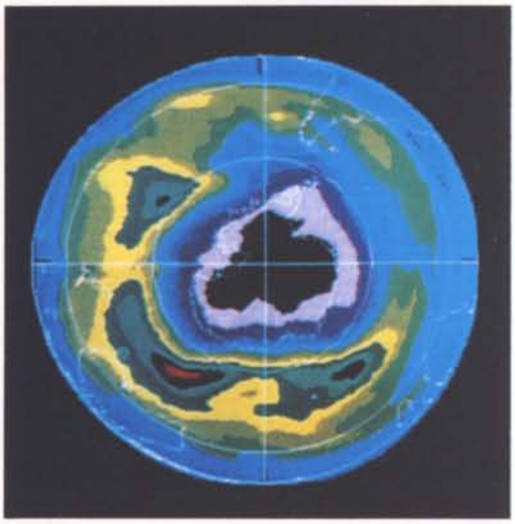
   Horizon-2000 derives its necessary flexibility from the inclusion of approximately ten medium- and smaller-

sized spacecraft in the Programme. One of these, the astrometry mission Hipparcos, is due for launch on 25 July this year; a second, the infrared space observatory ISO, entered its main development phase (Phase-C/D) ten months ago; and Huygens, a probe to explore the Saturnian moon Titan, was selected for inclusion last November. A call for new ideas for this class of mission is currently being distributed to the scientific community.

The time schedule, as laid down in 1984, has had to be adjusted on several occasions to take account particularly of the launch delays that have affected the Hubble Space Telescope and Ulysses missions, both of which have Shuttle launches which have been repeatedly postponed following the 'Challenger' accident.

In December 1988, our Member States agreed on a 5% annual increase in the Agency's level of resources, from which the Science Programme is funded, until 1992.

2. In the Earth-Observation Programme, we are expecting the first European Remote-Sensing Satellite, ERS-1, to be launched in the autumn of next year. We now very urgently need a decision on a follow-up satellite, ERS-2, since ERS-1 will deliver data for a period of only two or three years. In the field of Earth observation, and in particular in climatology, to which ERS-1 is to a large extent devoted, only data acquisition over long periods, measured in decades rather than years, will provide information of sufficient quality to allow the right actions to be taken for preserving our environment. This addresses several very important areas, such as atmospheric chemistry, especially the ozone hole, and the influence of greenhouse gases on the Earth's climate. It is therefore hard to comprehend why certain Governments are still hesitating to decide on the funding for ERS-2 as agreed upon in The Hague, while the leading politicians in those same countries are expressing deep concern about the dangers to the environment.



3. In the field of télecommunications, preparations have been completed for starting Phase-B of the Data-Relay Satellite (DRS) Programme by the end of this year, as agreed by the Ministers in The Hague. It is still to be decided whether some private financing of DRS is feasible; we are engaged in intensive discussions with industry and the banks on this issue. However, the decision to embark on this project should not be further delayed. Clarification of private funding will take more time, since completely new questions have to be addressed, but it should not withhold a Member State's commitment to this project.

It is equally important for the telecommunications scene in Europe that ESA continues its advanced research and development work for future generations of telecommunications satellites, in particular through its Sat-2 project, which will develop the first technical means for optical communication between satellites in orbit.

Sat-2 needs to receive the green light very soon if it is also to be used for gaining experience for DRS, as agreed upon in The Hague.

4. The Ariane-5 Programme is steadily advancing, with the entire system design now frozen and fabrication of prototype components and their testing well under way. Apart from the development of the launcher itself, the Ariane-5 Programme includes much civil construction work and the erection of test stands. This too is advancing well, as is the entire Programme, within the cost and time schedules, with the first launch foreseen for 1995.

5. Activity within the Columbus Programme is currently focusing on the proposals for the main development phase (Phase-C/D), following release of an Invitation to Tender in summer 1988. Consolidation of these proposals involves a substantial and difficult coordinatory role for the prime as well as the element contractors. Within the Agency, considerable effort is being devoted to meeting the technical requirements and schedule constraints within the financial envelope set in The Hague.

   For the Polar Platform, two competing concepts are being finalised by industry prior to a final selection in October. A concept study for the ground segment was submitted at the end of last year, and we are about to initiate the follow-up detailed definition phase, not only for Columbus, but for all the elements of the in-orbit infrastructure.

   Thanks to the establishment of appropriate management mechanisms which now function routinely, coherence with all programmes of the Agency is ensured. The same can be said of the working relationship with NASA.

6. In the Hermes Project, detailed studies of the three prime components — the spaceplane itself, the expandable resource module, and the propulsion system — are under way. The main design parameters, in particular the take-off and landing weights, could be retained, though the overall weight margin is still quite small. Other important questions have not yet been completely settled, such as the rescue system and the spaceplane's aerodynamic shape, which is steadily being improved.

The design challenges of Hermes are extremely stimulating for European industry. The boundary conditions that Hermes must satisfy are quite severe: namely to be compatible with the launch capacity of Ariane-5 and the payload capacity of the Free-Flying Laboratory. They provide a unique opportunity for creative thinking and new technology developments, and should thus not be seen as a drawback, as Hermes is technically by far the most demanding project in the Agency's Long-Term Plan.

It would, however, be very naive to believe that if we were not able to find answers to these questions and thus would drop Hermes, that such a setback would be advantageous for the selection of the even more advanced systems like Sänger or Hotol. It would be naive both in a technical and in a political sense. Let's take the development of Sänger; this project needs a forerunner in order to lay the necessary technical base, especially in terms of hypersonics, advanced materials, and many other new technologies. If Hermes were not to be carried through, another project of similar size would be necessary. It is just wishful, and counter-productive, thinking to believe that Sänger could be realised without such an intermediate project. That would indeed be counter to all previous experience with new high-technology projects.

Nevertheless, I very much welcome the decision to start technology activities for programmes such as Sänger, particularly since it will stimulate a lot of training and research work at universities. I particularly welcome the establishment of the Sonderforschungsbereich on hypersonics, by Deutsche Forschungsgemeinschaft, at several German universities. As far as work in industry is concerned, one should always bear in mind that Sänger will have to become a European project if it is to be carried out at all; the same holds true for Hotol. It is always a problem if projects are started nationally and do not become Europeanised soon enough, something that is presently much lamented in the military sector also.

The painful difficulties experienced in setting up the industrial structure for Hermes are due mainly to the delayed Europeanisation of this project. ESA would be in a much easier position if the Ministerial Council in Rome in 1985 had already accepted Hermes as a European project. Nobody should be eager to duplicate bad examples, and we should try to learn from them.

7. Let me finally come to an overall review of the balance between the programmes in the Long-Term Plan: France and the Federal Republic of Germany, the two largest contributors to the ESA budget, who, with Italy, have also been the main initiators of the Ariane-5, Columbus and Hermes Programmes, have particular responsibility for this balance in the execution of the Long-Term Programme being maintained. This means that the big contributors to the in-orbit infrastructure programmes must also ensure that user programmes in Earth observation and telecommunications can be carried out in the foreseen time schedule. That they do so is important particularly for the smaller Member States, which have joined ESA because they are not capable financially of developing satellites and spacecraft on their own. Some of them are becoming increasingly suspicious that the two large contributors might not fulfil their obligations as agreed upon in The Hague, or at least not as quickly as one expects them to.

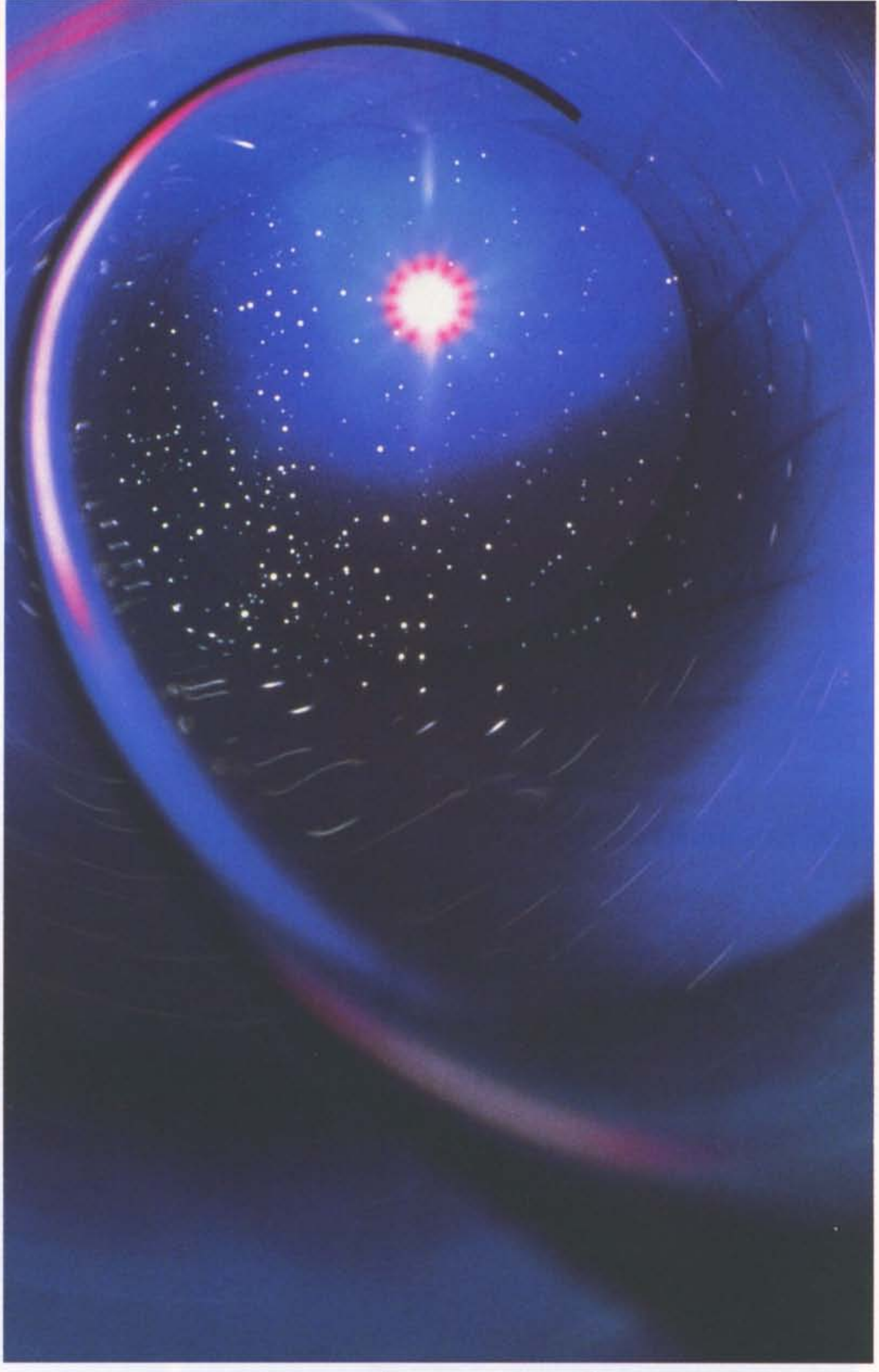
Cooperation and autonomy

I would like to close my presentation with some reflections on autonomy and cooperation, both mentioned in the title and often regarded as not fitting very well together. I think both are indeed complementary. Autonomy means above all competence, particularly in those areas where, in the end, competition is healthy and necessary. Our twenty-five years of experience with international cooperation have shown that it works best between partners of comparable strength who are both potentially autonomous. This applies not only to applications and marketing, but also to science. It is essential, for example, that scientists compete with each other, while it is also absolutely necessary that they cooperate with each other and exchange ideas and results.

Autonomy also means that in some areas we must make our own way. Ariane-5 and the Hermes spaceplane — or, in a word, European space transportation systems — are good examples in this respect. The fact that Europe needs its own access to the International Space Station, and a manned capability in space beyond, must prevail (over cost considerations and potential offers of cooperation that would probably not turn out to be very successful). This is because in this area Europe must accept that the United States and the Soviet Union are autonomous, and that they can and will accomplish transportation in space on their own, even if they do suffer setbacks from time to time. It is equally important, however, that they accept the fact that Europe too will eventually be autonomous.

There are many other areas beyond the International Space Station and space science where Europe wants to cooperate on a long-term basis. A number of programmes are likely to be too costly for one Government or agency on its own. The basis for real partnership lies in mutual interest, as is the case — to cite just one prominent example — with the International Space Year. Its main theme will be 'Mission to Planet Earth', after the world's leading politicians have finally recognised the importance of the environmental problems and accepted that a huge interdisciplinary research programme is necessary to meet these daunting challenges. The International Space Year will hopefully become a substantial contribution to this indispensable global effort, thereby serving as yet another example of the fact that the European Long-Term Space Plan and its objectives of 'autonomy and cooperation' do contribute to the benefit of the people of Europe and the entire world.

The demands made on individual electronic systems and their components increase with the degree of complexity of satellites and space transport systems. Cable systems are no exception. During ascent and while in orbit, they are subjected to extraordinary stress, such as the extreme mechanical load during lift-off, outgassing processes while entering the vacuum and continual bombardment by ultraviolet and hard gamma radiation during the entire operation time. Successful cable systems must remain intact throughout and function reliably.
GORE offers High Voltage Cable Constructions for travelling wave tubes and other high voltage applications. These high voltage cables are designed for extremely rapid gas emission. Emission rates are unequalled, thanks to use of braided exterior shielding made of microporous GORE-TEX®. Air and other enclosed gasses can escape fully and freely into the vacuum during ascent. Gas discharges inside micro gaps in the insulation material of cables caused by strong electrical fields are called corona. Until now, the corona process led to the destruction of the insulation and thus to the unavoidable failure of the cable. GORE High Voltage Cable Constructions feature superior corona resistance characteristics, thanks to dielectrics made of CR-PTFE (Corona-Resistant-PTFE), the best insulation material now known for high voltage applications.
GORE Cable Systems assure outstanding performance in tough everyday use. One reason is application-oriented development of cables. GORE believes, cables should be considered as fundamental construction elements and vital working parts at an early development stage of any space project. Frequently it's thanks to GORE Cable Systems that technically innovative concepts become reality. So contact us right now. We'll advise you and design your individual cable system, provide a prototype and begin manufacturing within the shortest period of time.

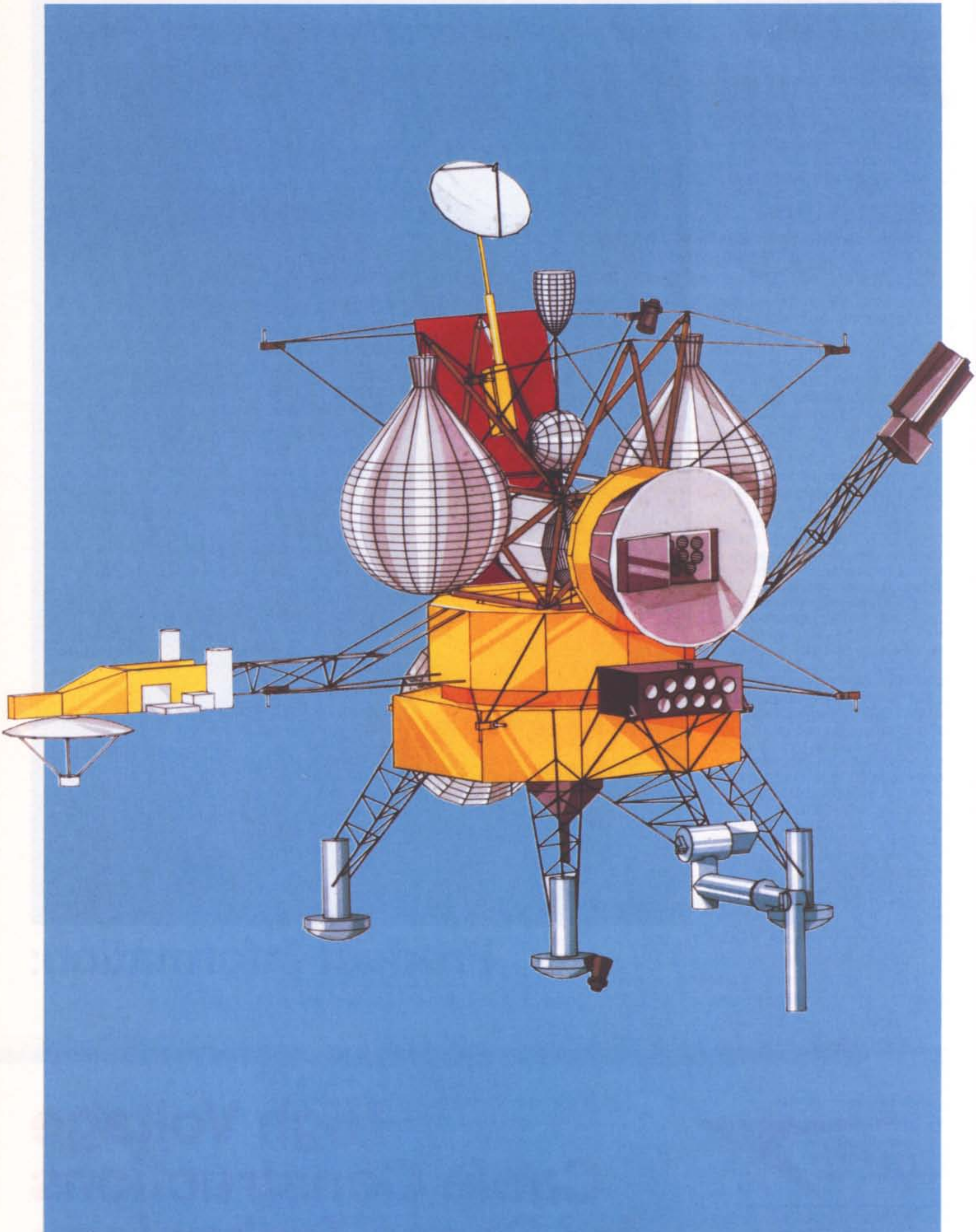


Product Information:

GORE

W. L. GORE & Co. GmbH · Nordring 1
D-8835 Pleinfeld · West Germany
Phone: (09144) 601-429
Hermann-Oberth-Straße 22
D-8011 Putzbrunn · West Germany
Phone: (089) 4612-507

High Voltage Cable Constructions for Space Technology



Rosetta/CNSR — ESA's Planetary Cornerstone Mission

A. Atzei & G. Schwehm
Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

M. Coradini
Directorate of Scientific Programmes, ESA, Paris

M. Hechler
Directorate of Operations, ESOC, Darmstadt, Germany

J. De Lafontaine & M. Eiden
Technical Directorate, ESTEC, Noordwijk, The Netherlands

Rosetta — the Comet-Nucleus Sample-Return mission — is one of the four scientific 'Cornerstone' missions to which the Agency has committed itself in its approved Long-Term Programme 'Horizon 2000'. The comet-nucleus samples that it will provide will allow us to study some of the most primitive material in the solar system and the physical and chemical processes that marked the system's beginnings 4.6 billion years ago.

The name 'Rosetta' is derived from the famous 'Rosetta Stone', an ancient Egyptian tablet whose deciphering led to the understanding of hieroglyphics. It is hoped that the Rosetta mission will shed a comparable amount of light by establishing the correspondence between interstellar matter, cometary material and the primitive meteorites that we already have in our collections on Earth.

From the outset, this ambitious programme was conceived as a collaborative effort between ESA and one or more international partners. It involves the procurement, launch and operation of a complete spacecraft system capable of landing on a comet, retrieving samples and returning them to Earth (Fig. 1). Partnership has already been proposed by NASA, whose Solar-System Exploration Committee has recommended a comet-nucleus sample-return mission for the beginning of the next century.

Mission objectives

Background

Today, everything we know about the objects and materials beyond our solar system, and most of what we know about the solar system itself, has come from remote observation, through the medium of electromagnetic radiation over the entire range of wavelengths. A very great deal can be learned by this means, a premise made abundantly clear from an inspection of astrophysics books and journals. However, considerably more can be learned when cosmic materials are brought into the laboratory for study using the powerful analytical techniques now available.

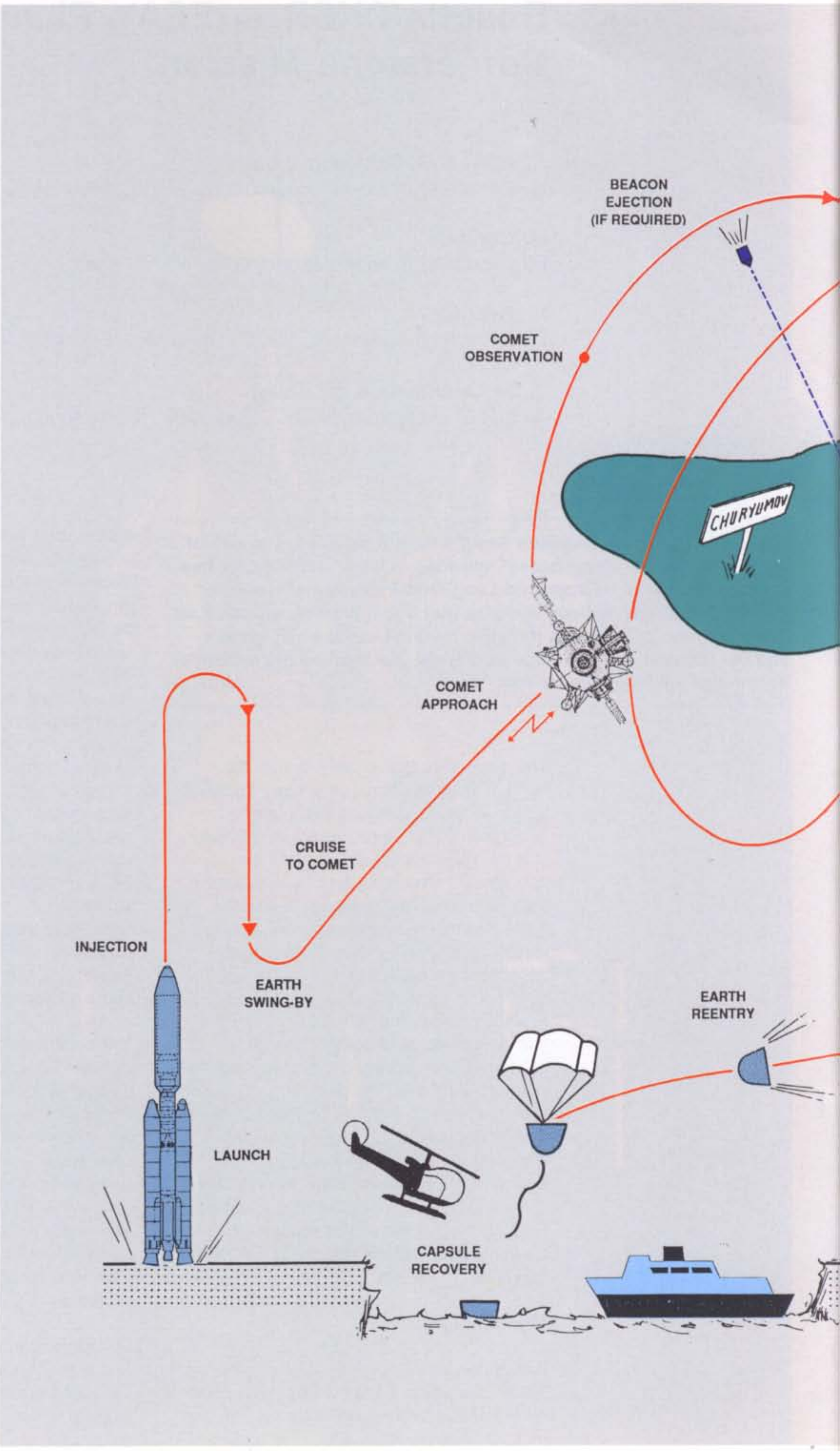
A striking example of this was the evolution in our knowledge of the Moon that occurred when lunar samples were brought back to Earth in 1969-72. The discovery that the Moon had an energetic origin and was extensively melted at the outset, led to a new outlook on the initial state of the Earth, whereby our planet is now thought to have had a similar high-temperature beginning.

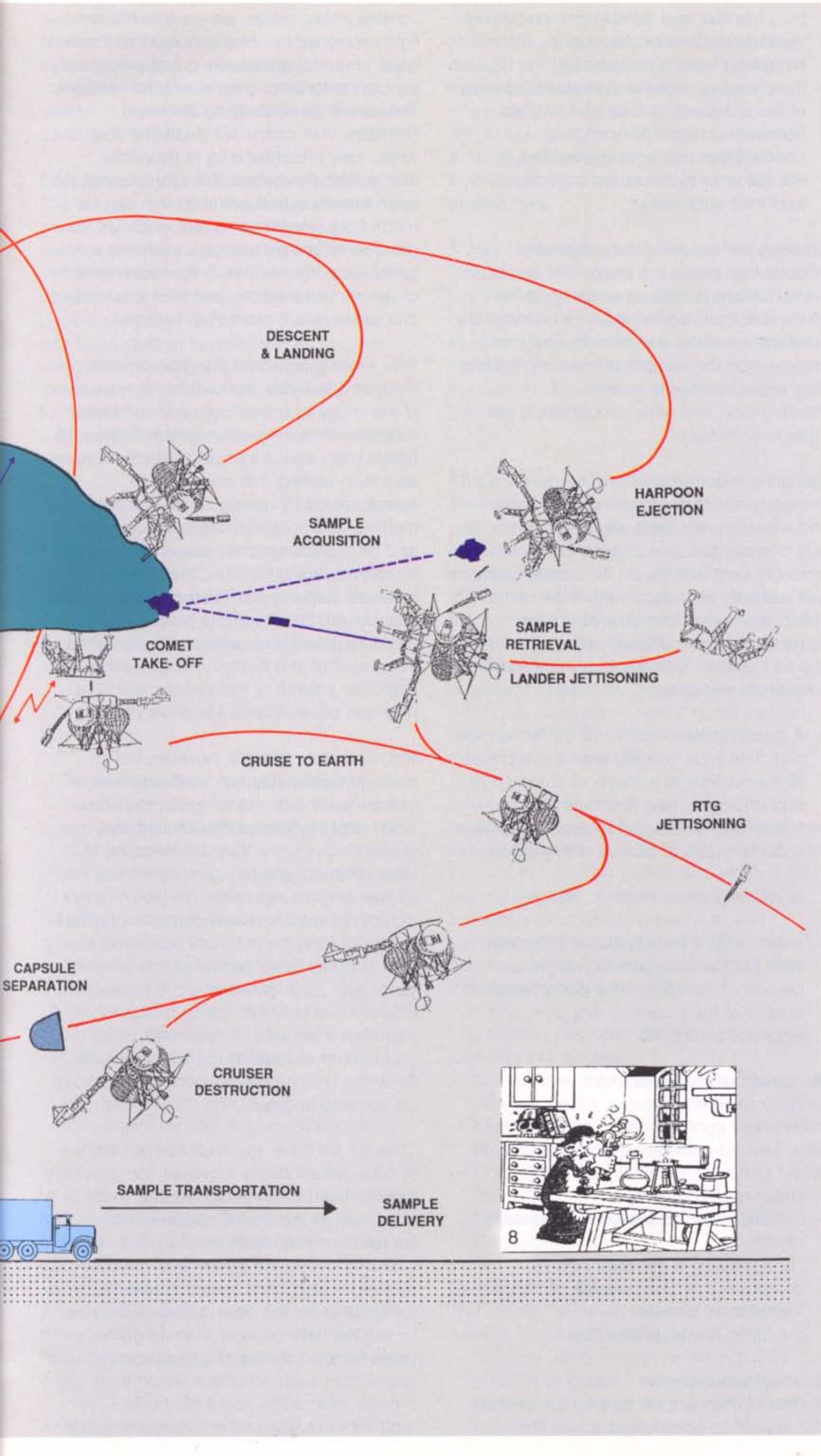
The comet-nucleus sample analysis will increase our understanding of the origin and early evolution of the solar system and reveal important new avenues of enquiry. We will learn the nature of the raw material of the solar system, which at present can only be guessed at. The substance of even the most 'primitive' chondritic meteorites has been so extensively reshaped by nebular and planetary processes that its pre-solar properties have been almost totally destroyed.

Scientific objectives

The prime scientific objective of the Rosetta mission is to return a comet-nucleus sample to Earth whilst preserving such fundamental properties as:

Figure 1. The Rosetta/CNSR mission scenario




DESCENT
& LANDING
HARPOON
EJECTION
SAMPLE
ACQUISITION
SAMPLE
RETRIEVAL
COMET
TAKE- OFF
LANDER JETTISONING
CRUISE TO EARTH
RTG
JETTISONING
CAPSULE
SEPARATION
CRUISER
DESTRUCTION
SAMPLE TRANSPORTATION
SAMPLE
DELIVERY
8

— the chemical and isotopic composition of the individual molecular species of remaining volatile compounds,
— the chemical, isotopic and structural state of the individual phases and crystals constituting higher temperature condensates and aggregates, and
— the complex hydrocarbon compounds and their aggregates.

Knowing the nature of the condensed material that joined the proto-solar accretion disc is certain to help us understand the processes that transformed it into meteorites, asteroids, satellites and planets. The ices preserved in the sample will provide the first data applicable to the question of condensation and other processes in the outer solar nebula.

Sampling requirements
Cometary material consists of both volatile and refractory elements and compounds. Its bulk composition and physical properties probably vary laterally on the comet's surface and vertically with depth within the comet. To obtain optimum information about the cometary nucleus, different types of samples should therefore be collected; three types are considered essential:

1. A core sample (approx. 10 kg) is the most complete type, running from the surface of the nucleus to a depth of at least 1 m, and preferably 3 m. It should be subdivided and stored in separate units in order to preserve coarse stratigraphy.

2. A volatile sample (approx. 100 g).

3. A non-volatile sample, to be collected from the nucleus' surface, weighing between 1 and 5 kg. It is designated for studies of the refractory inorganic and organic compounds.

We expect laboratory analysis of these properly returned cometary materials to make major contributions to many different fields beyond cometary science itself, such as:
— stellar nucleo-synthesis;
— conditions and processes in interstellar clouds;
— condensation in the solar nebula;
— composition of planetesimals and formation of planets;
— pre-biotic chemical evolution.

Solar-system evolution
Studies of the complex carbon compounds that appear to constitute much of the cometary dust grains are expected to shed light on the evolutionary process that created great chemical complexity out of presumably simpler molecules in the interstellar medium. The possibility of studying individual cometary dust grains will open the door to a whole new understanding of interstellar matter. With the help of the inferences about grain formation and evolution that can be made from laboratory studies, it should be possible for astrophysicists to achieve a new generation of advances in their interpretation of remote observations and their modelling of processes in the interstellar medium.

One exciting aspect of the grain-by-grain study of interstellar dust will be its expansion of the range of galactic ages of accessible materials. When the solar system formed 4.6 billion years ago, it sampled galactic material as it then existed; this material was homogenised by mixing on a small scale, melting, and (to some degree) vaporising and recondensing; then, this material was incorporated into the Sun, the planets, asteroids and comets. Thereafter, the system was closed. Studies of the planets or Sun, therefore, provide us with information about the chemical and isotopic composition of a particular volume of interstellar material at only one point in time, 4.6 billion years ago.

With cometary material, however, the homogenisation has not been extensive or irreversible. It is therefore anticipated that, when dust particles are separated and studied individually, they will be found to have different galactic ages. Some may have formed very shortly before the solar system did; others may have wandered in interstellar space for long periods, perhaps since shortly after the 'Big Bang' more than 10 billion years ago. Such grains would have very different and very interesting nuclide-abundance patterns. A systematic study programme devoted to such particles will allow the Galaxy's nucleo-synthetic history to be mapped in detail.

Thus far, we have assumed that comets are of solar-system origin. However, the possibility has not been totally excluded that some or all comets in the Oort Cloud were not accreted in orbit about the Sun, but were captured during the passage of the solar system through giant molecular clouds. If this turns out to be the case, comet nuclei may be substantially younger than 4.6 billion years. Isotopic studies of individual dust grains from such a nucleus would then provide information about the nucleo-synthetic evolution of the Galaxy after solar-system formation as well as before. Its ices and carbon compounds would provide information about condensation in a molecular cloud or around another stellar system — topics of no less interest than our solar system itself.

Supplementary in-situ cometary science
The sample collection should be accompanied by adequate in-situ measurements and remote observation for site selection and sampling documentation. The prime scientific objective of the Rosetta mission is to bring back a sample of the comet nucleus that can be studied in Earth-based laboratories using the most sophisticated analytical techniques. In other words, the real science for which the mission is designed will only start once the samples have been returned to Earth.

The highest priority in terms of in-situ science will therefore be given to those measurements needed to select and document the sampling site, to monitor the cometary environment for spacecraft hazards and contamination, and to support the near-nucleus navigation during the final approach and landing phases.

Significant in-situ science is foreseen during four phases:

- Target acquisition: characterisation of the nucleus, provision of high-precision orbit information, and definition of the gas and dust emission patterns.
- Coma transit: navigational support through the active coma, assessment of nucleus activity, mapping of active areas of dust and gas jets and evaluation of hazards to the spacecraft, determination of the rotational size of the nucleus.
- Site selection: definition of suitable sampling site(s) and of approach strategy.
- Sample acquisition: support to near-surface operations, surface characterisation, sampling-site documentation and studies related to sample extraction.

In addition, two enhancements to the mission have been identified. One is a suite of remote-sensing and in-situ experiments to study the cometary coma. The second is a surface-science package that could remain active on the nucleus after the departure of the sampling module, and thereby study any variations over a large fraction of the comet's orbit.

An imaging system and a radar sounder are regarded as essential for supporting spacecraft navigation and landing and for detailed nucleus mapping. The Thermal-Infrared Radiometer should provide information on nucleus surface-temperature distribution to support landing-site selection. A Neutral Mass-Spectrometer and Dust Monitor are required to monitor the comet's environment.

A major effort will go into the development of instruments to support the sampling, including measuring the temperature profile in the drill hole and the bulk temperature of the sample collected. A stereo vision system to provide high-resolution optical monitoring of the sampling process is presently under detailed study.

The mission scenario
The mission design has been dictated primarily by the capabilities of available expendable launchers and conventional chemical spacecraft-propulsion systems. Without an Earth-gravity assist on the way to the comet rendezvous, and an aerocapture at Earth return, the launch mass — namely the spacecraft dry mass plus all the propellant needed to generate the requisite flight-path changes — would by far exceed the capabilities of a Titan/Centaur launch into the required escape orbit.

However, with an Earth-gravity assist and aerocapture, several comets with orbits at low inclinations to the ecliptic, a perihelion of less than 1.5 AU, and an aphelion of up to 6 AU can be reached. In such a mission, using conventional chemical propulsion, the rendezvous takes place close to the comet's aphelion, which is a desirable feature from the spacecraft-safety standpoint.

The mission has been designed around the following four targets:
- Comet Churiumov-Gerasimenko: launch in January 2001
- Comet Dutoit-Hartley: back-up, launch in March 2001
- Comet Wirtanen: back-up, launch in May 2001
- Comet Hartley-2: back-up, launch in December 2002.

Spacecraft concept
The mission scenario is based on a three-module spacecraft configuration:
- a carrier, which would be provided by NASA and based on the Mariner Mark II design, will provide the major resources during cruise phases;

- a lander, which would be provided by ESA, carries the sampling facility, the anchoring system, the landing instrumentation and major payload elements. This module will be left on the comet;
- an aerocapsule, also to be provided by ESA, designed to carry the cometary samples back to Earth and protect them during Earth-atmosphere re-entry.

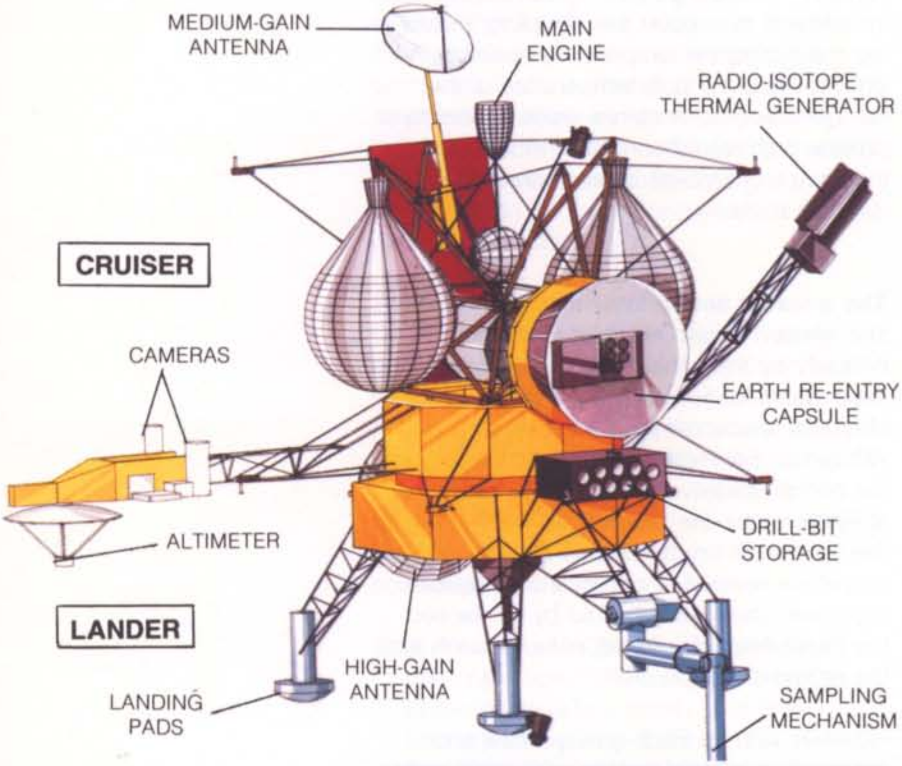


Figure 2. The Rosetta/CNSR space segment: carrier, lander and aerocapsule

The integrated spacecraft concept is shown in Figure 2.

Launch and cruise

A Titan/Centaur launcher, which would be provided by NASA, will inject the Rosetta spacecraft into an escape trajectory, nominally in January 2001, to rendezvous with Comet Churiumov-Gerasimenko. The initial orbit is heliocentric with an approximately two-year period. This trajectory will be corrected one year after launch by a deep-space manoeuvre, which will ensure an Earth swingby at a distance of 300 km, 11 months later. This will place the spacecraft on a higher heliocentric energy trajectory, which intersects the comet orbit close to its aphelion at 5.5 AU (Fig. 3).

Comet approach

The spacecraft will arrive in the vicinity of the comet in June 2005. For the expected cometary visual magnitude of around 13 (albedo 0.03), comet acquisition is expected to occur between 3 and 1 million km from the target, depending on the spacecraft pointing stability that is achievable.

For about 25 days, the spacecraft will travel at a relative speed of about 1 km/s, along a biased trajectory, towards a point about 100 000 km from the comet, on its sunlit side. This trajectory is designed to ease comet detection, due to its motion relative to

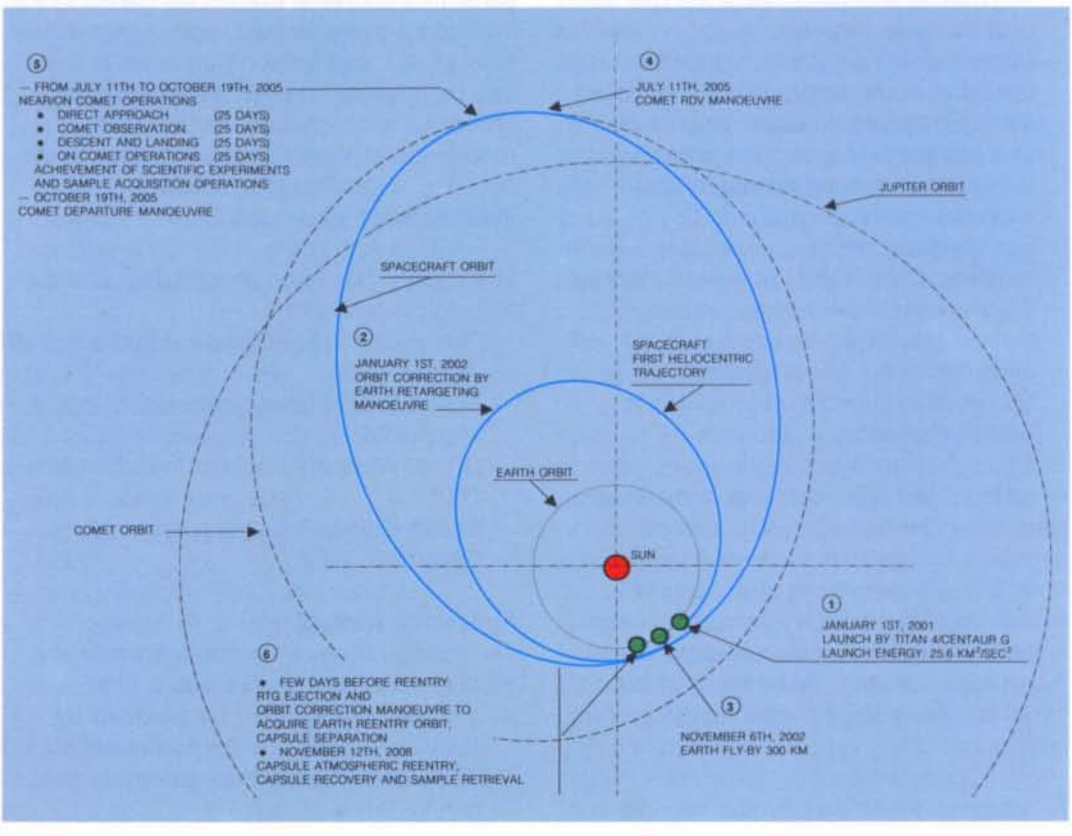


Figure 3. Baseline Rosetta/CNSR trajectory to Comet Churiumov-Gerasimenko

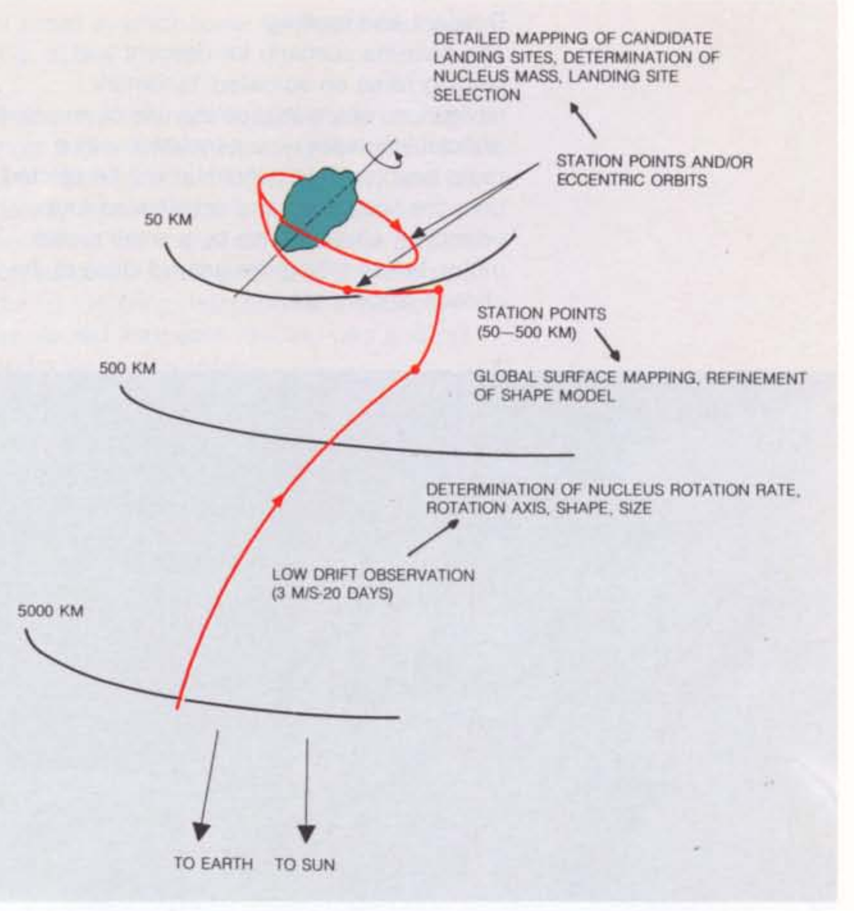


Figure 4. Comet observation and approach scenarios

the star background, and to prepare for ideal lighting conditions during the subsequent 'Direct Approach Phase'. The spacecraft will be guided from the ground, using the images derived from the on-board tracking camera.

When the spacecraft passes close to the Sun—comet line, a pair of trajectory manoeuvres will be performed to reduce the relative spacecraft speed to about 100 m/s, and to redirect it onto a path aimed at a point about 5000 km from the comet's optical centre (Fig. 4). During the next 20 to 25 days, the relative speed of the spacecraft will be gradually reduced to about 10 m/s and the target point moved closer to the comet. The observation phase will begin when the spacecraft is some 5000 km from the comet's surface.

Comet observation

Knowledge of the comet's characteristics, needed for site selection and navigation, will be gathered during this phase. At approximately 5000 km from the comet's surface, the spacecraft will move close to the Sun—comet line (about 100 km target-point offset) to allow full observation of the comet's surface as it rotates under the spacecraft. A relative velocity of 5 to 10 m/s will allow 5 to 10 days of observations, covering many comet rotations.

The on-board cameras will take a sequence of images of the comet, which will be sent back to the ground for processing. It will then be possible to arrive at a preliminary model of the comet's shape by matching successive contour images, and a kinematic model of the comet can also be derived (spin rate and phase, spin-axis orientation).

When about 100 km from the comet, the spacecraft's motion towards the comet will be halted and it will begin moving parallel to the comet's orbit with a relative velocity of 0.5 to 1 m/s, sweeping back and forth close to the comet—Sun line or staying at hold points. The spatial resolution of the camera at the cometary surface will be better than 1 m at a distance of 100 km. Propellant consumption to maintain that altitude range will be of the order of a few kilogrammes per week. Radar altimeter data will then be available. A total of about 15 days in this mode is foreseen.

A detailed map of the comet's surface topography, an albedo map, and a temperature and spectral-signature map are being developed and will be used to identify candidate landing sites that are suitable both from a safety (flat areas) and from a scientific point of view.

Once three or four candidate landing sites have been selected by a joint Science and Engineering Team, the spacecraft will be manoeuvred to perform hyperbolic flybys of the comet, passing less than 20 km above the candidate landing sites when illumination conditions are good. The purpose of this subphase, which will last for 15 to 20 days, is to refine our information on the landing site, in particular by subsurface sounding and roughness mapping using microwave instruments.

Another important task is improvement of the comet dynamic model (gravity-field harmonics) by tracking the spacecraft's orbital motion. An elemental-composition analysis using gamma-ray instrumentation and a volatile-release analysis may also be attempted. Closed orbits around the comet may also be exploited when feasible.

The ground-team's decision on the prime landing site will conclude the observation phase, and preparations for descent and landing on the comet will then commence.

Descent and landing

The baseline scenario for descent and landing relies on so-called 'landmark navigation', which implies the use of an active artificial landmark — a penetrator with a radio beacon. This penetrator will be ejected from the spacecraft and accelerated to a velocity of about 50 m/s by a small rocket motor, before hitting the ground close to the chosen landing site.

gradually reduce its vertical velocity as the altitude decreases. The polarised signal from the beacon will allow lateral positioning errors to be controlled and ensure accurate landing of the spacecraft within 20 m of the chosen point.

The microwave instrument will also monitor the surface roughness, to determine whether the predicted landing area is safe, and

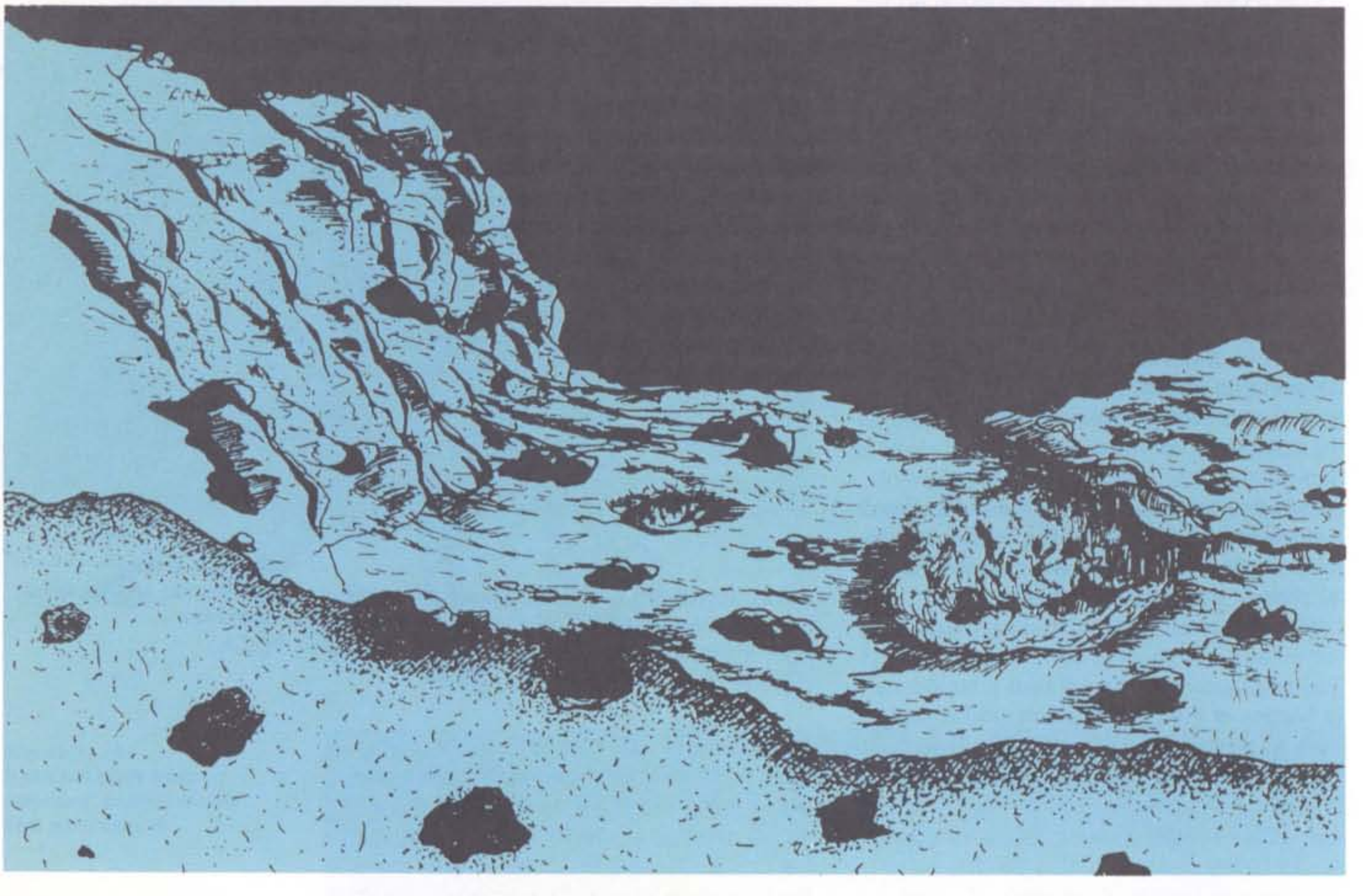


Figure 5. Artist's impression of comet-nucleus morphology and layering

whether the sampling operation will be possible. If not, the spacecraft will be autonomously commanded to a higher altitude where it will acquire a 'safe mode', awaiting further instructions from the ground. The final descent and landing phase is expected to last about 1 hour.

The beacon will be activated during a subsequent pass over the landing site. The spacecraft will then return to an altitude of about 100 km to wait for ground analysis at the beacon location, using images, together with directional information from the beacon signal. The final decision on the landing site relative to the landmark will be uplinked to the spacecraft, and another comet approach to a corridor above the landmark initiated. Synchronisation with the landmark's motion will then be performed and the final descent under autonomous control will start, with the spacecraft acquiring a landing-pads-downward orientation.

While the scanning altimeter continuously monitors the surface vertical, Doppler radar measurements will be used to cancel the spacecraft's residual lateral velocity and

A back-up scenario, based on 'predictive navigation', will be implemented in the event of a failure or malfunction in the artificial landmark/penetrator system. A de-orbit manoeuvre injects the spacecraft into an elliptic intercept orbit aimed at the selected landing site. The computation of the de-orbit manoeuvre in this case is based entirely on prediction, using the geometric, kinematic and dynamic models determined during the previous mission phases. The landing accuracy achievable therefore depends upon the accuracy of the cometary models and the spacecraft manoeuvring accuracy. During the final descent, however, range and Doppler measurements would be continuously monitored for collision-avoidance purposes. At any indication of unsafe operations, descent would be be autonomously aborted and a safe altitude acquired to await further ground commands. Low landing precisions must be accepted in the unlikely event that this scenario has to be used.

Sampling

The most likely composition for the cometary nucleus is that of a finely grained structure of amorphous and/or crystalline ice (water ice or hydrates including carbon dioxide, carbon monoxide and other gases), including micron-sized dust particles (carbonaceous and/or siliceous minerals).

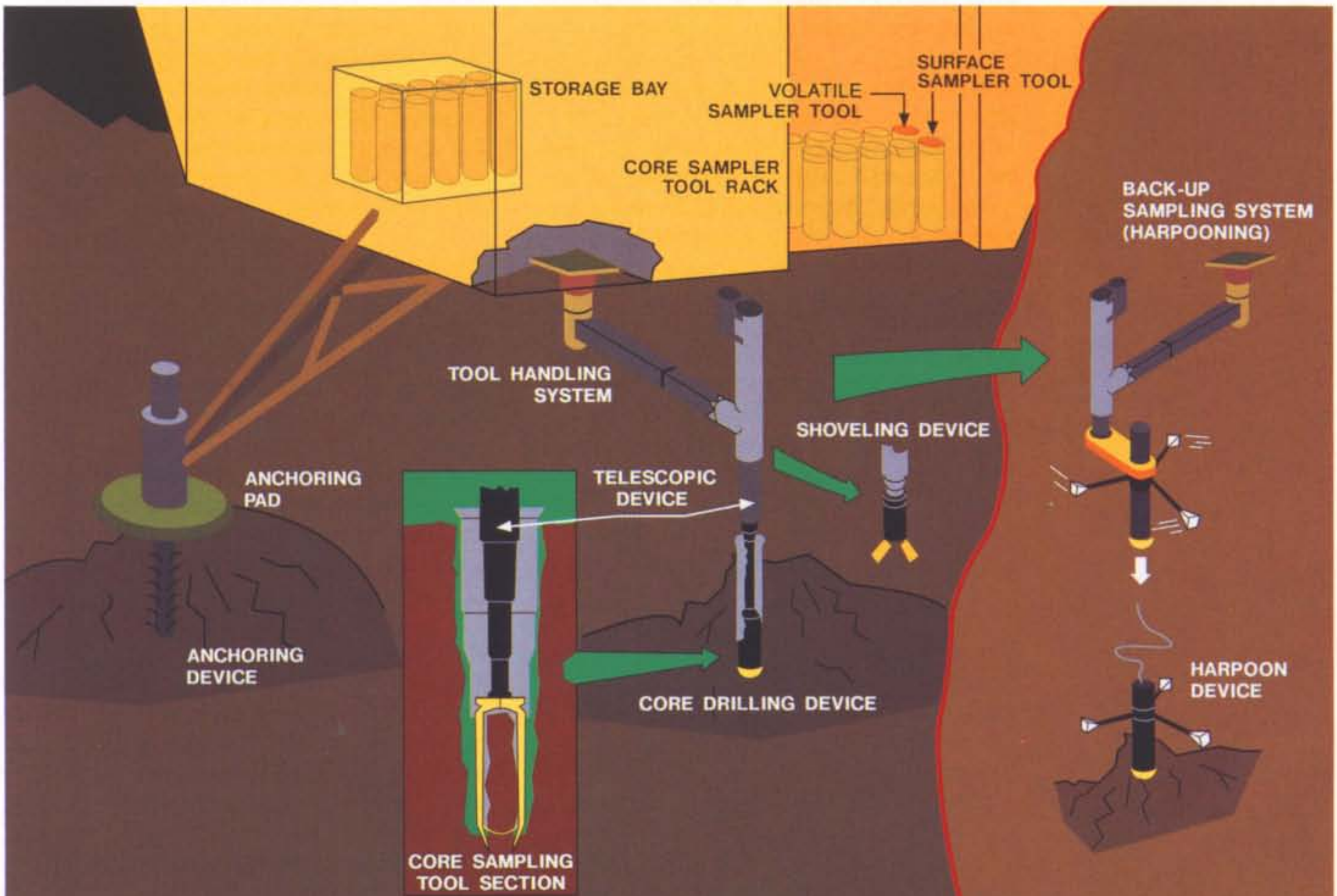
The structure is expected to be very porous and non-uniform, and irregular surface patterns are likely to occur: some loose material, such as dust, pebbles, or even boulders, could be found overlying a rough irregular surface, with possible escarpements or areas in which lower layers are exposed (Fig. 5).

Due to the very weak gravitational field of most target comets, resulting from their small dimensions (about 10 km diameter) and low density (about 1 g/cm^2), a means of anchoring the spacecraft has to be provided to counteract forces and torques generated during sampling. Harpoon-like devices will be ejected from each landing pad and put under tension by tethers.

Once the spacecraft has been secured to the nucleus, the sampling facility will be deployed (Fig. 6). A robotic manipulator arm will first collect surface samples by grasping material within an approximately 1 m radius. Two surface-sampling tools, 50 cm long and 10 cm in diameter, will be filled and then stored in the aerocapsule. Finally, the robotic arm will grasp the core-sampling tools, which are the same size as the surface-sampling tools.

Between two and six core samples will be collected by drilling at the same location to increasing depths using the extending feature of the robotic arm. Drilling speed will

Figure 6. Schematic of the sampling process



be automatically adjusted to fit the soil characteristics and a sample cutter mechanism, mounted at the end of each sampling tube, will be activated when the drill tool has reached maximum depth. A period of ten days has been planned for the sampling operations.

Should landing or anchoring not be possible due to extremely unfavourable surface features or properties, a back-up sampling scenario would be implemented. The spacecraft will then be kept hovering above the surface and a hollow penetrator will be ejected with an axial velocity and spin rate adequate to collect a sample on impact. The sample will be retrieved using a tether connected to the robotic arm. This back-up sampling would not, however, satisfy the full scientific requirements (sample depth and width) of the mission.

Return to Earth

Once sampling has been completed and the samples have been properly stored in the aerocapsule, the carrier spacecraft will separate from the lander platform, which will be abandoned on the comet, and will take off at a velocity of about 10 m/s. It will slowly move away from the comet for about 10 to 20 d. The Earth-return-manoeuvre sequence will then be initiated from the ground.

The primary activities during the three-year return trip will be navigation, tracking and orbit correction, and temperature control for the samples (160 K). The spacecraft will subsequently approach the Earth at a velocity of 10.2 km/s in November 2008.

Earth approach and re-entry phase

At the end of its cruise phase back from the comet, the spacecraft will arrive on a return trajectory that misses the Earth by about 1000 km. At approximately one million kilometres from the Earth (about 24 h before re-entry), the spacecraft's Radioisotopic Thermal Generator (RTG) power source will be ejected. Half an hour later, a manoeuvre will be executed to redirect the spacecraft onto its re-entry trajectory.

When the spacecraft is still 100 000 km from Earth on this trajectory (2 h before re-entry), the aerocapsule will be separated from the cruiser. While the former continues on towards its re-entry point, an orbital manoeuvre will deflect the cruiser onto an Earth-avoidance path.

Braking during the high-velocity re-entry will be achieved through atmospheric friction below an altitude of about 200 km. The small lift-to-drag ratio will allow the aerocapsule's trajectory to be carefully controlled within the narrow re-entry corridor. The final aero-capture trajectory will be constrained by: the maximum accelerations that can be tolerated by the capsule and the samples (50 to 100 g); by the maximum heat flux that the thermal-protection material can withstand; and by the integrated heat load that can be managed such that the sample-container temperature remains acceptable.

During the most critical part of the atmospheric phase, ground communications will be interrupted (ionisation blackout) and autonomous aerocapsule navigation, guidance and trajectory control will be mandatory. Accelerometer outputs will be used to plot a reference drag profile along which the capsule will be manoeuvred to the chosen landing zone (precision of less than 20 km). At about 25 km altitude, when travelling at Mach 1, the aerocapsule's parachutes will be deployed for final descent.

The Preparatory Programme

Due to the unconventional nature of the Rosetta mission scenario, new technologies and techniques are required for its successful implementation. To this end, ESA has initiated a special Preparatory Programme, which began in 1986 and will continue until 1991 (by which time a definite financial and programmatic commitment to this mission will have been decided).

The scope of this Preparatory Programme is to define a mission scenario and a system design for which the feasibility of the requisite technologies can be demonstrated. ESA will bear the overall programme responsibility, especially on the technology side. NASA will provide essential support to the mission-definition activities by defining those programme elements that would be nominally provided by NASA, i.e. the carrier spacecraft, the launcher and the Deep-Space Network support.

Programme elements

The ESA Preparatory Programme involves both European industry and the international scientific community. The latter is primarily involved with the definition and characterisation of the interfaces between the spacecraft and the comet, including comet-material composition and cometary environments.

The major Programme elements are:
- The System Definition Study, which is defining the overall mission design, including planning, costing and harmonising the several technological activities listed below.
- The Autonomous and Advanced Navigation Study, which is addressing guidance, navigation and control aspects during the terminal phase of the near-comet operations.
- The Aerocapture Study, which is defining the Earth-atmosphere re-entry parameters and the major design aspects of the re-entry vehicle.
- The Sample-Acquisition System Study, which has to provide a reliable and flexible facility for the collection of the cometary sample, and for the anchoring of the spacecraft to the comet surface.
- The Sample-Material Characterisation, to produce materials analogous to cometary matter and measure its major mechanical properties.
- The Approach and Landing System Study, which has to define and develop suitable instrumentation for sensing the comet, selecting a landing site, and landing.
- The Thermal-Protection and Descent-System Study, which is defining the thermal protective material and decelerator needed by the Earth-atmosphere re-entry vehicle.
- The Autonomous-Spacecraft Data-Management Study, which will encompass the detailed architectural design and testing of those spacecraft functions requiring onboard autonomy.
- The Electric-Propulsion (development), which, although not baselined for Rosetta, would provide greater flexibility in the planning and design of high-energy solar-system exploration missions.

Model Payload

Site Selection	
Essential:	Imaging System IR Mapper (incl. thermal wavelengths) Radar Altimeter/Sounder
Highly Desirable:	Neutral Mass-Spectrometer Dust Detector
Augmentation:	Test Penetrators Accelerometers
Surface and Bore Hole	
Essential:	Temperature Profile in Drill Hole Bulk Temperature of Collected Sample Optical Monitoring of Sampling Processes
Highly Desirable:	Measurements of Local Temperature
Augmentation:	Imaging or Analysis of Bore Hole to Determine Stratigraphy
Environment	
Essential:	Neutral Mass-Spectrometry Dust Monitoring (Mass and Velocity Distribution)
Desirable:	Plasma Science

Conclusion

Rosetta will be the first of a new category of space missions, having a different intellectual thrust. It will set a precedent by collecting samples that formed outside the solar system. It will apply a particular scientific approach that has long been used for planetary materials — their direct study in analytical laboratories — to astrophysical objects that have so far been studied only by remote observation.

Rosetta is, by its very nature, a challenging space mission, and is therefore an ideal candidate for international cooperation. The details of such a collaboration are currently under discussion with NASA.

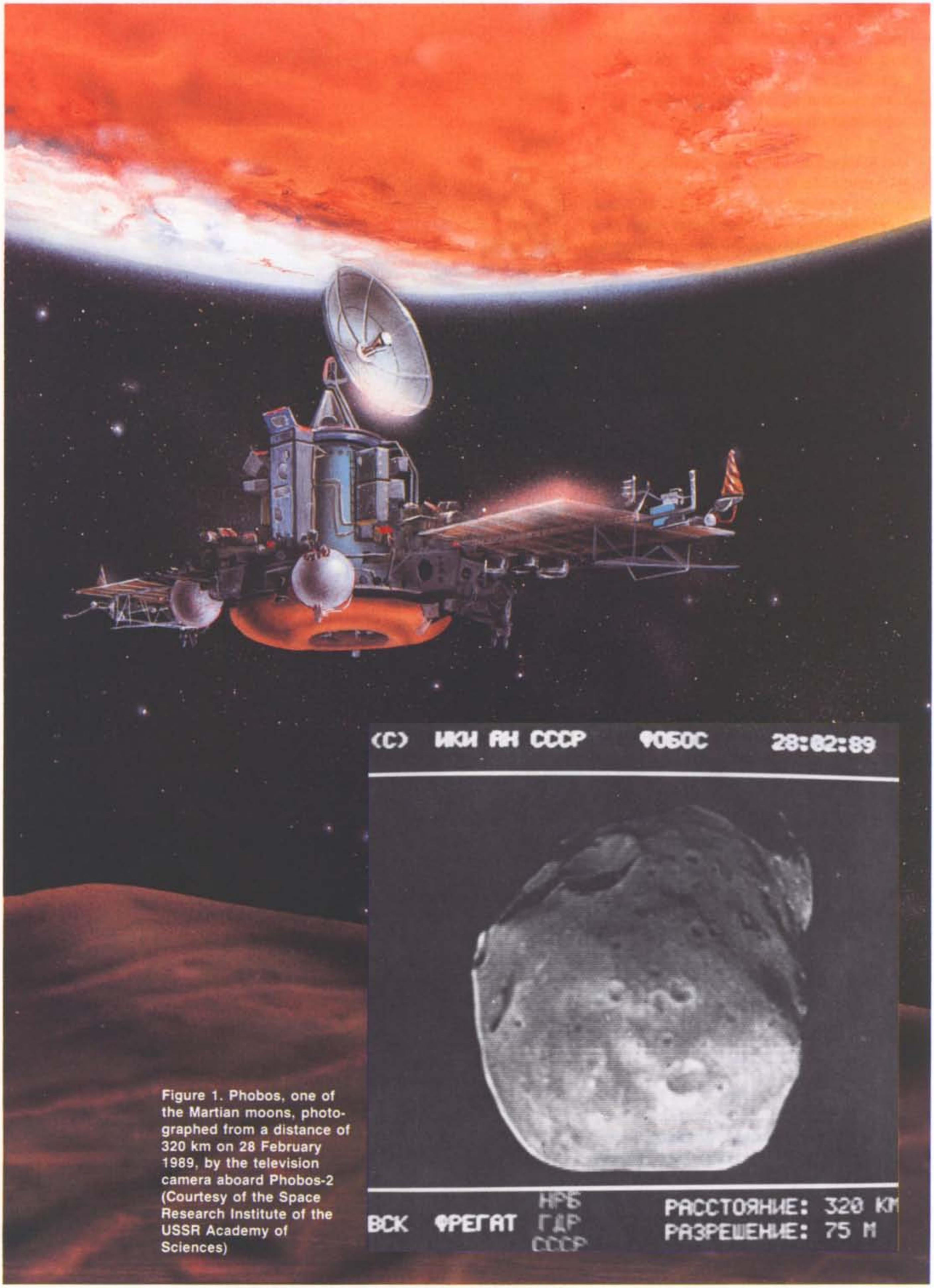


Figure 1. Phobos, one of the Martian moons, photographed from a distance of 320 km on 28 February 1989, by the television camera aboard Phobos-2 (Courtesy of the Space Research Institute of the USSR Academy of Sciences)

First Results from ESA's Plasma-Wave System aboard Phobos

R.J.L. Grard
ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

The two Soviet Phobos spacecraft were launched towards Mars, from Baykonur, on 7 and 12 July 1988. Their scientific objectives were to: (i) study the Sun and the interplanetary medium during their transit from Earth to Mars; (ii) explore the magnetosphere of the red planet; and (iii) perform a close flyby of one of the Martian moons, Phobos (Fig. 1), after which the mission was named. Both spacecraft carried an experiment developed by ESA's Space Science Department, the so-called 'Plasma-Wave System (PWS)*'.

* The PWS instrument was developed by ESA's Space Science Department with the collaboration of the Laboratoire de Physique et Chimie de l'Environnement (CNRS, France), the Institute of Geophysics and Planetary Physics (UCLA, USA), the Space Research Institute of the USSR Academy of Sciences (IKI, USSR), and the Space Electronics Laboratory of the Polish Aviation Institute (IL, Poland).

The two Phobos spacecraft carried largely identical instrument packages developed by a 13-member consortium, including ESA. The 800 kg scientific payload carried by Phobos-1 and -2 was allocated to 23 different experiment packages, 17 of which were flown on both spacecraft. Despite the premature loss of the mission**, many of the Phobos instruments (16 out of 23), including the ESA Plasma-Wave System, returned new and very important measurements.

After its capture by Mars' gravitational field, Phobos-2 was performing a complete orbital revolution in 3 d 5 h 37 min in the planet's equatorial plane, which is inclined at 25° with respect to the Martian ecliptic. The altitude of the spacecraft above the planetary surface varied between about 870 km at periapsis and 80 000 km at apoapsis (Fig. 2).

Figure 3 shows a continuous sequence of measurements collected by the Plasma-Wave System around the periapsis of the first orbit. It shows that the interaction between Mars and the solar wind gives rise to a number of phenomena similar to those that the PWS observed near Earth just after launch (see ESA Bulletin No. 56, p. 81).

Well upstream of the Martian environment, electron plasma oscillations are observed in

** Phobos-1 was unfortunately lost at the end of August 1988, after a telecommanding error disabled its attitude-control system. Earlier this year, communications problems prematurely ended the Phobos-2 mission also, on 27 March 1989, 13 days before its expected rendezvous with the Martian satellite.

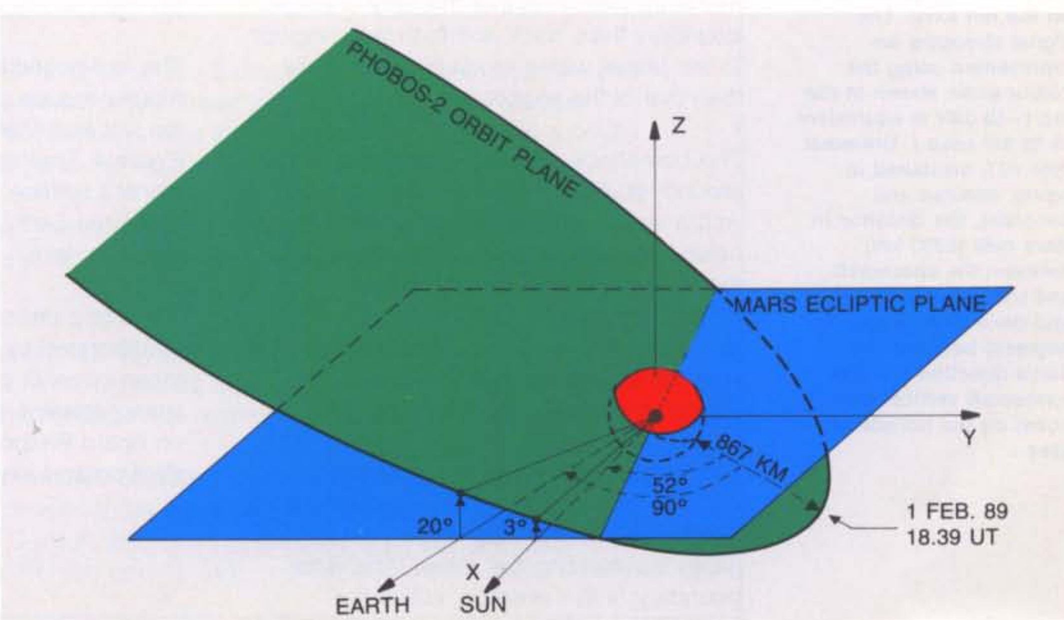


Figure 2. Geometry of the first orbit of Phobos-2 around Mars (not to scale)

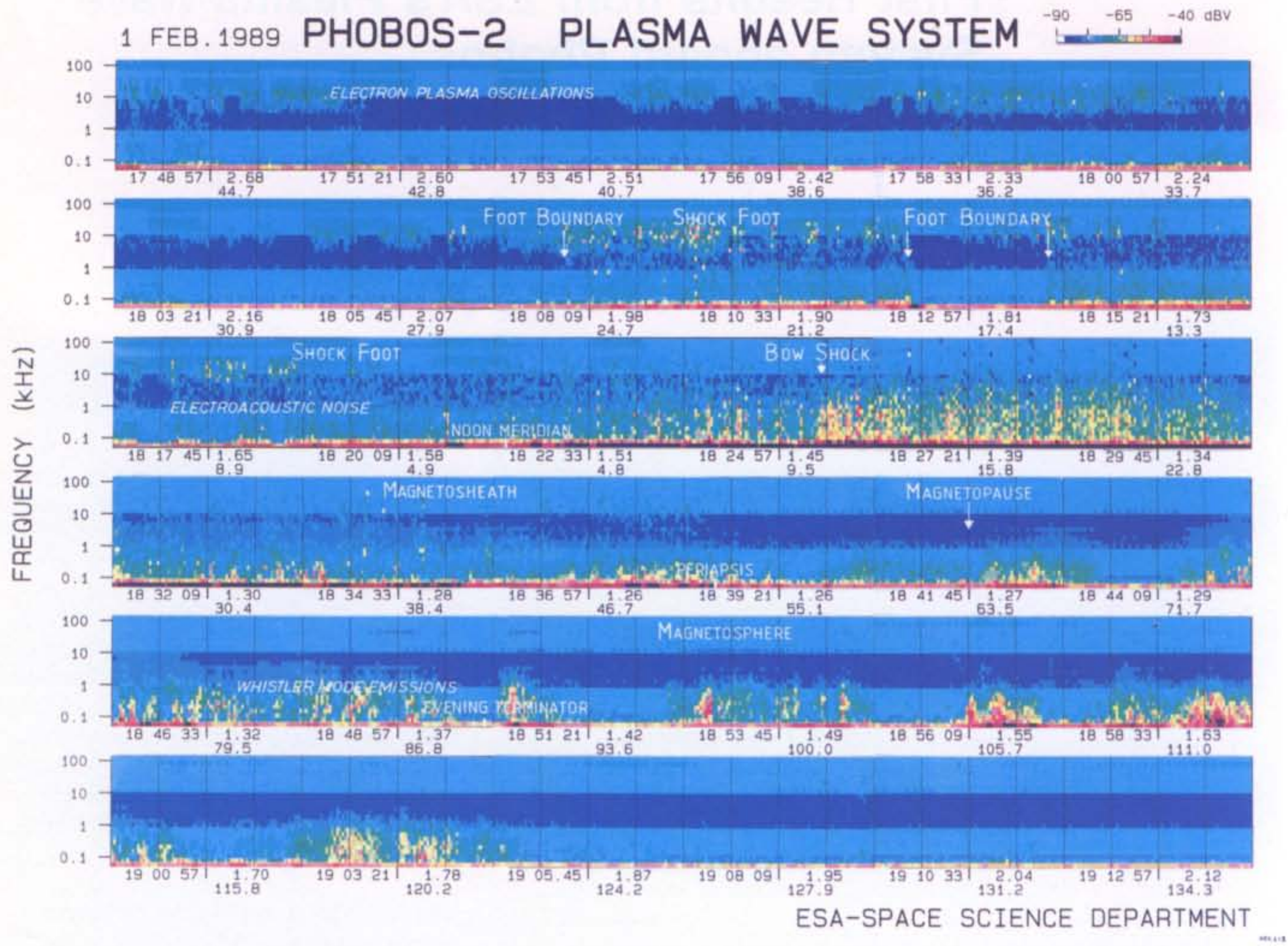


Figure 3. Dynamic spectrogram of the waves measured by the Plasma-Wave System (PWS). Each raster line represents the time profile of the signal delivered by one of 25 nearly contiguous filters (frequency range indicated on the left axis). The signal strengths are represented using the colour scale shown at the top (−40 dBV is equivalent to 10 mV r.m.s.). Universal time (UT, measured in hours, minutes and seconds), the distance in Mars radii (3393 km) between the spacecraft and the planet's centre, and (below) the angle (in degrees) between the Sun's direction and the spacecraft vertical are noted on the horizontal axes

a frequency band centred around 13 kHz (Panel 1), from which it is inferred that the solar wind contains approximately 2 protons and 2 electrons per cm^3. The outer boundary of the shock foot (a forerunner of the bow shock) is crossed three times on the in-bound section of the spacecraft trajectory (Panel 2), indicating that this very unstable boundary flaps back and forth with respect to the planet with a much higher velocity than that of the spacecraft.

The bow-shock crossing is detected at around 18.25 UT (Panel 3), and coincides with a visible increase in the electro-acoustic noise level. Downstream of this boundary, in the magnetosheath, the solar wind is decelerated and its kinetic energy is partly dissipated through the generation of electro-acoustic waves, which fade away as the spacecraft approaches the magnetopause.

The obstacle offered to the solar wind is not the solid body itself, but the magnetosphere, which contains the magnetised and ionised gases surrounding the planet. The outer boundary of this obstacle, called the 'magnetopause', is crossed at 18.42 UT, but cannot be easily identified from the wave measurements (Panel 4). Relatively intense electromagnetic and electrostatic waves are seen in the magnetosphere; this activity becomes burst-like and vanishes as the spacecraft passes through periapsis and moves away from the planet (Panels 5 and 6).

The foot-boundary, bow-shock and magnetopause crossings observed during the first four Martian orbits are sketched in Figure 4. Their relative proximity to the planet's surface results from the fact that, unlike the Earth, Mars has a very small magnetic field.

This interpretation of the wave data is largely corroborated by the independent measurements performed with the other PWS sensor (plasma probe) and other instruments on board Phobos-2 (magnetometers, and electron and ion detectors).

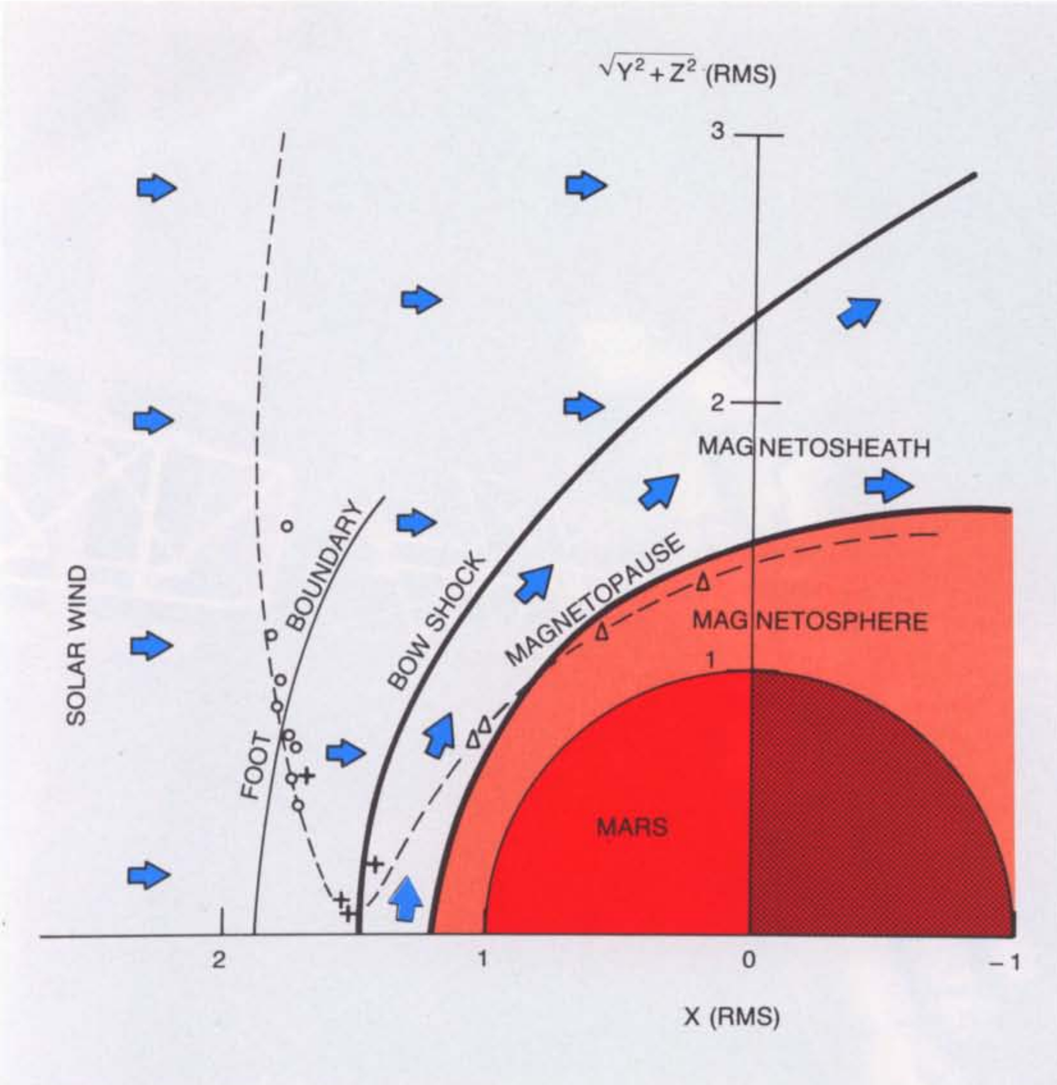


Figure 4. Locations of the shock-foot, bow-shock and magnetopause boundaries as observed during the first four Phobos-2 orbits (indicated by circles, crosses and triangles, respectively). Distances are measured in Mars radii (1 R_m =3393 km), and the x-axis points towards the Sun. For comparison, the average position of the Earth's bow shock at the subsolar point is at about 14 Earth radii (1 R_e = 6378 km)

Mars and its Moons

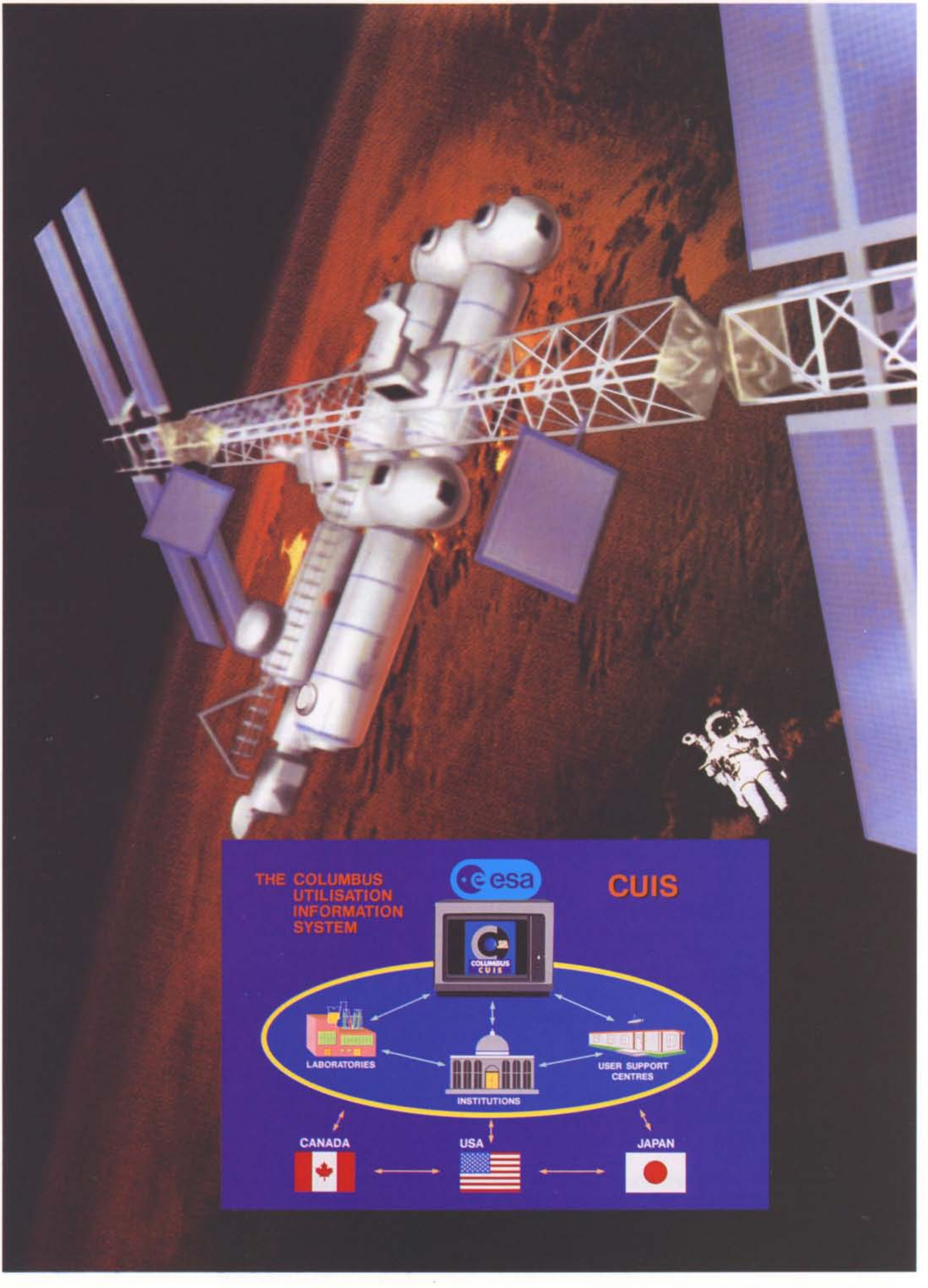
The existence of two Martian satellites had been predicted by Johannes Kepler in 1610, without any scientific justification, and had been assumed, in 1720, by Jonathan Swift in 'Gulliver's Travels':

....'They have likewise discovered two lesser stars, or satellites, which revolve about Mars; whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half.'....

It is perhaps worth noting that Swift was quoting orbital periods not too different from the real ones: 7.6 and 30 h. Thirty yers later, Voltaire went back to the same idea (in Micromégas):

....'En sortant de Jupiter, nos voyageurs traversèrent un espace d'environ cent millions de lieues et côtoyèrent la planète Mars. Ils virent deux lunes qui servent à cette planète, et qui ont échappé aux regards de nos astronomes.'....

The two satellites were eventually officially discovered during the nights of 11 and 17 August 1877 by Asaph Hall at the Washington Observatory, who christened them after Phobos and Deimos, the sons of Aphrodite and Ares (the Greek counterpart of Mars, the Roman god of war).


THE COLUMBUS UTILISATION INFORMATION SYSTEM
esa
CUIS
COLUMBUS CUIS
LABORATORIES
INSTITUTIONS
USER SUPPORT CENTRES
CANADA
USA
JAPAN

CUIS: The Columbus Utilisation Information System

G. Alvisi & M. Douzal
Information Systems Division, ESRIN, Frascati, Italy

G. Peters & Ph. Willekens
Promotion and Utilisation Department, Directorate of Space Station and Platforms, ESA, Paris

Why an electronic Utilisation Information System?
To date, ESA's utilisation of manned spacecraft has been limited mainly to Spacelab, which heralded Europe's entry into manned space flight. There have been several Spacelab flights, each lasting some 8 to 10 days and involving a considerable number of European experimenters. The experience gained with Spacelab has proved how difficult a task it is to keep the user community informed about the latest system developments, and to maintain user inputs in a form that does not require further processing.

The launch of Columbus and the Space Station 'Freedom' in the early 1990s brings with it the possibility of 30 years of utilisation and the opportunity for innumerable flights and experiments. There will be the possibility of exchanging experiments every three months in the Columbus Attached Laboratory, and every six months in the Columbus Free-Flying Laboratory. This operational scenario will provide European users with the facility to conduct a large number of experiments producing a great deal of information.

The traditional paper-based information system used for Spacelab is certainly not adequate for coping with the increased amount of information involved in the case of Space Station/Columbus, and a more efficient electronic system is needed for four main reasons:
— the sheer volume of information
— the large number of experimenters
— the short interval between flight opportunities, and
— every user is already equipped with computers, which are becoming ever more powerful.

The Promotion and Utilisation Department (PUD), charged with the preparation and coordination of Columbus utilisation, has decided to develop an information system called CUIS (Columbus Utilisation Information System). This system will not only provide Columbus users with information much more efficiently, but will also facilitate the preparation of the experiements to be flown. Technical implementation of the system has been delegated to the Information Systems Division at ESRIN.

The objectives for CUIS
The CUIS objectives can be summarised as follows:
— to provide access to all information relevant to the utilisation of Columbus, at the level of detail needed by both potential and selected experimenters
— to provide for the rapid exchange of information
— to help the selected experimenters to prepare the information needed by ESA
— to distribute experiment results to the user community efficiently.

Information access
The volume of information produced during a space project is enormous and all experimenters have experienced the difficulty of finding urgently needed information on a specific phase of an experiment among the thousands of pages produced during experiment preparation. Even when the information is found, there is no guarantee that it is complete and reflects the latest project status.

The implementation of a central electronic archive will give CUIS users access to the latest information. This will avoid postal delays and errors due to not using revision packages, problems that often occur with the conventional paper-based information system. The development of electronic tools will permit the retrieval of complete, updated information on a specific area of interest within the scope of the particular project or experiment.

CUIS will furnish electronic access to such areas as:
- the Engineering Database, which contains details on the technical capabilities, payload interfaces, and design constraints of the Columbus flight elements
- the Instrument and Facility Database, which contains information about flight instruments and multi-user facilities, and
- the Operations Database, which contains details about both flight and ground operations.

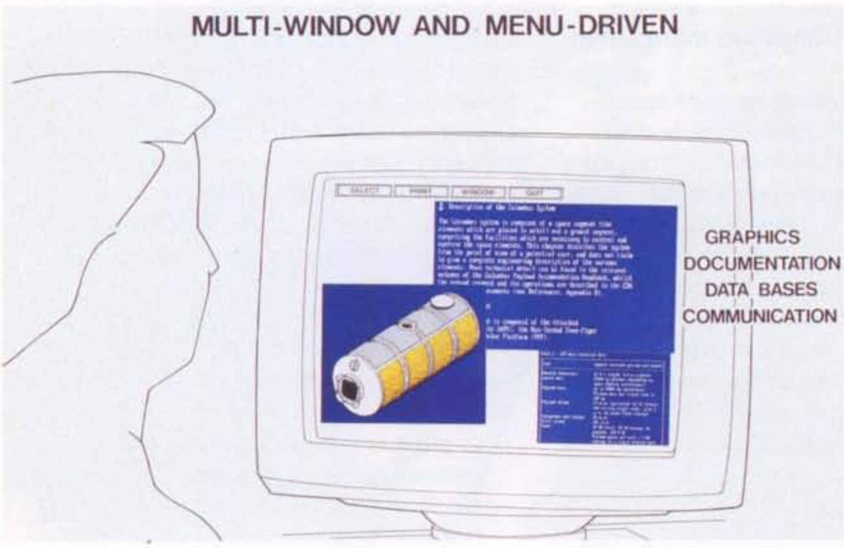


Figure 1

Information search and retrieval software will allow users to find:
- general information about Columbus and its utilisation potential
- general information about mission opportunities and detailed descriptions of specific mission increments, i.e. mission durations between two Shuttle visits to Space Station or two Hermes visits to the Columbus Free-Flyer.
- detailed technical information about system-to-payload interfaces
- Columbus instrument and payload data
- detailed information about mission and payload operations, and
- access to selected external databases (e.g. those of the international partners related to Space-Station utilisation).

Information exchange

One essential element that determines the total time needed to prepare an experiment is the lead time required to exchange information between the various parties involved. The implementation of an efficient electronic system for Columbus information exchange will drastically reduce these delays. To facilitate and accelerate the flow of information between ESA and the experimenters, and between the experimenters themselves, CUIS will provide four crucial communications services (Fig. 1):
- electronic mail
- computer conferencing
- bulletin-board services, electronic newsletters, etc., and
- file transfer.

Access to the services will be possible via public networks connected to the ESRIN computers. In addition, it is planned to connect CUIS in the future to information systems developed by the other Space-Station partners, NASA, NASDA and Canada.

Information requested by ESA

In order to conduct an experiment in space, ESA requires specific information from the particular experimenter concerned. This information is usually a general description when the experiment is first proposed, but becomes progressively more detailed during the selection process and again, after the experiment has been accepted, during the design, development and acceptance phases.

To reply correctly to ESA's requests, it is necessary for the experimenter to examine several documents and to be aware of the procedures involved. The CUIS expert system will help the user in this process, giving him expert advice and presenting him with the supporting information he needs to reply to specific questions. CUIS will also provide the user with planning, scheduling, and control tools.

As an additional benefit, the information provided by the users will already be in the correct electronic form to be processed directly by ESA.

Distribution of results

The CUIS system can also be used after the experiments have been completed to distribute the results to the scientific community. It will also permit a general exchange of information and discussion on the results. In the experimental stage, therefore, CUIS will be used to transfer low-rate data from Columbus telescience testbeds.

CUIS design and implementation drivers

The Columbus Utilisation Information System will have the same lifetime as Space Station 'Freedom' (30 years). In view of the rapid evolution taking place in the software and

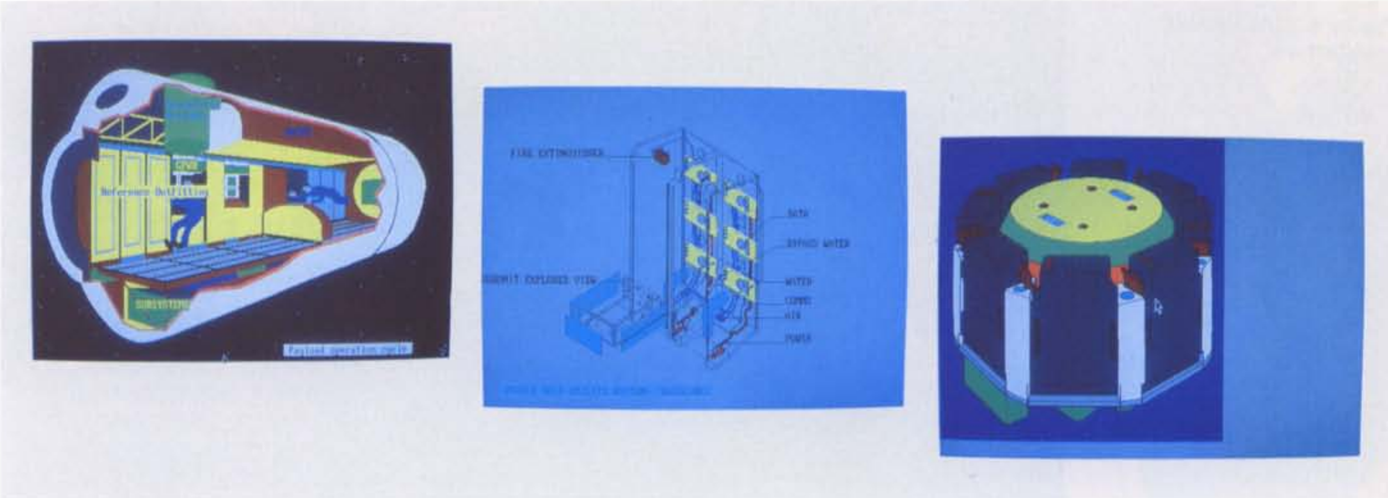


Figure 2. The hypertext concept underlying CUIS. The user can navigate through text and graphics, and traverse and select various levels of the information tree on an iterative basis

hardware domains, the CUIS system clearly needs to progress constantly during its lifetime in order to make full use of this evolution.

The computer hardware is expected to change completely every few years, while the lifetime of the software components is expected to be somewhat longer, but still subject to constant evolution. The greatest stability is needed in the human interface, because any change here will require the retraining of a large population of users. Moreover, they may have little or no experience with this specific information system.

The cost drivers for a system such as CUIS, which must evolve as the computer technology progresses over a period of 30 years, lie more in the areas of maintenance, enhancement and operation, rather than in the initial development. In designing the initial system, therefore, it is necessary to keep these factors in mind at all times in order to keep operating costs at a reasonable level without reducing the number or quality of the functions provided.

Off-the-shelf products

To reduce maintenance costs, off-the-shelf products will be used whenever possible. These products will evolve with the technology, and their maintenance costs will be spread over thousands of copies sold in the public domain by the manufacturer concerned.

Layered system

The major CUIS system components are:
— the hardware and operating system

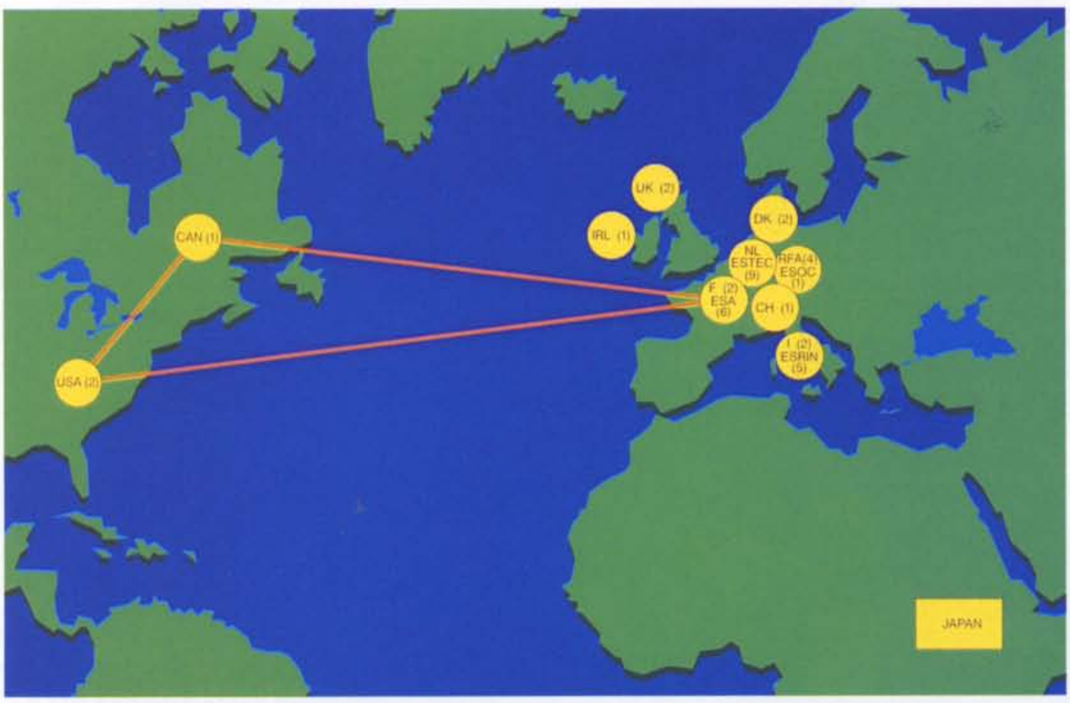


Figure 3. CUIS connected-user status per 16 June 1989

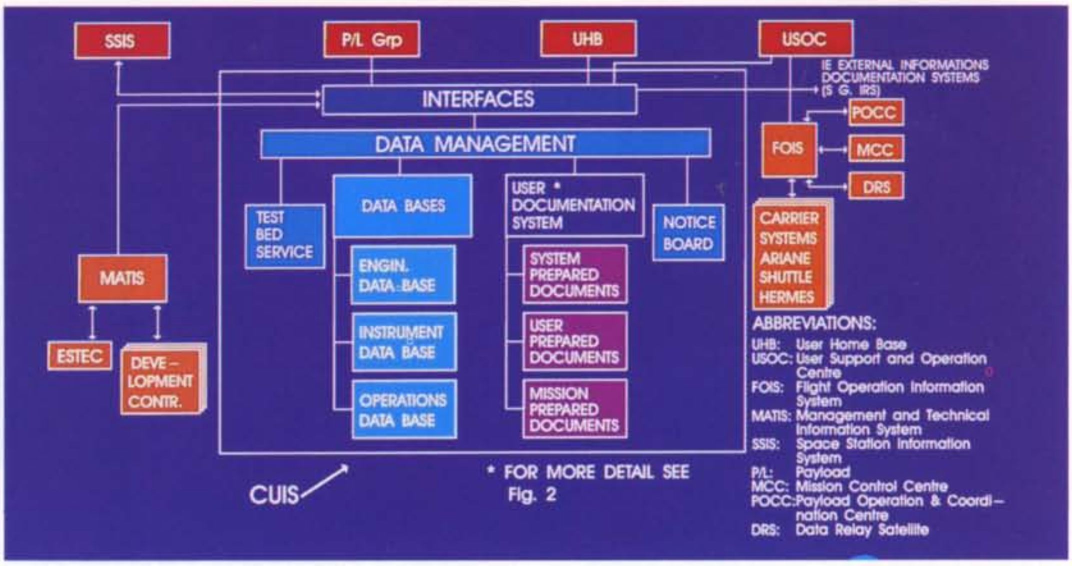


Figure 4. CUIS system architecture

— off-the-shelf programmable software packages
— applications written to integrate those packages into CUIS, and
— the man/machine interface to access the system's functions.

The interfaces between these layers must be well defined and each layer must be independent of the others. The layered system design will permit changes to be made in any of the layers as the technology evolves, with minimum modification to the other levels, and with a consistent reduction in maintenance costs.

Easy use of the system

The human interface is one of the key elements of CUIS as its users will be scientists and not information specialists. They will use CUIS in support of the preparation and execution of their experiments, and no special training must be required for this. The interface should make use of the most modern technology at the outset, but be as 'stable' as possible to avoid the need for user retraining.

User involvement

As the system is to be designed for the users' benefit, they must be given an opportunity to make the final recommendations. It is therefore planned to make extensive use of prototypes, which will be validated directly by the users before implementation in the CUIS system.

Impact on information preparation

The human brain is capable of synthesising and navigating through very complex, unstructured information. The computer does not have this capability and so, to take maximum advantage of current and future developments in information technology, it will be necessary to have well-structured information.

The cost of structuring the information in the proper way from the beginning is comparatively low, and a good architecture will certainly simplify its modification and evolution later in the system's lifetime. Consequently, a substantial effort must be made in parallel with the system's design and development to define the correct information structure. Initially, this effort will be concentrated on the Columbus Payload Accommodation Handbook, but will soon be extended to the complete spectrum of information to be handled by CUIS.

Implementation of CUIS

The CUIS prototype has already been distributed to a number of selected users and their experiences will be discussed at a workshop to be held at ESRIN in the autumn of 1989.

The results of this trial, and additional user requirements identified during this period, will then be used to develop an initial system. In parallel, new functions will be experimented with on the prototype before transferring them to the operational system.

The ultimate goal is to develop, in cooperation with the users, a system that is not only capable of meeting both the users' and ESA's requirements, but is also capable of drastically simplifying the work involved in preparing Columbus missions and experiments.


For those who study the earth, there's no better place to be.
Satellites provide the ideal platform for Earth Observation Sciences: from disease detection in crops, to glaciation, pollution, weather monitoring and study of the seas.
All these tasks can be carried out by Marconi satellite payloads. On ERS-1, Europe's first remote sensing satellite, the Active Microwave Instrument (AMI) and Synthetic Aperture Radar (SAR) are provided by Marconi. On other satellites, such as the Meteosat series, Marconi equipment provides the visible and infra-red imaging electronics as well as attitude measurement and control and communications equipment. For the future, Marconi are developing microwave radiometers ranging in frequency from 1 GHz to 183 GHz. Demonstrator programmes are also underway for advanced synthetic aperture spaceborne radars and microwave radiometers.
We are forging a European lead in earth observation instrument experience and manufacturing strengths. If you need to study the earth from space, Marconi are in the best position.
Marconi
Space Systems
Marconi Space Systems Limited, Anchorage Road, Portsmouth, Hampshire, England, PO3 5PU
Telephone Portsmouth (0705) 664966 Telex MARSAT G 86666
Marconi

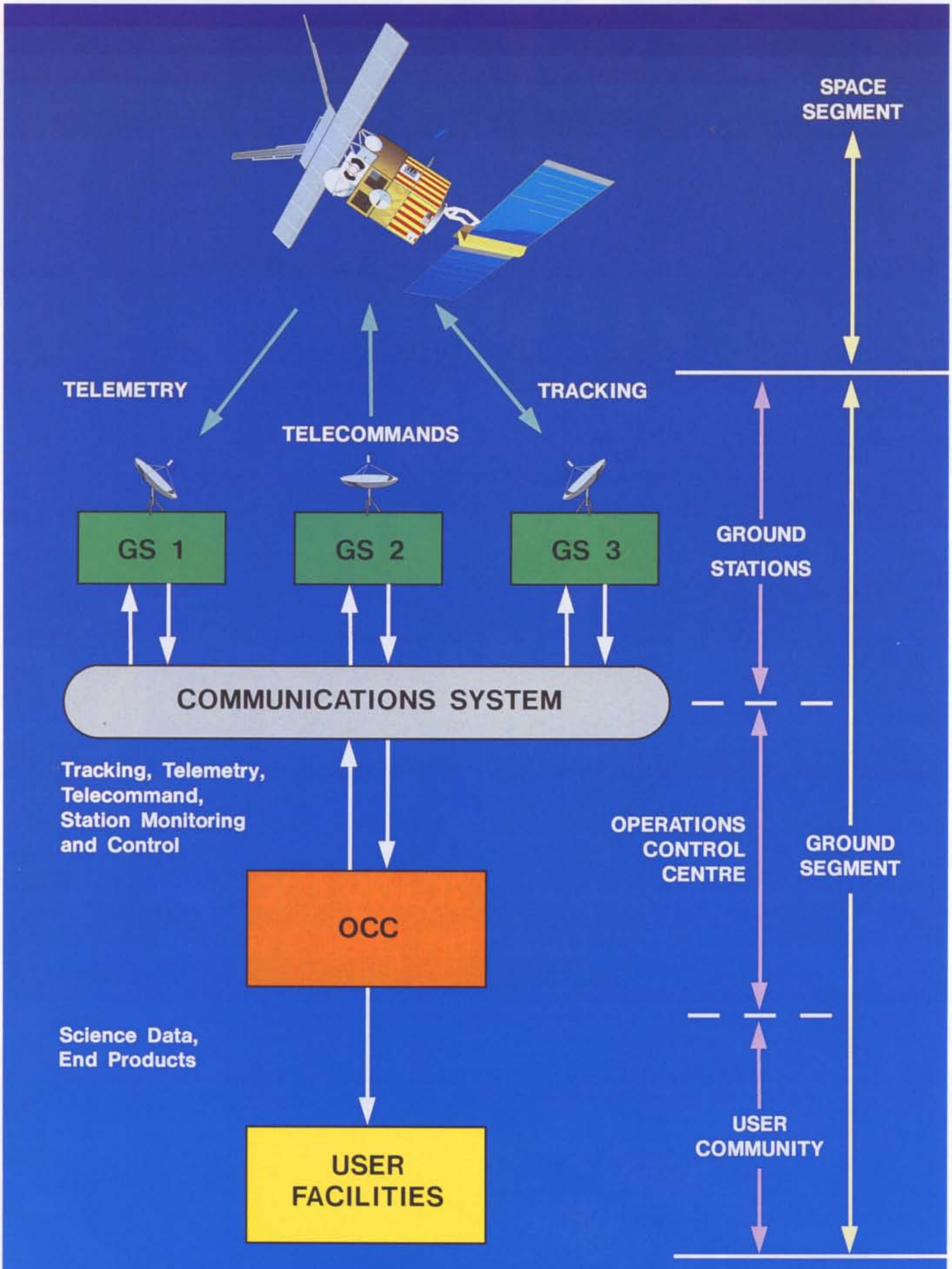


Figure 1. A typical satellite mission system

Use of Spacecraft Simulators at ESOC

J.J. Gujer & E. Jabs
ESA Computer Department, European Space Operations Centre (ESOC), Darmstadt, Germany

One of the critical keys to space-mission success is a well-prepared ground segment. All ground-segment elements have to undergo a series of test and validation procedures during the mission-preparation phase, and operations staff involved have to be adequately trained. After launch too, any modifications to the operational system must be thoroughly validated before implementation, and training activities must continue to maintain the requisite level of staff proficiency. The impossibility of having long periods of access to, or of performing the most critical tests with, the real spacecraft has prompted ESOC to develop dynamic (closed-loop) simulators for both pre- and post-launch test purposes.

Introduction

A satellite mission can be considered in its simplest form to consist of a space segment, a ground segment and a user community (Fig. 1). The ground segment for an ESA mission, as implemented within the Directorate of Operations at ESOC, includes:

- a set of ground stations, which function as an interface between the space segment and the ground segment; they acquire telemetry data, uplink telecommands and perform satellite-tracking operations;
- a communications network, which transfers information (telemetry, telecommand, tracking, station monitoring and control data, voice) between the ground stations and the Operations Control Centre;
- the Operations Control Centre (OCC), which is responsible for spacecraft monitoring and control operations. This is a complex system involving communications interfaces, computer hardware and software, and spacecraft-control peripherals operated by skilled personnel according to well-defined procedures;
- payload data-processing facilities, the function of which is largely mission-dependent and varies from pre-processing and distribution of raw scientific data to the generation of complex end-products.

All of the ground segment's components need to be thoroughly verified and validated before launch. We will concentrate here on the tools required for testing and validating the OCC and for training its personnel.

Historical background

The only telemetry data sources available to ESOC until 1973 for mission preparation and ground-segment validation were the spacecraft qualification models (for very limited periods of time) and magnetic tapes produced as part of the spacecraft checkout process. These tools were considered sufficient in the context of the relatively simple control and data-processing facilities used in those days at the Operations Control Centre.

With the enhancement in the ground-segment capabilities necessary to support the new geostationary missions, the existing validation tools became inadequate. A series of studies and prototype implementations were performed to assess the usefulness of software programs for generating spacecraft-like telemetry and responding realistically to telecommands. These studies confirmed the suitability of software simulators for ground-segment testing and validation.

The first simulators were essentially batch-type telemetry generators, offering limited facilities for testing and validating the telecommand system. The first closed-loop simulator, capable both of producing telemetry and reacting to telecommands in real time, was developed for the Agency's Geos spacecraft in 1977 (Fig. 2). Since then, simulators have been developed and used for all missions supported from ESOC, including the OTS, Meteosat, Marecs, ECS, Exosat, Giotto, Olympus, Operational Meteosat and Hipparcos spacecraft. Simulators for Eureca, ERS-1 and Italsat are currently under development.

Between 1977 and 1988, there has been a continuous evolution in the architecture of the simulators and the way in which the simulations are performed, in particular:
— Decoupling of simulators from the computing facilities used for operations control. Originally, the simulators used to be run on the same computer as the spacecraft-control programs, causing undesirable interactions between the test tool and the system under test. Today, all simulators are run on dedicated computers.
— Standardisation of simulator computing facilities. Ten years ago, computer systems from different manufacturers were used as hosts for the various spacecraft simulators: CII 10070 for Geos; ICL 4/72 for Meteosat simulator development; ICL 2980 for Meteosat simulator operation; Gould-SEL 32/77 for ECS. Today, Gould computers are used exclusively.
— Definition and implementation of a 'General-Purpose Spacecraft Simulation Package' (GPSSP), grouping spacecraft-independent software functions (e.g. man/machine interface, ground-station interface, task scheduler) within a standard reusable framework, with well-defined interfaces to spacecraft subsystem models.
— Increased complexity of spacecraft subsystem models, reflecting the evolution in today's spacecraft, the major change in this area being the implementation of onboard processing functions by means of software.
— Wider scope of application, with spacecraft simulators now also being used during operational phases.

Figure 2. The Geos satellite, for which the first closed-loop simulator was developed in 1977

Requirements for simulation tools

Fifteen years ago, the only requirement for simulators was for the validation of spacecraft control systems. As the complexity of the missions and the spacecraft increased, the role of simulators was extended to support further aspects of mission preparation and operation.

Today, the requirements for close-loop simulators originate from four applications:

Test and validation of Operations Control Centre facilities

Before the OCC facilities (hardware, software and interfaces to the various ground stations) are accepted for participation in the mission-readiness rehearsals, a series of tests and validation activities have to be carried out. These usually start 12 to 16 months prior to launch, and continue until about 2 months before launch. After launch, the test and validation process has to be repeated each time an OCC element is modified or replaced in order to correct faults or to improve the system's performance.

A tool is therefore required that realistically simulates the interface to the ground stations and models the spacecraft's behaviour. In particular, such a tool must be capable of:
— simulating the formal structure and temporal behaviour of telemetry data as received from the ground stations;
— accepting telecommand messages in the format in which they are transmitted to the ground stations for uplinking to the spacecraft, and processing these telecommands as the spacecraft would do;
— simulating, at protocol level, the behaviour of various other ground-station equipment items, such as the tracking system.

Test and validation of flight-control procedures

During the mission-preparation phase, flight-control procedures for operating the spacecraft have to be developed, tested and validated, using documentation supplied by the spacecraft manufacturer. These procedures cover all mission phases and modes of operation, including contingency situations.

Throughout the mission, modifications to existing flight-control procedures or new procedures may be required as a result of, for example, non-nominal spacecraft operation. Such modified or new procedures also need to be tested and validated thoroughly.

To support these activities, a tool is needed that simulates the behaviour of the spacecraft, as seen from the ground, covering both the nominal operating modes and the foreseen contingency modes. In particular, such a tool must:

- react to telecommands as the real spacecraft would do; this applies to all types of telecommands, whether executed directly or routed to the on-board processor for delayed execution;
- generate realistic housekeeping telemetry for both platform and payload;
- operate in real-time: all on-board phenomena having an effect on telemetry must be simulated with the same time behaviour as observed on the real spacecraft;
- allow for failures to be introduced at subsystem/unit/equipment level.

The need to simulate payload data is generally restricted to the housekeeping data required for health monitoring.

Modifications to the simulation tool may be required after launch to take into account non-nominal behaviour of the real spacecraft.

Staff training

During the mission-preparation phase, operations staff need to;

- be trained in how to use the spacecraft monitoring and control facilities available at the OCC;
- become familiar with the mission and spacecraft characteristics;
- acquire the level of proficiency required for the planned operations.

After launch, the same type of training is required for the phasing in of new personnel. Experienced staff also need training to maintain their level of proficiency, especially in those operational areas that are not exercised on a routine basis (e.g. contingency procedures, complex manoeuvres, etc.).

To be meaningful, the staff training has to be performed on the actual spacecraft monitoring and control facilities (Fig. 3) or, at the very least, on a true copy of these facilities.

photo: picture report

Figure 3. Dedicated control room at ESOC in Darmstadt

Staff training starts approximately 9 to 12 months prior to launch and continues throughout the mission. The training tool must provide the person responsible for performing the training with the ability to:

- define the requisite test scenarios and set up the tool accordingly;
- monitor both the training tool's performance and the progress of a training session;
- control and influence the execution of a session (hold/restart, injection of failures and contingencies, modification of selected spacecraft-related parameters, etc.).

Mission-readiness rehearsals

Approximately 2 to 3 months prior to launch, a system-wide simulation programme is implemented to ascertain the readiness of the OCC to support the launch and the mission operations. During these simulations, the main sequences of events planned for the launch, the commissioning and the routine phases are rehearsed, with all mission-control and support teams participating.

These rehearsals require a tool that combines all the capabilities described in the context of the applications listed above.

Simulator architecture

Overall architecture

There are several architectural options for satisfying the requirements for testing, validation and training within the OCC:

- a common tool can be implemented covering all needs for simulated data or, alternatively, several specialised tools may be used;
- spacecraft simulation tools based at ground stations may be used in a configuration involving actual station equipment and the communications network; alternatively, a combined spacecraft/ground station simulation tool may be implemented at the OCC with direct interfaces to the OCC computers;
- standard spacecraft monitoring and control work stations driven by the OCC computers may be used for staff training; alternatively, the training may be performed by using true copies of these devices connected to the simulator.

When the first real-time simulators were implemented at ESOC, trade-offs between these options resulted in the selection of an OCC-based common tool interfaced directly to the OCC computers. The staff training proper was performed on actual spacecraft monitoring and control peripherals driven by the OCC computers. The architecture that resulted from these choices has been found to be suitable, with very slight modifications, for all present OCC needs and still forms the baseline for all simulators currently being developed at ESOC (Fig. 4).

A simulator based on such an architecture can be seen as consisting of five functional blocks (Fig. 5):

- a spacecraft model, which simulates the space segment, including the space-to-ground link;
- an environment model, which calculates the positions of the relevant celestial bodies in relation to the spacecraft, as well as the position of the spacecraft in its orbit;
- a ground-station model, which simulates relevant equipment located at the ground stations, typically telemetry pre-processor, telecommand encoder and tracking systems;
- a communications interface between the simulator and the OCC's spacecraft-control computers;
- a simulator monitoring and control module, which provides the man/machine interface for the simulator operator and controls the other functional units.

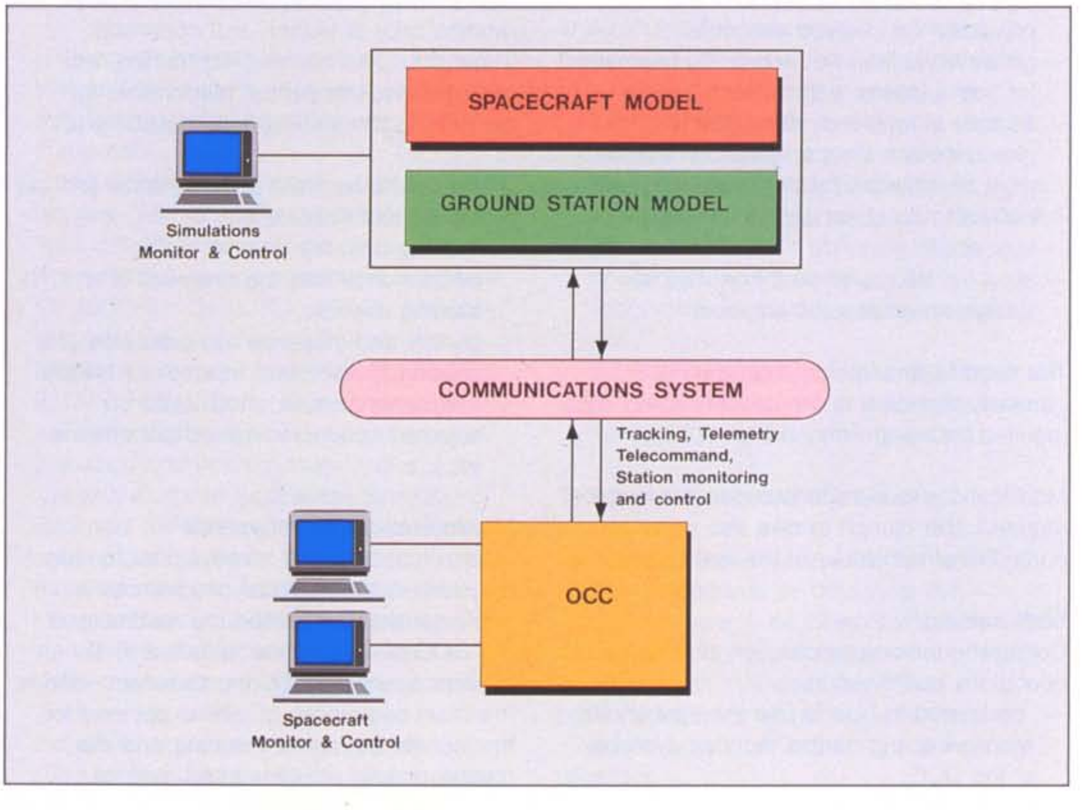


Figure 4. A typical simulation configuration at ESOC

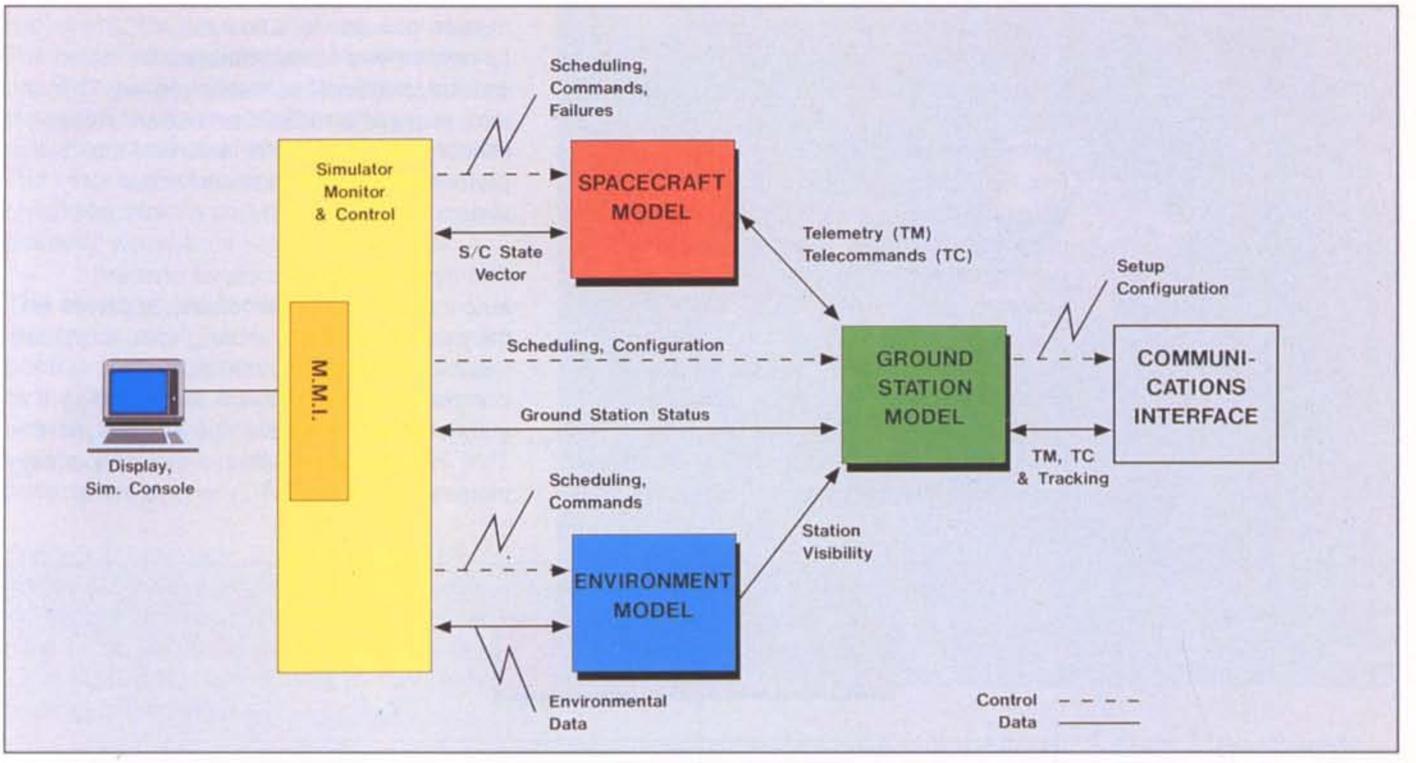


Figure 5. The architectural logic of ESOC simulators

The ground-station model, the communications interface and the simulator monitoring and control function are, to a very large extent, spacecraft-independent and therefore common to all simulators. It was therefore possible to group them into a standard package, which provides a general framework to all simulator designers and ensures that a certain level of commonality is maintained in the end-user interface throughout the various simulator implementations.

The General-Purpose Spacecraft Simulation Package (GPSSP)

The GPSSP's structure has been strongly influenced by the hardware and software architectures of the Gould family of computers, which have been used for simulator development and operation for almost 10 years. It provides the simulator developer with a set of program development tools, configuration utilities, prototype models and a run-time environment.

The program-development tools were originally implemented to supplement the limited facilities available on the simulations computers. Configuration utilities allow for the parameterisation required to support general models (e.g. telemetry encoding or telecommand decoding) and also provide standard facilities for configuring the data structures used by the run-time environment.

The run-time environment consists of a set of tasks and subroutines providing a basic architecture within which the environment- and spacecraft-specific models can be integrated. The following general facilities are supported:

— *Man/machine interface*, allowing the operator to monitor and control the status of the simulator, with telemetry parameters, simulator variables and event logs displayed in real time. Keyboard commands can be used to control the simulation and a graphics tool is available for offline evaluation of the data produced.

— *Interface for spacecraft-dependent models*, via a set of standard subroutines which can be customised by the simulator development teams and used to integrate spacecraft-dependent models within the GPSSP framework.

— *Master scheduler*, for controlling the timely activation of the various models.

— *Real-time maintenance and synchronisation*, for controlling the advancement of simulated time and ensuring synchronisation with real time.

— *Ground-station model*, which simulates the required mission-independent equipment and provides the communications interface to the spacecraft control computers. Limited mission-specific features may be introduced by customising some of the subroutines provided for this purpose. Major modifications, however, will usually require the development of a specific model.

The spacecraft model
Figure 6 shows the layout of a typical spacecraft model as implemented in most simulators. It closely reflects the standard decomposition of a spacecraft into subsystems.

Spacecraft subsystem models are usually implemented as subroutines within the GPSSP main task. The level of fidelity required for the simulation of any subsystem, and hence the depth of modelling, depends on how critical this subsystem is to the spacecraft's operation. The simulation of the radio-frequency, thermal and payload subsystems is usually straightforward. The complexity of the other models can vary greatly from one project to another.

The power model is usually fairly straightforward with respect to both power generation and distribution. In the case of ERS-1, however, an accurate power simulation had to be implemented which includes, in particular, a very detailed battery model. It is thus possible to validate the complex procedures for planning, monitoring and controlling the critical power resources onboard the spacecraft.

The Attitude and Orbit Control Subsystem (AOCS) is generally the most complex one to simulate. A realistic spacecraft dynamics model which simulates the effects of control and disturbance torques is required for all mission phases. All automatic AOCS functions need to be simulated for the various spacecraft operation modes. This, in turn, requires a realistic simulation of the sensor data, the control laws, and the performance of the reaction-control system.

The trend towards increased onboard autonomy, which is particularly apparent in the case of low-Earth-orbiting spacecraft, has resulted in a steady increase in the complexity of the onboard data-handling subsystems (DHSS) over the last few years. This, in turn, has resulted in a corresponding increase in the modelling requirements.

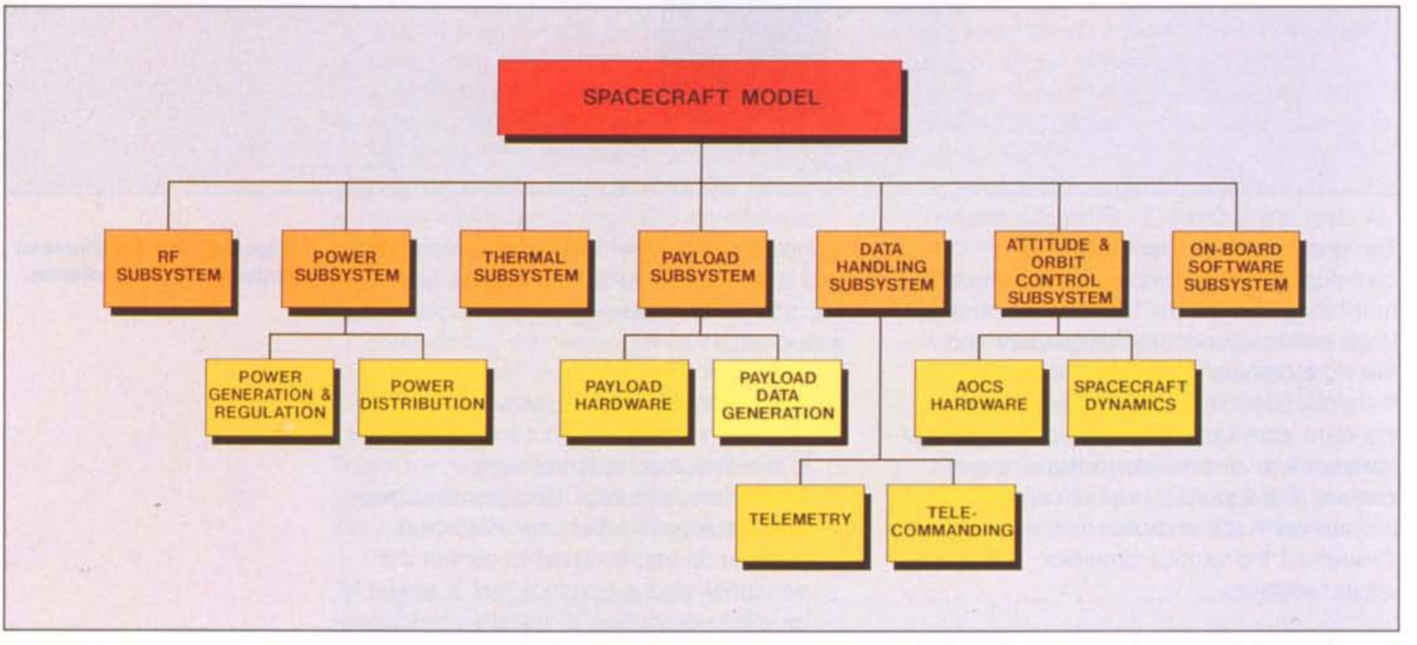


Figure 6. A typical spacecraft-model breakdown

Several options exist for modelling the DHSS and other onboard software subsystems:
- functional simulation: the relevant algorithms executed in the onboard computer are implemented as high-level language subroutines in the GPSSP. This approach has been used, for example, for the Hipparcos simulator (Fig. 7);
- software emulation: the instructions of the onboard software are executed by a program that emulates the onboard computer. This emulator is integrated into the simulator as a separate GPSSP task. This approach has been used for the Giotto and ERS-1 simulators;
- hardware emulation: a breadboard model of the onboard computer interfaced to the simulation computer is used to run the actual onboard software code. This approach has not yet been applied in the ESOC simulators.

The functional simulation is the simplest to implement, but it is also the least accurate. The two emulation-based implementations provide for very accurate simulations, but are expensive to implement. The software emulation requires a very powerful computer. The integration of an onboard-computer breadboard into a conventional ESOC simulator would be a very complex task.

The environment model

The environment model calculates the actual position of the spacecraft in its orbit, as well as the positions of relevant celestial bodies with respect to the spacecraft. Spacecraft visibility from ground stations is also considered.

Spacecraft orbits are usually modelled as simple Keplerian ellipses. Depending upon the mission, more complex models may be used which also consider perturbations (e.g. Earth oblateness and air drag for low-Earth-orbiting spacecraft).

Current limitations

For more than 10 years, the General-Purpose Spacecraft-Simulation Package has provided the simulator developer with a set of 'off-the-shelf' facilities for simulator monitoring and control and ground-station modelling. This has enabled him to concentrate his efforts on the spacecraft- and environment-modelling tasks, which has contributed significantly to reducing the development costs for new simulators.

Although the package has been constantly upgraded to reflect the continuous evolution that has occurred during recent years in the areas of spacecraft and ground-segment design, some limitations have appeared during the implementation of simulators for complex spacecraft like Eureca and ERS-1. They mainly concern the following areas:

Overall architecture

The GPSSP architecture is essentially centralised, providing a relatively rigid framework within which spacecraft subsystem and environment models are incorporated as subroutines with standard calling sequences. This approach is very efficient for spacecraft of low to medium complexity, where all spacecraft models can be implemented within a single task. For complex spacecraft, however, some of this efficiency may be lost, as limitations within the simulation computers impose a splitting of the various models into several tasks.

In addition, the increasingly decentralised approach being adopted for spacecraft design suggests that the design of spacecraft simulators should also be adjusted to reflect this trend.

photo: picture report

Figure 7. The Hipparcos satellite, for which functional DHSS simulation has been employed

Simulator development environment

Today's simulator development environment has been inherited from the past: it is essentially a Fortran-type environment with the most time-critical algorithms implemented in Assembler. The drawbacks of such an environment and its negative implications for software-development productivity and maintenance are well known. Current trends in onboard software development, particularly the use of well-structured languages like Ada, show the direction to be followed.

Simulator testing and validation

Testing and validation have always been a critical aspect of simulator development, due to the lack of a reference against which simulator performance can be measured. This applies particularly to simulators for complex spacecraft like Eureca and ERS-1.

A further complication results from the fact that, until now, the end-user has had to rely on the availability of the real spacecraft control facilities in order to perform acceptance testing on the simulator. This has introduced an undesirable coupling between two, in principle, independent software systems: the spacecraft simulator and the spacecraft control system.

Man/machine interface for simulator operation

The man/machine interface currently used for simulator monitoring and control, which is based on non-intelligent terminals with limited graphics capabilities, is no longer satisfactory by today's standards. Modern work stations with windowing and advanced graphics capabilities are now required to assist the simulator operator in the execution of his tasks.

Future developments

The developments currently foreseen in the simulator area are aimed at defining and implementing a state-of-the-art simulation package capable of satisfying the requirements for future simulators at a lower cost and without the limitations imposed by the current GPSSP.

To achieve this goal, the following activities are planned:

— Trade-off analysis of a centralised versus a decentralised architecture, taking into account the requirements for future simulators and the trends in spacecraft and ground segment design.

— Investigation of the suitability of modern software development environments for the development of spacecraft simulators, with Ada as a prime candidate.

— Implementation of a new simulation infrastructure in accordance with the results of the architecture trade-off and based on the software development environment selected. A work-station-based man/machine interface will be supported, which will provide all the necessary state-of-the-art facilities.

— Implementation of a consistent set of well-documented reusable spacecraft subsystem or unit models which, together with a standard environment model, should contribute to increasing the efficiency of simulator development.

The issue of simulator test and validation is not explicitly addressed by the above activities. The problems associated with a lack of test reference are not easy to overcome: the real spacecraft is only available for very limited periods of time, during which the main objective of any test is not to validate the simulator, but to ensure that the ground-segment facilities and the spacecraft are compatible. An interesting — but not straightforward — possibility for further investigation could be to use the satellite checkout equipment for simulator validation.

The use of the spacecraft control system can be avoided if the simulator includes an emulation of the required spacecraft monitoring and control facilities. This, however, is a very costly alternative and one that has not been considered so far.

Current planning foresees definition and implementation of the new simulator infrastructure within the next three years. The new man/machine interface will already be available by the end of 1990, allowing, retrofitting into existing GPSSP-based simulators if necessary.

Conclusion

Over the years, spacecraft simulators have proved to be very valuable tools for supporting the various mission-preparation and mission-operation related activities at ESOC. Since the first real-time spacecraft simulator was implemented in 1977, their scope of application has widened considerably. In addition to being the principal tool for Operations Control Centre (OCC) validation, they are now also being used for testing and validating flight-control procedures and for staff training.

Owing to the increasing complexity of future missions, the level of utilisation of spacecraft simulators is likely to increase further in the future. To support the requirements arising from this new generation of spacecraft, a new simulator infrastructure will be developed which will provide state-of-the-art facilities for cost-efficient simulator implementation and user-friendly operation.

The New ESTRACK Station at Maspalomas

C.M.A. van den Berg
ESA Stations and Communications Engineering Department, European Space Operations Centre (ESOC), Darmstadt, Germany

The inclusion of the Masplomas Station on Gran Canaria in ESA's Ground Station Network was recommended in late 1985. The initial phase in its implementation was completed at the beginning of 1989. The first mission to be supported will be the Agency's Eureca platform, but the station will also provide additional coverage for launch support and for future scientific missions.

There are many reasons for the choice of the Maspalomas site for the building of this latest ESA Ground Station. The need to support Eureca and the Inter-Orbit Communications (IOC) Experiment imposed geographical constraints. In addition, some coverage for transfer-orbit support was desirable.

The site's most important advantages are as follows:

1. It is a large area with a good basic infrastructure (Fig. 1). The greater part of the operations building consists of a large equipment room, which is divided into two sections. The south section contains the new equipment connected to the new 15 m antenna, and will also be linked to the IOC ground terminal during the Eureca-1 mission.

   The operations building also contains about twelve large offices, a canteen, a large tape-storage room, a photographic laboratory, stores, a screened room, an equipment repair room, and a conference room.

   A new power plant has been installed to improve the reliability/conditioning of the local power supply. Diesel generators provide a back-up supply.

2. It is a national facility on the territory of an ESA Member State. The site previously belonged to NASA and was used for the Mercury and Apollo projects. Thereafter, it was taken over by INTA (Spain) and has been used to receive signals from Earth-resource satellites (e.g. Landsat and Spot) via a 10 m S-band antenna. Substantial

basic knowledge and experience was therefore already available at the station. The existing INTA staff will now be gradually increased and further trained on the newly installed equipment.

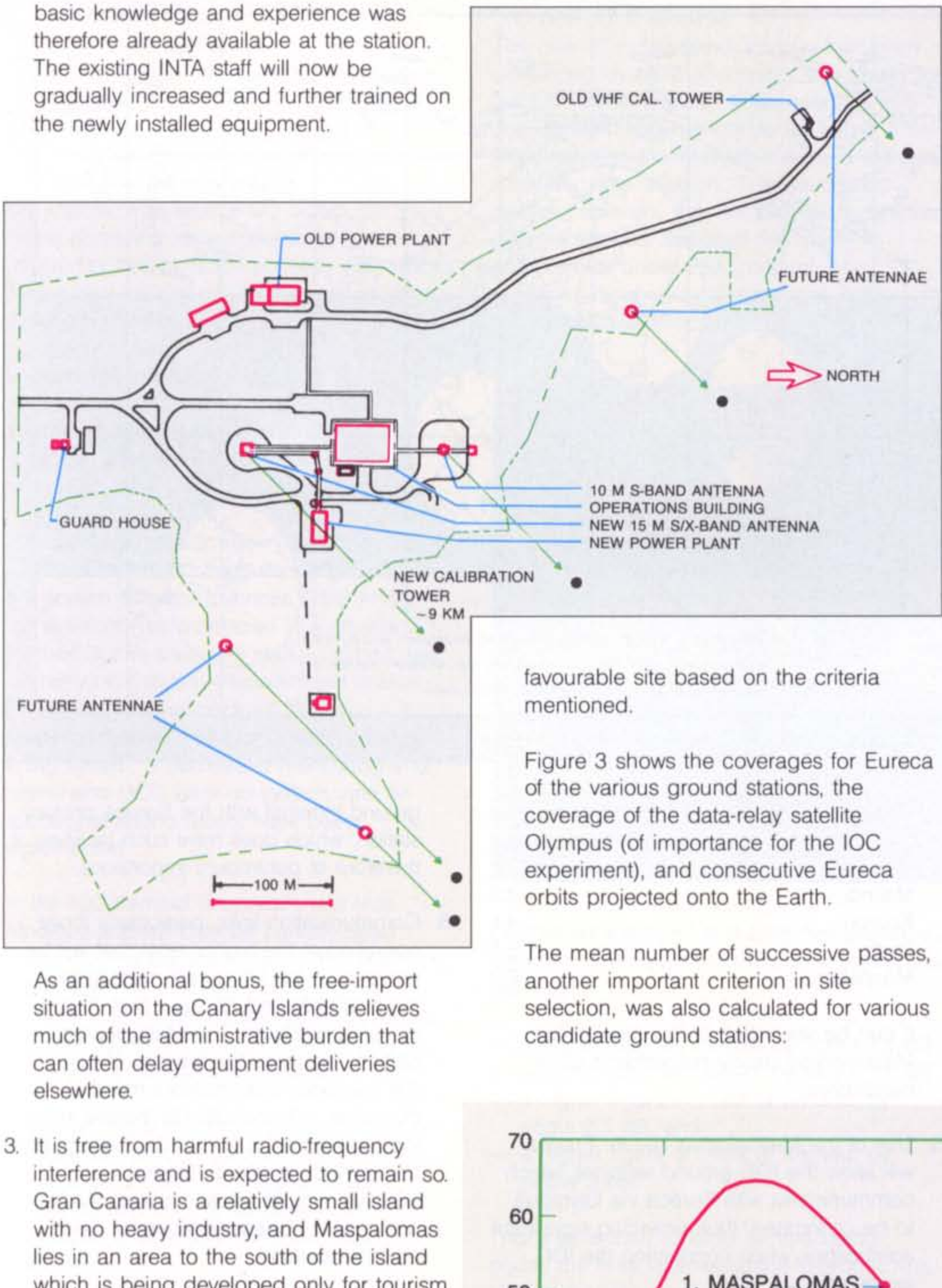


Figure 1. Layout of the Maspalomas site

As an additional bonus, the free-import situation on the Canary Islands relieves much of the administrative burden that can often delay equipment deliveries elsewhere.

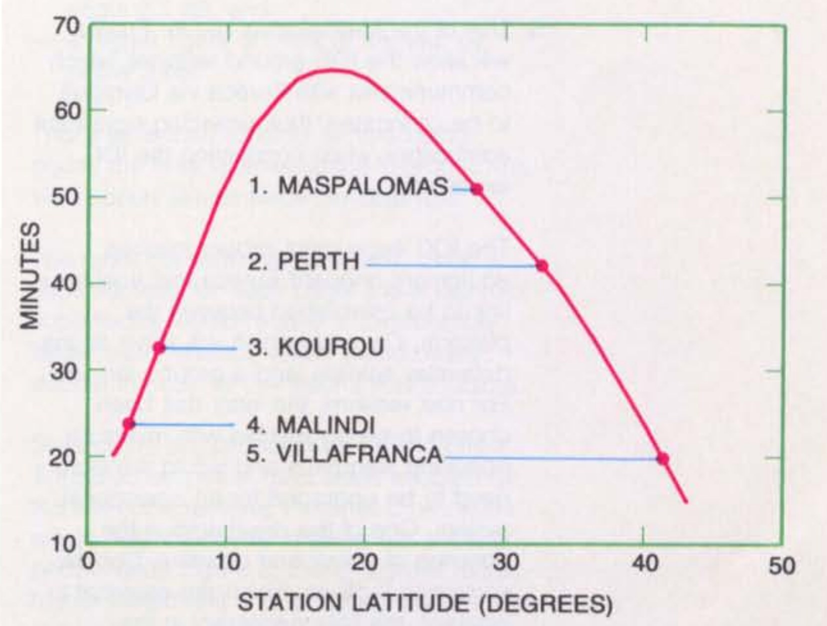
3. It is free from harmful radio-frequency interference and is expected to remain so. Gran Canaria is a relatively small island with no heavy industry, and Maspalomas lies in an area to the south of the island which is being developed only for tourism.

4. Its position at a latitude of 27.8°N provides near-optimum communications conditions for Eureca and its Shuttle-launched successors, which will be in near-equatorial orbits inclined at 28°. To ensure the safety of Eureca-type missions and to acquire a maximum of useful payload data, it is important that a site be chosen providing a sequence of long overflights for successive orbits. The average accumulated visibilities of Eureca from Maspalomas and some other candidate stations are shown in Figure 2. The latter shows Maspalomas to be a very favourable site based on the criteria mentioned.

Figure 3 shows the coverages for Eureca of the various ground stations, the coverage of the data-relay satellite Olympus (of importance for the IOC experiment), and consecutive Eureca orbits projected onto the Earth.

The mean number of successive passes, another important criterion in site selection, was also calculated for various candidate ground stations:

Figure 2. Accumulated sequential coverage for Eureca



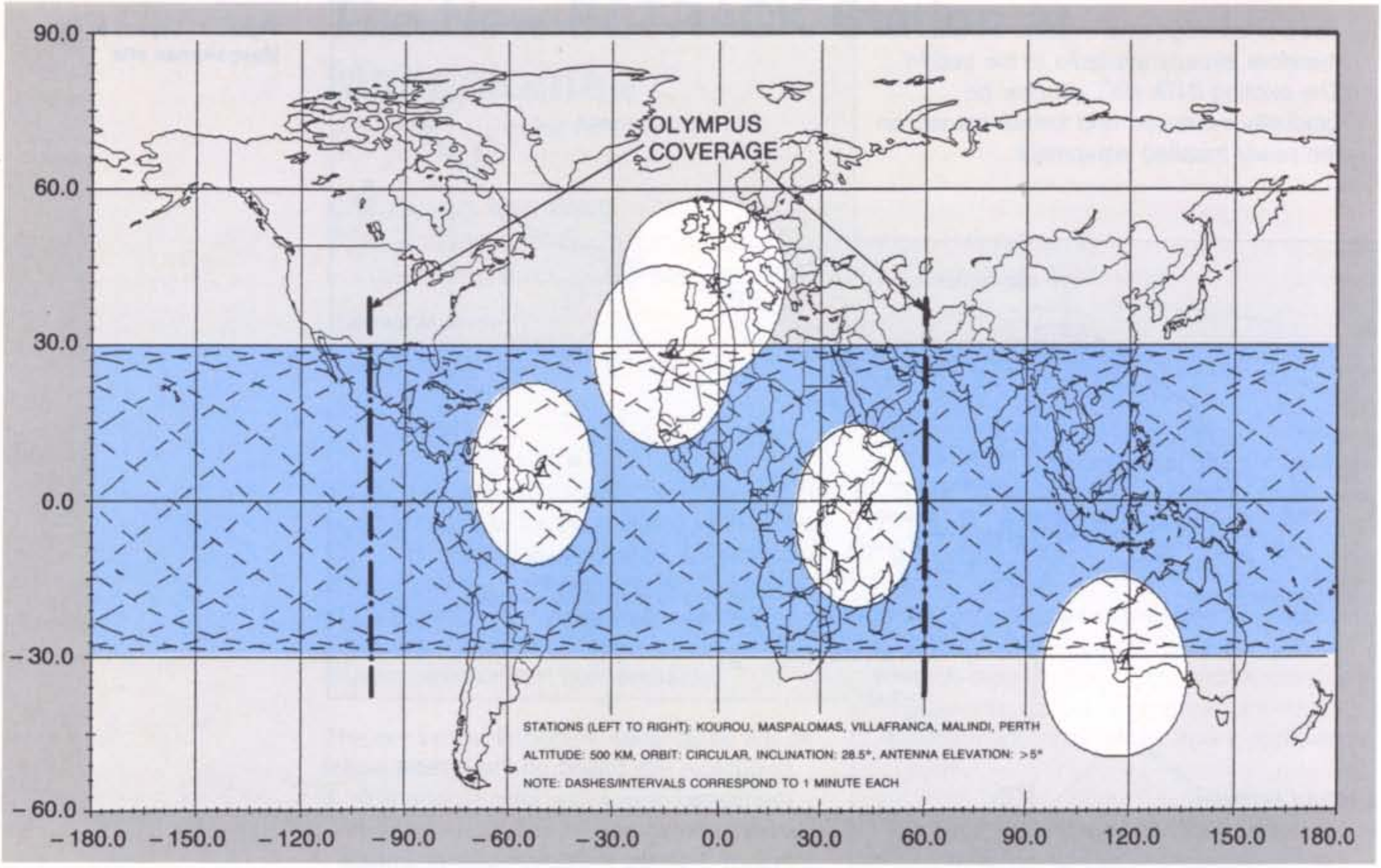


Figure 3. Ground-station coverage for Eureca

Ground Station	Mean number of successive passes
Malindi	3.3
Kourou	4.1
Perth	5.4
Maspalomas	6.2

It can be seen that, in this respect also, Maspalomas clearly outperforms other candidates.

5. Use of the Maspalomas site for Eureca will allow the IOC ground terminal, which communicates with Eureca via Olympus, to be co-located, thus providing significant advantages when conducting the IOC experiment.

   The IOC experiment proper involves equipment onboard Eureca that enables a link to be established between the platform, Olympus which will serve as the data-relay satellite, and a ground terminal. For cost reasons, the latter has been chosen to be compatible with minimum operating standards and would therefore need to be upgraded for an operational system. One of the drawbacks is the absence of uplink and downlink Doppler-correction facilities, which are essential to establish the links necessary in the operational system. Co-location of the IOC ground terminal with the Eureca primary station, which does have such facilities, is therefore of paramount importance.

6. Communication links, particularly those operating at the higher rates that will be required in the future, will need to be more reliable and cheaper than those currently available. The Maspalomas Station, being on the territory of one of the European Community's member countries, will undoubtedly benefit in the long run from the tremendous efforts now being made by the European telecommunications administrations to harmonise modern services for data communication.

7. Its position at 27.8°N is also advantageous for some of the Agency's future scientific missions, and for some of the operations envisaged in the context of the Columbus Programme.

   The Columbus Programme (see ESA Bulletin No. 56, pp. 10–18) requires global operations during the launch and early orbit phases. The Maspalomas location is particularly advantageous for this type of operation. Subsequent routine operations within the Columbus Programme will rely heavily on communications using data-relay satellites such as the future ESA

DRS system. A station like Maspalomas will therefore also be very useful as a back-up for the communications schemes envisaged, particularly during critical operations.

The new station equipment
The Maspalomas Station will initially be used as the primary Eureca operational ground station. For this, a radio-frequency (RF) link to Eureca and links from it to the ground, both at S-band (2 GHz), are required.

The ground antenna chosen is a 15 m dish (Fig. 4) manufactured by MBB/Krupp (Germany), and developed from those already in use elsewhere in the ESTRACK network.

The baseband equipment in the main equipment room is configured (Fig. 5) such that several different antennas (front ends) can eventually be interfaced in a standard manner. During the initial start-up phase, two telemetry chains, two telecommand chains, an communications node (X-25), an advanced multipurpose tracking system, a timing system, a centralised monitoring and control and OCC back-up system, and an operational testing facility have been implemented.

As the IOC terminal is operationally less important and will only be partially used during the first Eureca mission, the existence of two downlink and two uplink chains, together with the necessary signal switching and distribution facilities, provides a fully redundant system for that mission.

A new feature of the Maspalomas Station is the inclusion of integrated test equipment which, together with centralised station monitoring and control, facilitates the automation of extensive pre-pass testing, including:

- antenna performance checks using radio stars
- range calibration and integrated Doppler quality checking
- station configuration and data-flow testing
- technical performance checking, etc.

Ceselsa (Spain) was selected as the main contractor for the procurement, integration, commissioning and testing of the station. This company had no direct experience in this particular field, and therefore relied on the transfer of information from, and guidance by, ESOC throughout these phases.

The new 15 m antenna
The new 15 m S/X-band antenna has been developed by MBB (Germany) specifically for the ESTRACK network. A Cassegrain configuration has been adopted with a dual-frequency-band concentric feed and shaped main and sub-reflectors. The waveguide system, diplexers, etc. are provide by Spinner (Germany), who designed the main components under ESA contract. The antenna's mechanical construction is the responsibility of Krupp (Germany).

Figure 4. The new 15 m S/X-band antenna

Compared with S/X-band antennas available commercially elsewhere (outside Europe), this one has:

- a higher gain at S-band, by about 1.3 dB
- a higher gain at X-band, by about 1.7 dB
- a higher figure of merit at S-band, by about 2.5 dB, and
- a higher figure of merit at X-band, by nearly 3 dB.

This means that, all other factors being equal, the Maspalomas space-to-ground link will support almost twice the data rate.

The more conventional approach, using a separate feed for each band and a dichroic subreflector, would require a considerably larger main reflector, which would nearly double the cost of the mechanical structure.

State of the art, uncooled FET (Field-Effect Transistor) amplifiers have been adopted for the low-noise receiver. Parametric amplifiers would only marginally improve the antenna performance (figure of merit), against much higher investment and operating costs and a reduction in reliability. The measured figure of merit (G/T) is 28.5 dB/K at S-band, and 38 dB/K at X-band, for antenna elevations of more than 10°.

The new antenna features an 'elevation-over-azimuth' mount, which does not allow the tracking of low orbiters passing almost directly overhead (antenna elevations close to 90°). For such passes, the antenna has to rotate by 180° in azimuth very quickly. Except for a negligible number of cases, this deficiency has been solved by using programmed antenna steering making use of the fact that the antenna receives signals within a cone rather than from a single point. Moreover, a fast-moving spacecraft passing directly overhead is much closer than those for which the radio-frequency link is generally designed, thereby effectively widening this receiving cone.

The prediction of overhead passes, the switchover to programmed steering, and the programmed steering itself are performed by a newly developed Front-End Controller (FEC). This Controller is capable of calculating azimuth and elevation data for spacecraft using state vector and other parameters.

The new 15 m antenna's servo system allows high slew rates and accelerations:

Azimuth:	15°/sec	7.5°/sec^2
Elevation:	5°/sec	2.5°/sec^2

The downlink baseband equipment
The downlink demodulation equipment (Fig. 5) handles two main modulation schemes; those whereby a portion of the carrier is left in, and those whereby no carrier is present in the downlink spectrum.

Both schemes are to be used with Eureca, the first for communicating with the Space Shuttle, and the second as the nominal mode during the mission. The second scheme, with no remnant carrier present, is new for ESTRACK stations and requires the implementation of a different autotracking mode and carrier-restoration process for signal-demodulation purposes.

MBB has developed a new tracking receiver which employs a cross-correlation tracking mode with which Eureca can be automatically tracked in suppressed carrier mode. Satellites International Ltd. (UK) was chosen to develop the demodulator to handle BPSK (Binary Phase-Shift Keying), QPSK (Quadrature Phase-Shift Keying), and UQPSK (Unbalanced Quadrature Phase-Shift Keying) modulation schemes, conforming to the ESA Radio-Frequency and Modulation Standards.

A second type of demodulator is provided to handle 'classical' subcarrier telemetry. This

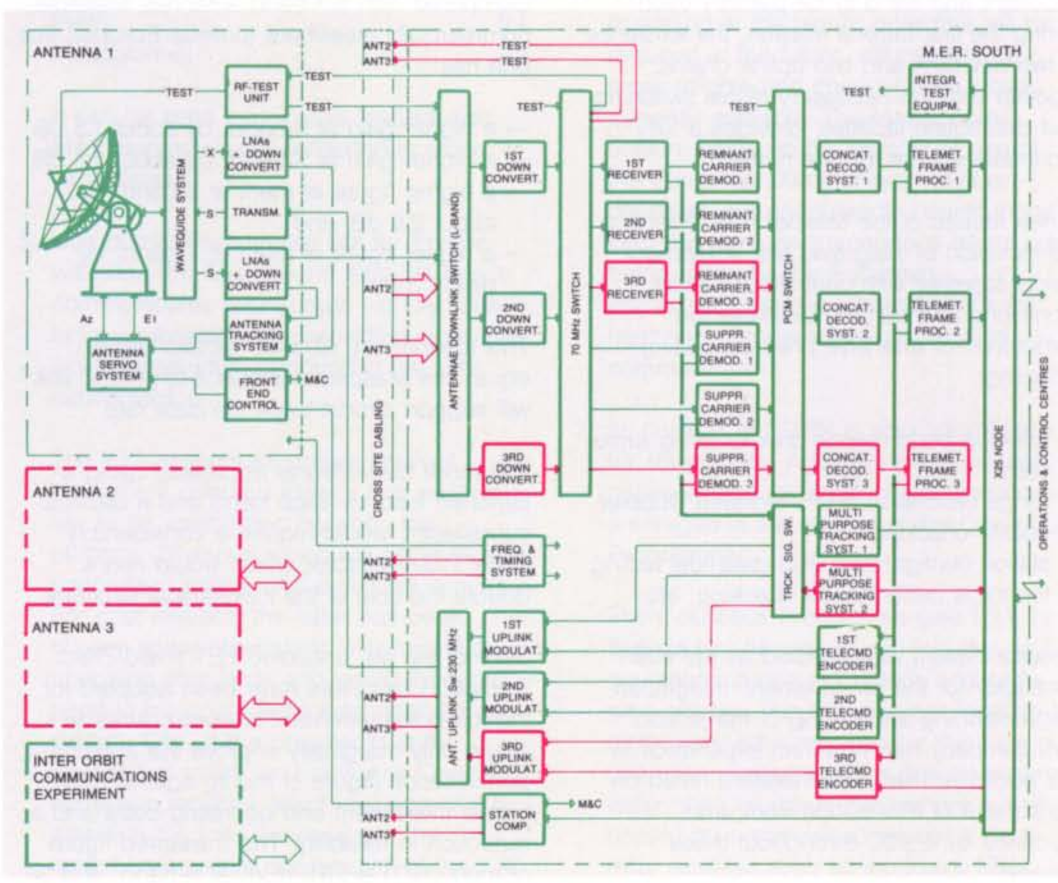


Figure 5. Block diagram of the Maspalomas Station

remnant carrier demodulator has been developed by Bell (Belgium) to function with the extremely poor signal-to-noise ratios found with encoded data. It is an improved version of the 'High-Performance Demodulator' used during the Giotto project.

The outputs of both types of demodulators are connected to concatenated decoder systems for decoding sequentially encoded data with different encoding schemes. Both demodulators provide signal-quality information which can be used by the decoder to optimise the decoding. The concatenated decoders, from CRI (Denmark), are capable of decoding two sequentially applied encoding schemes as defined in the ESA telemetry coding standard.

The concatenated decoders are connected in turn to telemetry frame processors, the output of which is connected to the standard ESTRACK X-25 communications network.

The MK III telemetry frame processor adapted for the Maspalomas Station by Ceselsa (Spain) has the following new features:

- It handles and stores packetised telemetry data.
- It implements all but one of the communications levels recommended by the International Standards Organisation (ISO) for Open Systems Interconnections (OSI).

The uplink baseband equipment
New command encoders for packetised uplink telecommanding will be available by late-1989. Autonomous checking of the link conditions will be one of the functions of this new equipment.

The ground communications node
ESA uses a private X-25 communications network to link its ESTRACK ground stations with its Operations Centre (ESOC) in Darmstadt (Germany) via leased lines. A new node has therefore been installed at the Maspalomas Station, using equipment supplied by SESA (France).

The multipurpose tracking system
A range and Doppler tracking system has been installed for orbit-determination purposes. This multipurpose tracking system is a further development of the Deep-Space Tracking System (DSTS) developed by ATNE (France) for the Giotto project. It is capable of handling signals with fast-changing Doppler and gives faster acquisition times, so that low-orbiting spacecraft can now be handled by the same system.

The reference-frequency and timing system
This system, supplied by Oscilloquartz (Switzerland), uses a caesium frequency standard, which has a high long-term stability, but lower short-term stability. Good short-term stability is important primarily for achieving the station carrier phase noise specification. The caesium frequency standard has therefore been 'cleaned up' using a high-performance tracking oscillator developed by Oscilloquartz. The output frequency has the long-term stability of the caesium standard, combined with the short-term stability and phase noise of the best quartz oscillators.

Time setting, time drift and caesium-standard quality checking are performed using the American satellite-based Global Positioning System (GPS).

The central monitoring and control, OCC backup and operational test facility
At the Maspalomas Station, this standard ESTRACK facility has been extended to include automated pre-operational testing, by employing many integrated test aids, both in the main equipment room and on the antenna itself. This avoids the many local manual operations that would otherwise be necessary, allows potential operational problems to be detected more quickly, and simplifies fault finding.

Conclusion
The equipment installed at the Maspalomas Station generally represents 'state of the art' technology. The extensive use of digital signal-processing techniques results in negligible losses in the space-to-ground links. The use in the ground network of the X-25 data communications standard, in combination with the installation of the ESTRACK network node at Maspalomas, ensures reliable communications between Gran Canaria and the Agency's Operations Centre at ESOC in Darmstadt.

Powering ESA's Spacecraft

D. O'Sullivan
Power and Energy Conversion Division, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

The unique feature of the majority of spacecraft power-system designs is the need to provide continuous power to the spacecraft's payloads and service subsystems in an environment where the power source (usually a solar array) is routinely interrupted by the passage of the Earth between the satellite and the Sun (eclipse).

Other mission features, such as degradation of the solar array due to its bombardment by space radiation, tilting of the array with respect to the Sun, and widely fluctuating load consumption, are drivers in the definition of the 'ideal power system' for a particular mission.

Reliability is also an essential parameter in the choice of a power system for a spacecraft, which may be required to operate autonomously for up to a decade. The system must be able to cope with payload and nonessential-equipment failures and safely recover normal operation with a minimum of disturbance to the spacecraft.

Introduction

Every spacecraft power system consists of five basic elements:
- energy source: usually a solar array, sometimes a radio-isotope generator (RTG);
- energy storage: mainly nickel-cadmium or nickel-hydrogen batteries, used to provide basic power in eclipse or peak power in sunlight;
- power control unit: power electronics required to manage and regulate the system;
- power distribution and protection: switchgear and protection devices;
- secondary power conversion: converters associated with particular subsystems and payloads.

As with most engineering choices, there are many ways of achieving the basic objective of providing power to a given satellite using the above elements. The purpose of this article is to attempt to illustrate how the goals are met using modern power-system design techniques which, as we will see, are radically different from their relatively straightforward terrestrial counterparts. In fact, spacecraft power electronics are frequently at the forefront of the majority of new control concepts being applied in terrestrial systems.

Orbit basics

The key problem to be solved in the power-system design is associated with the charging and discharging of the satellite's batteries, and the type of orbit has a major role in determining how significant a task this is.

Orbits are largely grouped into four main types:
- Low Earth Orbit (LEO): near the Earth, with eclipses lasting about 0.5 h during each 1.5 h orbit;
- Geostationary Orbit (GEO): 36 000 km above the Earth, with a 1.2 h eclipse for a 24 h orbit;
- Highly Elliptical Orbit (HEO): perigee near Earth, apogee far removed, and variable eclipse/orbit ratios;
- Deep-Space Orbits: few eclipses, but large variations in solar energy.

Of the above, the LEO is unique in its high eclipse-to-sunlight ratio (about 30%), all others giving a relatively short time in eclipse compared with the orbital period. The impact for a LEO power system is therefore unique in that a 0.5 h heavy discharge must be replenished in a period of less than 1 h. This inherent high charge rate and associated high power requirement call for a very careful design approach, since the batteries are usually essential to mission success in such an orbit. Moreover, the method of charging significantly affects the size of the solar array needed.

The other orbits, whilst less demanding, involve varying degrees of difficulty depending on the eclipse operational requirement (e.g. reduced or full power needed in eclipse) and the power level and reliability requirements imposed by the mission.

Mission types
Again, the various missions can be loosely grouped into five basic categories:
- Science: various orbits, and power-level needs of between 200 W and 1.5 kW. Scientific requirements can have major impact on power-system choice. Payloads calling for extremely low electric, magnetic and electromagnetic fields, for example, can result in the rejection of conventional power-regulation schemes (e.g. pulse-width modulation), materials and components (e.g. nickel-cadmium batteries and relays).
- Telecommunications: GEO orbits, full telecommunications in eclipse at power levels up to 3 kW, or direct television broadcasting with low eclipse powers (circa 500 W) but high sunlit powers of up to 10 kW, and sometimes a combination of both!
- Earth resources: LEO orbits, high powers (circa 6 kW), with high peak power requirements of up to 10 kW and high stresses on batteries, which are key elements in determining mission lifetime.
- Meteorology: GEO orbits and power needs of between 300 W and 1.5 kW.
- Manned missions: LEO Space Station, laboratory or manned-vehicle applications with power levels in the range 3—30 kW. These missions also impose severe reliability, safety and maintenance requirements.

Energy source and storage characteristics
To understand what the power-system task really involves, it is essential to provide a brief resume of the characteristics of the basic elements used in system design:

Solar arrays
Taking a grossly simplified equivalent-circuit model of a solar array as our example (with a current source feeding a 'diode' type of characteristic, with some imperfections simulated with resistors), the current delivered is essentially proportional to the solar energy received by the array. It will therefore vary with:
- the angular pointing of the array with respect to the Sun (cosine factor)
- the distance between the Sun and the spacecraft (especially important for deep-space missions — inverse square law),
- the radiation damage experienced by the array(s) (cumulative with lifetime).

The current produced therefore exhibits large variations during the mission lifetime. Similarly, the voltage characteristic is logarithmically dependent on the current. Perhaps the most significant factor affecting this characteristic, however, is the array temperature, which is spacecraft thermal- and configuration-design dependent (spinning or three-axis-stabilised spacecraft, etc.) and in the case of deep-space programmes is drastically affected by the variation in Sun-to-spacecraft distance.

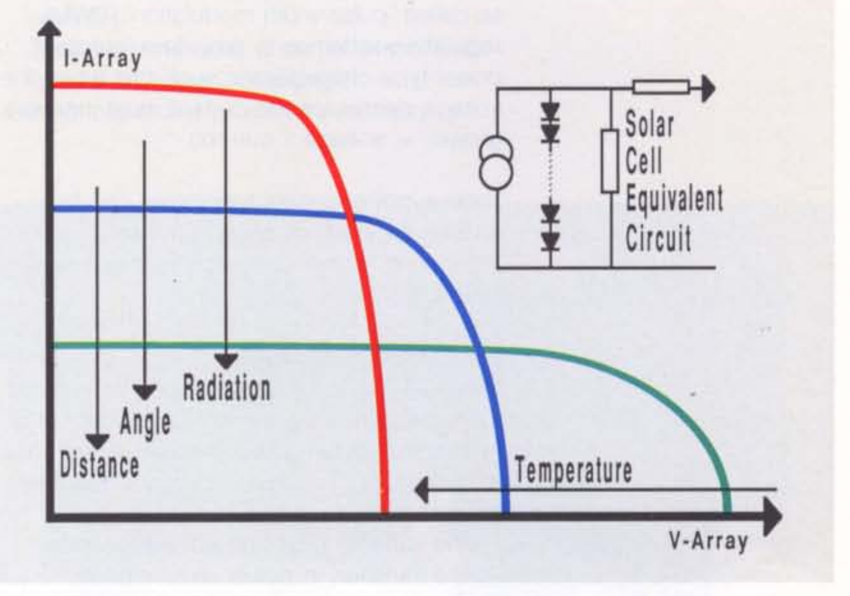


Figure 1. Solar-array characteristics showing the relationships between array power, current and voltage

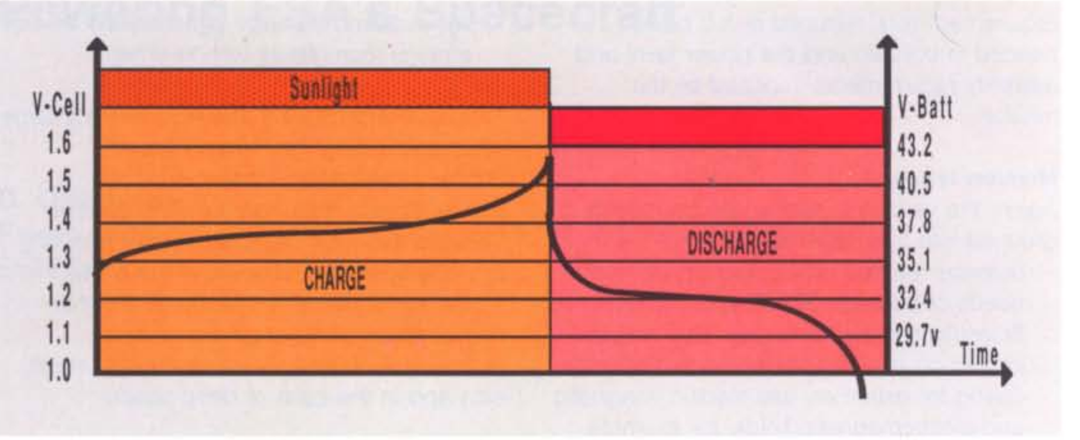
Hence the solar array, whilst being a convenient source of energy, requires a significant power-regulation effort, either at system level or by the spacecraft subsystems and payload equipment.

Batteries
As might be expected, the batteries also pose a problem for the system designer, since the battery voltage characteristics are heavily dependent on the mode of operation, namely charge or discharge.

A typical battery charge/discharge profile is shown in Figure 2. This 'typical' curve is further affected by battery temperature, charge and discharge rates and lifetime.

Subsystem and payload converters
Power converters fall into two basic categories; those that convert directly using fixed-ratio DC/DC converters and those more sophisticated types that can tolerate a variation in input voltage. The latter rely on

Figure 2. Battery charge/discharge characteristics



so-called 'pulse-width modulation' (PWM) regulation schemes to provide a 'constant' power-type characteristic such that when the voltage decreases the current must increase (power = voltage x current).

Various power-system topologies can be chosen for each of these converter categories, further complicating the overall situation.

Power-system topologies

Given all the variables described above and the significant weight involved in power-system components, each power system has to be largely custom-configured for each mission, due to:

- the variable orbit and eclipse periods;
- the variation in power requirements (hundreds of watts to tens of kilowatts);
- the payload requirements (scientific, telecommunications, Earth resources, manned vehicles, etc.).

The various elements of the system outlined above have to be grouped together to form a power network or so-called 'power bus' rather like, though much more sophisticated than, the electrical system in a car. The solar-array and battery energy sources are associated with power controllers, regulators and converters, such that power is delivered to the user points in an acceptable form, whilst ensuring the management of the energy flow both in sunlight and in eclipse.

Figure 3. ESA's Ulysses spacecraft, powered by a radio-isotope generator (RTG) (lower right)

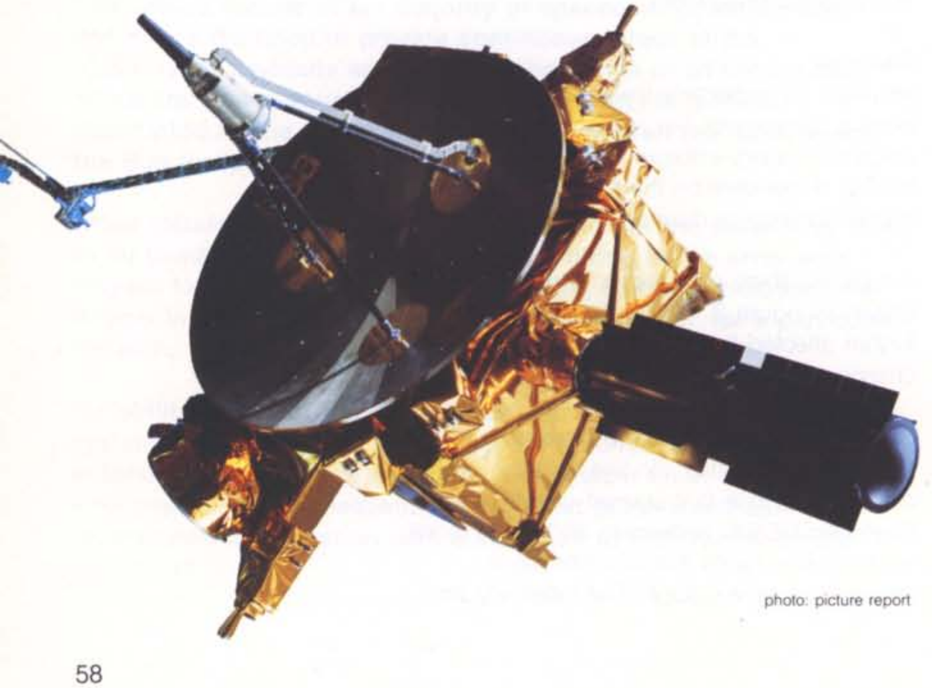


photo: picture report

In some systems, the emphasis is on minimising the mass of the centralised power system (associated with the solar array and battery management), leaving the user to cope with the wide variations in power characteristics, requiring the use of complex PWM converters. This so-called 'unregulated power bus' approach is mainly used only for LEO applications, where the addition of power regulators, with a power level equivalent to the total bus power, has major mass impacts (especially the Battery Charge Regulator, or BCR).

Alternatively, the regulation of the power bus (or busses) can be performed centrally, with two basic objectives in mind:

- optimisation of solar array and battery design;
- simplification of the user interface, in the interests of simpler converter design, greater standardisation of equipment, and simpler electromagnetic-cleanliness control aboard the spacecraft.

Essentially, the major mission variability affecting the user is the variation in bus voltage. During sunlit operation, this is dependent on the variation in voltage from the solar array. The simplest method of regulating out this variation is to shunt (or bypass) the current source, so that the resulting net current exactly matches the load demand.

Similarly, in eclipse operation from the spacecraft's batteries, the variation in battery voltage during discharge must be eliminated from the power bus by the addition of a battery-discharge regulator to maintain a constant voltage.

In addition, the task of replenishing the spacecraft's batteries in sunlight must be accomplished with a changing battery voltage characteristic during the charging process, absorbing power-bus current and, at the same time, maintaining the bus voltage regulation. This function is performed by the battery charge regulator.

Again, as in the case of the payload and service converters, there are dozens of competing approaches for tackling each regulator function.

In 1977, a major breakthrough in power-regulator design was made when it was discovered that by incorporating a so-called 'inner current feedback' or 'conductance control loop', power modules could be paralleled like building blocks, resulting in simple control-loop design and improved dynamic performance. The three-domain (shunt, battery-charge and battery-discharge) control system that this makes possible results in a power bus that is always capable, irrespective of Sun/eclipse status, of delivering peak power to the user. This type of system is suitable for all types of mission applications, although for LEO its use is limited (due to the high power-conditioning mass associated with that orbit) to applications where high-voltage power busses are required.

A further alternative is the sunlight-regulated power bus, in which the problem of regulation in eclipse is delegated to the spacecraft user, similar to the case of the unregulated-bus concept. This imposes the use of sophistocated PWM converters on all users of the bus, and is therefore not ideally suited to full-eclipse operation.

A 'hybrid power bus' has also been developed, to bridge the gap between the regulated-bus and unregulated-bus approaches, specifically to meet the requirements of LEO applications. In this case, about 50% of the solar array is connected to a regulated bus, while the remaining array sections are dedicated to battery charge control (thereby replacing the battery-charge regulators used in the regulated-bus scheme).

The dilemma of choice

The many mission, orbit and payload requirements, combined with the available power-bus configurations and the vagaries of human preference and experience, imply that the probability of two system designers agreeing on the same concept is not always very high.

LEO applications

As a rule of thumb, for each kilowatt of power required by the spacecraft loads, the power to be handled by each of the power-system elements can be broken down as follows:
— 1 kW discharged from the batteries;
— 1 kW to recharge the batteries (caused by relatively low energy-cycling efficiency of batteries);
— 2 kW from the solar array (of which 1 kW is used for battery charging);
— 2 kW capability for a shunt regulator.

photo: CRC, ottawa

Figure 4. One of the two large solar arrays for ESA's 'Olympus' telecommunications satellite

A regulated power system would require a total of 4 kW of power-conditioning equipment for each 1 kW of load, versus 2 kW for a 'normal' GEO application. Hence this topology is only selected when specific requirements dictate it, one example being the need to provide a high-voltage (120 V) power bus whilst maintaining relatively low battery voltages. A similar use is justified when the designer wishes to allow changes in battery configuration or technology by buffering the batteries from the bus by means of a battery regulator unit.

The two real contenders for LEO missions are:
— the unregulated power bus;
— the hybrid power bus.

The apparently obvious choice here is the unregulated scheme, where the main advantage lies in the fact that there is little power conditioning involved (2 kW for each kilowatt on the bus, as normally only a shunt regulator is employed for battery-charge control). However, this also has an inherent drawback when more than one battery system is required, as it is not possible to guarantee that parallel battery operation will be successful, and it is difficult to manage batteries individually.

A further disadvantage of such a choice is that pulsed power loads cause conducted noise that has to be tolerated by all bus users, including the service equipment. This tends to complicate the design of the user equipment, not least through the need to use complex PWM-type converters.

Figure 5. Nickel-cadmium batteries for the Olympus spacecraft

The hybrid power configuration has some of the sophistication of the regulated-bus concept and hence increased mass (3 kW of power conditioning for 1 kW of load), but it allows optimum use of the solar arrays (as 50% of them work at fixed high voltage), allows individual battery management, allows the number of battery cells to be varied ('linear' battery mass adaptation to load), provides a regulated bus interface (hence simpler power converters) to service and static payloads, and allows access to the batteries for pulsed power loads, such as radars, etc., hence simplifying EMC control.

GEO applications

Here again a difficult choice exists, but the main contenders can be reduced to:
— a sunlight-regulated bus;
— a regulated bus.

Again it is tempting to choose the configuration offering the simplest hardware, namely the sunlight-regulated concept. Elimination of the battery-discharge regulator is as an immediate gain, giving a typical mass reduction of 6 to 7 kg/kW of load power.

However, like all good things in life, they have to be paid for somewhere, and in this case it is the service equipment and payload converters that have to accept the unregulated interface in eclipse. This imposes a need to use more complex and heavier PWM-type converters, giving a mass penalty of 8 to 10 kg/kW of load power, with a further factor for equipment redundancy.

To avoid a phenomenon called 'power lock-up' with this configuration, the solar array needs to be oversized by about 18%, giving a mass penalty of 13 kg/kW of bus power. In a sunlight-regulated scheme, where there is one battery per bus, the number of cells is fixed and dictated by the bus voltage specification. The only method of battery optimisation is therefore one of custom-building battery cells to a specific cell capacity. The mass penalty here can be anywhere between 5 and 20 kg/kW of bus power.

The regulated-power-bus concept has the following unique advantages:

— peak power in excess of array capability can be delivered via the battery-discharge function, hence allowing the size of the solar array to be minimised;
— energy matching of batteries to eclipse load demand can be achieved by varying the number of cells used (typically 20 to 30 series-connected cells), the choice of a standard range of cell capacities, and the number of batteries used (any number of batteries can be connected to a bus, since this set-up provides individual charge/discharge management);
— user power converters can be of the simple DC/DC-converter type (lighter, and absence of overvoltage failure modes).

Optimum power-system selection

Although many performance criteria may be used in making the selection between viable alternative concepts (mass, efficiency, reliability, etc.), the majority can be translated directly or indirectly into mass or cost advantages or penalties. Realistic comparison is therefore only feasible when the total spacecraft system is included in the detailed analysis, and the efficiency and mass of each power-dimensioning element are taken into account.

As a typical example, a telecommunications payload may incorporate many different Travelling-Wave-Tube Amplifiers (TWTAs), powered by high-voltage power supplies (called EPCs) feeding antennas (which to further complicate life can be large or small!), and these are all powered from the spacecraft bus. For a certain requisite radiated signal power from the satellite, three parameters affect the power demand on the bus:

— antenna size and shape;
— TWTA efficiency; and
— EPC efficiency.

These equipment items in turn contribute to the effective mass per unit of power radiated to space:

— antenna mass;
— TWTA mass;
— EPC mass;
— batteries;
— solar array;
— power-system electronics.

When evaluating the optimum configuration for a given mission, the above mass and efficiency performances must be included in the power-system comparisons, with the ultimate objective of selecting the system yielding the lowest overall mass (since efficiency is translated into increased power/energy requirements, and hence can be represented by the equivalent solar-array or battery-mass increase).

In modern power-system design, therefore, this type of system-level computation can no longer be performed by simple hand calculation, due to the large number of system topologies, regulator alternatives, differences in payload converters (EPCs), and solar-array and battery technologies involved. Specialised computer programs are therefore being developed to provide accurate modelling of the efficiencies and masses of individual system components, such that a total system-performance criterion for each alternative system topology, with a given selection of equipment, can be established.

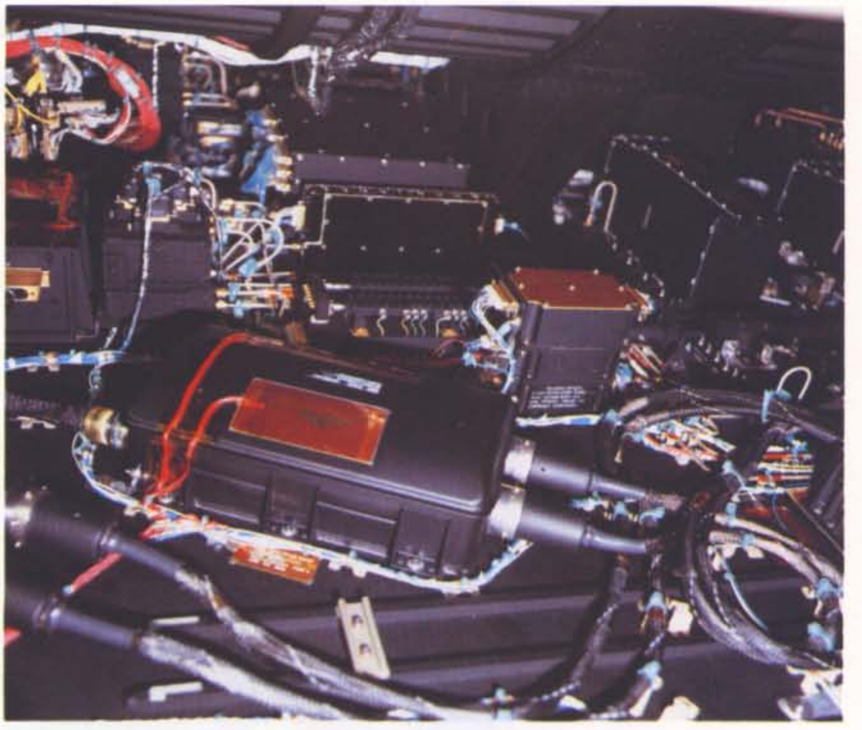


Figure 6. Electronic Power Conditioner (EPC) for a 230 W (RF) Travelling-Wave-Tube Amplifier (TWTA)

Conclusion

I have attempted to illustrate in much simplified terms how the task of optimally configuring a power system to meet the requirements of a specific mission is approached. Although many other inherent system and technology choices — such as solar-array and battery technology, alternative regulator concepts, resonant versus 'square-wave' converters, AC versus DC distribution, solid-state versus electro-mechanical switchgear, etc. — have scarcely been mentioned, it has hopefully been demonstrated that the choice of power system has major impacts on system mass and that each system therefore tends to be tailored to a given mission. It should also be evident that, with all the alternative options open to the designer, it is far from certain that any two designers will arrive at the same choice. The one major objective of all specialists in this field is to provide a common standard of interfacing for payloads and service equipment so that, although individual power levels or detailed configurations may be custom-trimmed, there will at least be a similar voltage specification for similar mission types.

Readers seeking a more detailed discussion on this topic are referred to the paper 'Satellite Power-System Topologies', in the latest issue of the ESA Journal (No. 89/2, June 1989).

Le 'juste retour': contrainte ou instrument d'intégration européenne?

E. Morel de Westgaver & P. Imbert
Bureau de la Politique Industrielle, Direction de l'Administration, ESA, Paris

Le 'juste retour' se définit comme le rapport entre la part de l'ensemble des contrats placés par l'Agence, attribuée à l'industrie d'un Etat et le pourcentage de contribution moyen de ce même Etat. Cette notion, qui n'existait pas lors de la création de l'ESRO mais qui a été retenue en 1968 lorsque le Directeur général a été conduit à garantir aux Etats membres un retour minimum de 70%, a bien sûr été reprise lors de la fondation de l'ESA.

Dans la Convention de l'ESA, le principe du 'juste retour' est traité brièvement au sein de l'article VII et d'une manière un peu plus détaillée dans l'article IV de l'Annexe V. Par contre, lors de la réunion du Conseil de l'Agence au niveau ministériel à La Haye en novembre 1987, les problèmes de politique industrielle, essentiellement axés sur cette notion de 'juste retour', couvraient un quart du texte de la Résolution qui a été adoptée. Cette simple comparaison montre l'importance grandissante du retour industriel au sein des activités de l'Agence.

Il apparaît donc utile de rappeler l'évolution qu'a connue, ces dernières années, le principe du 'juste retour', d'analyser les raisons de cette évolution et la méthode appliquée pour le calculer et enfin d'en voir les résultats concrets sur l'industrie européenne et sur la gestion des programmes de l'Agence. Cet article, qui n'engage que la responsabilité de ses auteurs, porte sur des sujets qui font l'objet de fréquentes polémiques. C'est pourquoi, ces derniers reconnaissent par avance, qu'en dehors des aspects factuels, les considérations exposées ici ont pour but essentiel de stimuler la réflexion.

Evolution de la notion de 'juste retour'
La Convention de l'Agence, approuvée en 1975, prescrit que 'tous les Etats membres participent de façon équitable, compte tenu de leur contribution financière, à la mise en oeuvre du programme spatial européen et au développement connexe de la technologie spatiale'. Cette notion de 'juste retour' est liée à une clause de préférence à accorder aux industries de l'ensemble des Etats membres mais dans un contexte de recours à l'appel à la concurrence, 'sauf lorsque cela serait incompatible avec les autres objectifs définis de la politique industrielle', ce qui est relativement vague mais semble cependant indiquer la préséance de la règle de l'appel à la concurrence.

De plus, dans le texte même de la Convention, la notion de 'juste retour' est subordonnée à la nécessité de 'répondre aux besoins du programme spatial européen .... d'une manière économiquement efficiente' et à la volonté d''améliorer la compétitivité de l'industrie européenne dans le monde'.

L'Annexe V à la Convention, qui traite de la politique industrielle, est cependant plus précise sur la notion de 'juste retour': la clause de préférence y est rappelée ; la manière dont la répartition géographique des contrats servant de base au 'juste retour' est calculée, y est brièvement décrite; le principe d'une pondération de la valeur de chaque contrat 'en fonction de son intérêt technologique' y fait l'objet d'une description plus détaillée que dans le texte de la Convention elle-même. Il est également précisé que 'la répartition des contrats passés par l'Agence doit tendre vers une situation idéale dans laquelle tous les coefficients de retour global sont égaux à 1'. La situation de la repartition des contrats fait l'objet d'examens formels tous les trois ans, qui peuvent conduire le Directeur général, si le coefficient d'un Etat membre est inférieur à 0,8, à faire des propositions visant à redresser cette situation particulière dans un délai d'un an. Ces propositions ne peuvent cependant déroger aux 'règles de l'Agence régissant la passation des contrats. Si, après ce délai d'un an, le déséquilibre persiste, le Directeur général soumet au Conseil des propositions dans lesquelles la nécessité de redresser la situation l'emporte sur les règles de l'Agence régissant la passation des contrats'.

Il ressort de ce qui précède que le 'juste retour' est, dans la Convention de l'ESA, un principe subordonné à d'autres objectifs techniques, financiers et économiques, qui ne peut conduire l'ESA à prendre des mesures exceptionnelles dans la passation de ses contrats que si le coefficient de retour d'un Etat s'avère être inférieur à 0,8 durant une certaine période.

Si l'on compare ces règles de base énoncées ci-avant avec celles actuellement en vigueur, qui ont été approuvées lors des réunions du Conseil tenues au niveau ministériel à Rome en 1985 et à La Haye en 1987, on constate que la notion de 'juste retour' a été profondément modifiée.

Dans la Résolution approuvée par le Conseil à Rome en 1985, il est demandé 'au Directeur général de prendre les mesures nécessaires pour parvenir d'ici la fin de la période triénnale (1985-1987) à une réduction substantielle des déséquilibres actuels dans la répartition géographique des contrats, dans le but de porter, d'ici à la fin de 1987, les coefficients de retour cumulés de tous les Etats à plus de 0,95'.

Par ailleurs, la limite de coefficient de retour au-dessous de laquelle des mesures de redressement de la situation doivent être prises et qui était fixée à 0,8 est portée à 0,9.

Pour le 'juste retour', qui doit toujours se rapprocher de la situation idéale, un objectif de 95% a été confirmé lors de la réunion du Conseil au niveau ministériel à La Haye. De plus, une garantie de retour d'au moins 90% est donnée aux Etats participant aux programmes facultatifs en cours et une compensation des déficits cumulés depuis 1972 est décidée.

On constate que, depuis 1975, le 'juste retour' et la notion d'équité entre Etats qu'il recouvre, sont devenus de plus en plus précis.

Il va de soi que cette évolution a eu certaines conséquences sur les modes de gestion de l'Agence, qui doit équilibrer la passation des contrats avec la contribution des Etats à 5% près.

Quels furent les moteurs de l'évolution de la notion de 'juste retour'?

Si, lors du début des activités spatiales européennes dans les années 1960, l'intérêt majeur de la participation des Etats à ces programmes européens était de nature scientifique, on constate qu'au cours des années 1970, le rôle des programmes spatiaux, comme un des moteurs du développement technologique, a pris une importance grandissante. La notion de programmes d'application et l'ouverture progressive d'un 'marché spatial' au niveau mondial ont transformé le domaine industriel.

L'industrie spatiale, qui emploie plus de 30 000 personnes en Europe est devenue un secteur industriel important où la compétition devient de plus en plus vive.

L'esprit de pionnier a fait place à des notions de stratégies d'entreprise, et cela d'autant plus que de très nombreuses technologies développées trouvent une utilisation dans d'autres domaines où la compétition entre firmes est encore plus importante.

Figure 1. La réunion du Conseil à Rome en 1985

On peut remarquer, à ce propos, qu'une étude, menée en 1988 par l'Université de Strasbourg auprès de 67 firmes participant aux programmes de l'ESA, montre que les contrats spatiaux génèrent des effets indirects en termes de développement technologique, de nouvelles opportunités commerciales, d'amélioration des méthodes d'organisation et de compétence du personnel, estimés à plus de trois fois la valeur de ces contrats. Ces effets indirects, qui pour 20% se situent en dehors du domaine spatial, augmentent l'attrait des contrats placés par l'ESA et donc la volonté des Etats de voir l'industrie de leurs pays en obtenir leur juste part.

L'augmentation des dépenses de l'Agence, qui sont passées de 329 MUC en 1975 à 570 MUC en 1980, à 1205 MUC en 1987 et à un budget de 1687 MUC en 1989, donne à celle-ci une influence grandissante sur le plan de charge de nombreuses entreprises, qui se sont équipées pour pouvoir satisfaire ses exigences.

Cet accroissement des dépenses demande également que leur justification soit de plus en plus étayée afin d'obtenir des Etats un financement adéquat. Cela conduit bien entendu les Délégations de ces Etats à insister vigoureusement pour que leur industrie nationale obtienne une juste part de ces dépenses, car c'est bien souvent le retour industriel attendu qui est l'argument ultime utilisé pour convaincre les autorités nationales du bien-fondé de la participation de leur pays à un programme facultatif.

Si l'accroissement des montants en jeu dans le cadre des grands programmes constituant la future infrastructure spatiale en orbite a conduit les Etats à être de plus en plus exigeants en matière de retour industriel, le fait que ces retours soient cumulés depuis 1972 a également amené ces Etats à s'interroger sur le bien-fondé de règles conduisant à mesurer uniquement des coefficients de retour. En effet, un déficit ou un surplus exprimé en pourcentage peut paraître tout à fait raisonnable alors que le montant absolu que recouvre ce pourcentage peut être jugé inacceptable.

Les règles actuelles du 'juste retour' et sa méthode de calcul

Comme expliqué ci-avant, les règles définissant le 'juste retour' ont été modifiées au cours du temps. Il convient donc d'en rappeler les principes essentiels.

- Le retour géographique est un *retour industriel* et non pas financier. La valeur des contrats placés par l'ESA dans l'industrie, les universités et centres de recherche des Etats membres et associés est pondérée en fonction de l'intérêt technologique des tâches réalisées. Les coefficients de pondération qui ont été décidés par le Comité de la Politique industrielle (IPC) sont de 0, 0,25, 0,50, 0,75 ou 1,0 en fonction de la nature du travail. Si l'on observe la valeur des contrats placés de 1972 à 1988, on constate que la valeur pondérée de ceux-ci représente 86,6% de leur valeur non pondérée. Ce pourcentage montre que la pondération en fonction de l'intérêt technologique a un impact qui n'est pas négligeable.
- Le 'juste retour' est une *notion globale*. Elle couvre la participation à l'ensemble des programmes facultatifs et obligatoires de l'ESA. Le retour est cumulé depuis 1972 et exprimé en unités de compte courantes.
- Le calcul du retour géographique se fait *programme par programme* et ensuite les résultats de chaque programme sont additionnés pour définir le retour global.
- Pour chaque programme, l'on compare la valeur des contrats attribués à l'industrie d'un pays avec le *montant idéal* des contrats qui auraient dû être attribués à ce pays selon son taux de contribution au programme considéré. Ce montant idéal est calculé en multipliant la valeur totale pondérée de l'ensemble des contrats placés au titre de ce programme par le pourcentage de contribution de chaque Etat.

Au-delà des ces grands principes, la manière pratique, dont le retour industriel est calculé, découle des décisions prises à la réunion du Conseil à La Haye.

La première de ces décisions, qui a consisté à compenser les déficits de retour géographique constatés au 31 décembre 1987, a fait prendre conscience de l'importance de disposer d'un instrument de mesure fiable et précis, ayant une nature comptable et rendant possible le calcul de déficits et de surplus exprimés en unités de compte et non plus uniquement sous forme de pourcentages permettant une marge d'incertitude.

Ceci a conduit l'Exécutif à rechercher une nouvelle source d'information pour calculer le retour géographique. Celle qui fut retenue est la banque de données financières de l'Agence (EFSY: ESA Financial SYstem) où sont enregistrés l'ensemble des paiements effectués à l'industrie et des engagements encore à régler, qui sont la différence entre la valeur d'un contrat et les paiements déjà effectués par l'Agence au titre de ce contrat et qui représente donc une obligation de paiement futur sous réserve que l'industrie concernée respecte les termes du contrat.

Les avantages liés à l'utilisation d'une banque de données financières comme EFSY sont bien entendu la rigueur comptable et la tenue à jour en temps réel. Il convenait cependant, en utilisant ces données à une autre fin que la tenue de la comptabilité de l'Agence, de ne pas perturber sa fonction principale.

Il a donc été décidé de créer une banque de données qui soit une copie parfaite d'EFSY mais qui permette d'effectuer les calculs de retour géographique. Cette nouvelle banque de données intitulée SYSTRI (SYStème de Traitement du Retour Industriel), qui sera opérationnelle dans le courant de l'année 1989, contiendra l'ensemble des données financières disponibles dans EFSY mises à jour en temps réel et, en addition, certaines informations relatives à chaque contrat de manière à permettre son utilisation comme instrument de calcul du retour géographique.

Le logiciel nécessaire pour effectuer des regroupements de données, l'application automatique des coefficients de pondération, le calcul des montants idéaux et des coefficients de retour géographique est en cours de développement.

Cependant, au-delà d'un instrument fiable et précis, l'Agence se doit aussi de pouvoir effectuer des prévisions du retour industriel à l'achèvement des programmes en cours. Cette nécessité découle de la décision prise par le Conseil siégeant au niveau ministériel à La Haye de garantir un coefficient de retour au moins égal à 0,9 pour chaque Etat participant à un programme facultatif.

Pour être en mesure de prendre en temps utile les mesures qui s'imposent pour être certain d'atteindre cet objectif, il convient de connaître les problèmes éventuels lorsqu'une marge de manoeuvre subsiste encore dans l'attribution des contrats.

Tenant compte de cette nécessité, le Conseil a, lors de sa réunion du 16 décembre 1988, approuvé une proposition de l'Exécutif qui consiste d'une part à s'appuyer sur la banque de données financières EFSY pour le calcul du retour géographique et d'autre part, à établir une fois par an, pour chaque programme facultatif en cours, des prévisions du retour géographique à l'achèvement du programme.

L'établissement de telles prévisions n'est bien entendu pas une chose aisée lorsque l'on sait combien d'événements imprévisibles peuvent surgir durant l'exécution des programmes de développement spatiaux.

La méthode, qui sera suivie, s'appuie d'une part sur les informations techniques, de calendrier et contractuelles à la disposition des responsables de programme et d'autre part, pour les contrats qu'il est prévu de placer après compétition ouverte, sur une extrapolation de la réalité observée.

L'évolution dans le temps de ces coefficients, qui deviendront au fur et à mesure de plus en plus réalistes, sera un outil essentiel pour l'Agence, permettant par anticipation de prendre les décisions nécessaires pour diminuer l'ampleur des problèmes à venir.

Le 'juste retour' sera dans ce cadre non pas uniquement un outil d'observation de la réalité passée et présente mais également un outil de bonne gestion.

Evolutions envisageables
Après avoir passé en revue les règles actuelles en terme de 'juste retour' qui découlent de la réunion du Conseil de La Haye, il est intéressant de voir les problèmes futurs qui influenceront celui-ci.

photo: MBB/ERNO

Figure 2. Atelier de production du lanceur Ariane chez MBB/ERNO, RFA

Le premier de ces problèmes est le passage qui s'effectuera sans doute entre la procédure actuelle qui consiste à passer les contrats en monnaie nationale et une attribution de contrats libellés en ECU.

Si cette nouvelle règle était adoptée, l'utilisation des données EFSY, où le critère de nationalité du contractant ou du sous-contractant est la devise utilisée, devra être revue.

Cette évolution possible a déjà été prévue en donnant à chaque firme un code fournisseur qui servira de base à l'attribution du contrat ou du sous-contrat au pays où cette firme est localisée.

Le second problème, qui est plus délicat et ne peut être traité par une simple adaptation de logiciel, est celui de la nationalité des firmes.

Les regroupements, qui sont en cours au sein de l'industrie européenne par la création de groupes multinationaux, ont une influence grandissante dans l'industrie spatiale. Par ailleurs, de nombreuses sociétés actives dans le secteur spatial ont, ces dernières années — et ce mouvement s'accélère actuellement — soit acheté des firmes, soit créé des sociétés filiales dans d'autres Etats membres où, en application de la règle du 'juste retour', des opportunités d'attribution de contrat par l'Agence existent.

Cette évolution, qui peut remettre en cause la notion de nationalité des firmes auxquelles


photo: british Aerospace

Figure 3. Intégration du satellite de télécommunications Olympus chez British Aerospace, R-U

des contrats ou sous-contrats sont attribués, devra faire l'objet d'une étude et de prise de décision.

En effet, les critères de nationalité d'une société, qui figurent dans l'Annexe V à la Convention créant l'ESA, sont peu précis et sujets à des interprétations multiples. Ces critères sont les suivants: 'localisation de son siège social, de ses centres de décision et de ses centres de recherche, et territoire sur lequel les travaux doivent être exécutés'.

Une procédure représentant une sorte d''acceptation' de la nationalité des firmes devra sans doute être mise en place au vu des problèmes de plus en plus nombreux auxquels l'Agence est confrontée par la mise en cause par certains Etats de l'appartenance réelle à l'industrie de leur pays de firmes à capitaux étrangers.

Enfin, un des problèmes, auquel l'Agence est de plus en plus confrontée, est le désir des Etats de traiter individuellement le retour géographique de chaque programme. Cette tendance, qui est naturelle dans la mesure où, au sein de l'Administration de plusieurs Etats, les différents programmes de l'Agence sont suivis par des services, départements ou même par des ministères différents, se retrouve également au sein de l'Exécutif où les responsables de programme veillent en priorité à maintenir un retour géographique équilibré au sein du programme dont ils assument la responsabilité.

Lors du Conseil réuni au niveau ministériel à La Haye, il a été décidé, comme exposé ci-avant, de laisser à l'Agence une souplesse dans la répartition géographique de chaque programme (coefficient de retour garanti à 0,9) dans la mesure où cette flexibilité permettait d'atteindre l'objectif global de coefficient de retour de 0,95 pour l'ensemble des programmes.

Il n'en reste pas moins que cette tendance à 'l'insularité' de chaque programme existe et qu'elle risque de réduire la nécessaire marge de manoeuvre permettant à l'Agence de compenser sur un programme les mauvais résultats constatés pour un Etat dans un autre programme et ce, suite à des problèmes techniques, de coût ou de capacité industrielle.

Les résultats de l'application du principe du 'juste retour'

Après avoir passé en revue l'évolution du principe du 'juste retour', quelques raisons de cette évolution et la situation actuelle, il convient de s'interroger sur l'influence qu'ont eue les règles de retour géographique applicables à l'attribution de contrats par l'Agence sur l'évolution de ses programmes et de ses procédures contractuelles, ainsi que sur l'industrie spatiale européenne.

Il apparaît évident que la certitude qu'ont les Etats à voir l'industrie de leurs pays bénéficier d'un 'juste retour', a facilité la souscription de ces Etats aux programmes de l'Agence et a également permis, dans une certaine mesure, la croissance importante des programmes spatiaux si on la compare à celle des autres domaines de la recherche.

En prenant pour exemple les six principaux pays contributeurs aux programmes de l'Agence, que sont la France, l'Allemagne, l'Italie, le Royaume-Uni, la Belgique et l'Espagne, on constate que, de 1983 à 1987, la part des dépenses publiques de recherche attribuée aux activités spatiales civiles, passe de 3,74% à 5,54% de l'ensemble des dépenses publiques de recherche et de développement. Alors que l'ensemble des crédits de recherche de ces six pays ont augmenté de 8%, les crédits consacrés à l'espace civil ont cru de 60% en valeur constante durant cette période de cinq ans.

Ce résultat appréciable, qui montre dans ces pays une volonté politique de soutenir les programmes spatiaux, peut s'expliquer en partie par l'intérêt industriel et technologique des activités spatiales et, particulièrement pour les pays n'assumant pas la maîtrise d'oeuvre des grands programmes, par la certitude d'obtenir un 'juste retour' pour l'argent investi.

Les garanties de retour géographique ont également apporté une certaine souplesse dans les procédures suivies pour la passation des contrats par l'Agence. La sécurité introduite par des règles précises a fait accepter aux Etats de ne pas contrôler l'ensemble du processus de passation des contrats et de laisser à l'Agence la pleine responsabilité pour les contrats en dessous d'une valeur qui dépend du type d'approvisionnement. Une telle souplesse qui est garante d'efficacité et de rapidité ne serait pas possible si aucun 'juste retour' n'était assuré.

Pour l'industrie, les règles de 'juste retour' permettent d'étayer ses prévisions à long terme de l'évolution possible du plan de charge et donc de faire en temps utile les investissements nécessaires. Le 'juste retour' est donc un des facteurs qui a permis une croissance harmonieuse de l'industrie spatiale.

Il est clair que, dans les pays dont l'industrie n'assume pas de maîtrise d'oeuvre majeure, l'existence d'une industrie spatiale a reposé essentiellement sur la certitude des responsables et des actionnaires de ces industries que, sous réserve d'offre acceptable sur le plan technique et celui des prix, des contrats leur seraient attribués en application des règles de 'juste retour'.

Ces règles ont également contraint l'Agence à rechercher dans certains pays des compétences nouvelles dans la mesure où la capacité existante n'apparaissait pas suffisante pour assurer un retour en ligne avec l'augmentation des contributions nationales à l'Agence. Si l'on prend le cas de l'Espagne par exemple, on est étonné de voir comment, en une brève période, les créneaux techniques couverts par l'industrie espagnole se sont diversifiés à tel point qu'une firme est depuis peu le centre d'excellence de l'Agence en matière de mécanique orbitale, domaine qui semblait hors de portée de l'industrie espagnole il y a quelques années.

photo: SEP

Figure 4. Atelier de production de moteurs d'Ariane à la SEP, France

Cette recherche de compétence nouvelle a également permis à l'Agence d'éviter d'être confrontée à des situations quasi-monopolistiques dans certains pays qui auraient conduit les quelques firmes actives dans le domaine spatial à profiter des règles du 'juste retour' pour s'assurer des marges financières confortables.

Par ailleurs, la contrainte imposée au maître d'oeuvre de sous-traiter une part importante des programmes dont il a la responsabilité à l'industrie d'autres pays européens a limité la concentration de l'industrie spatiale. En l'absence de règles de 'juste retour', on peut imaginer que les activités industrielles spatiales en Europe se seraient naturellement concentrées dans une dizaine de sociétés, ce qui aurait rendu illusoire la participation de nombreux pays à l'ESA.

Les règles du 'juste retour' viennent également dans une certaine mesure compenser l'impact, sur la compétitivité relative des firmes, de l'existence ou non de programmes nationaux dans le domaine spatial civil ou militaire. La règle du 'juste retour' protège en effet l'industrie des pays n'ayant pas ou peu de dépenses nationales dans le secteur spatial, et qui ne reçoit pas de financement public pour son maintien à l'indispensable niveau technologique.

Cependant, il convient de s'interroger d'une manière plus générale sur l'influence qu'a le principe du 'juste retour' sur la compétition entre firmes européennes et donc sur le coût des projets spatiaux.

Si l'on observe les grands programmes facultatifs de l'Agence, on constate que, dans la plupart des cas, le choix du maître d'oeuvre et des principaux responsables de sous-systèmes importants a été fait en application d'une procédure de gré à gré. Les motivations d'une telle procédure relèvent peu du principe du 'juste retour' mais plutôt de critères politiques qui échappent en partie au contrôle de l'Agence.

Par contre, le 'juste retour' oblige ces industriels, choisis a priori, à sous-traiter une grande partie de la valeur du programme à l'industrie d'autres pays européens en recherchant toutes les compétences disponibles. C'est dans le cadre de cette sous-traitance que le 'juste retour' pourrait conduire à des abus de la part de firmes situées dans certains pays. Ce danger d'abus est tempéré, comme indiqué ci-avant, par l'augmentation du nombre de firmes actives dans le secteur spatial, mais il n'en demeure pas moins qu'un risque existe.

En tout état de cause, ce risque ne pouvant porter que sur une part relativement limitée des programmes, l'influence de ces abus possibles générés par les règles de 'juste retour' reste faible et représente peu de chose en regard des bénéfices que l'ensemble des pays européens retirent d'une politique spatiale coordonnée.

D'autre part, il est inévitable qu'un grand programme entrepris par une cinquantaine de firmes pouvant appartenir jusqu'à 15 pays différents coûte un peu plus cher que le même programme réalisé par quelques entreprises localisées dans un ou deux pays. Les dépenses d'interfaces et d'intégration et les coûts inhérents à la gestion augmentent l'enveloppe financière indispensable à la réalisation des programmes de l'Agence.

Il n'existe pas de données permettant de comparer les effets financiers respectifs du choix a priori des contractants principaux, des règles de 'juste retour' et des dépenses d'interfaces, d'intégration et de gestion dues à l'aspect européen des programmes.

On pourrait bien entendu rêver d'un monde idéal où aucune contrainte ne serait appliquée à l'Agence. Cependant, dans ce monde idéal, il y a de fortes chances, bien que leurs coûts soient légèrement diminués, qu'aucun des programmes proposés ne trouve de source de financement suffisante.

Figure 5. Réunion du Comité de Politique industrielle à l'ESTEC en janvier 1989

Enfin, l'évolution des activités de l'Agence, où les programmes obligatoires, à taux de contribution variant peu, ont vu leur importance relative diminuer au profit des programmes facultatifs, où les pourcentages de contribution varient fortement d'un programme à l'autre, a contraint l'industrie à se restructurer pour respecter les règles de retour géographique.

Si, dans le cadre des programmes obligatoires, les consortia européens étaient à même de soumettre des propositions acceptables sur le plan du 'juste retour', il n'en est plus de même dans les programmes facultatifs où, dans chaque cas, un groupe industriel ad hoc se forme. Cette évolution a amené les firmes spatiales à ne pas créer uniquement des liens privilégiés avec certaines firmes mais à diversifier leurs relations industrielles en fonction de la nature particulière de chaque programme.

Ce dernier élément est un important facteur d'intégration de l'industrie spatiale européenne. En effet, les firmes, qui sont pour la plupart d'entre elles concurrentes dans certains programmes et travaillent ensemble dans d'autres, ont dû harmoniser leur méthode de gestion, veiller à maintenir leur prix compétitif et acquérir la souplesse nécessaire pour s'adapter à un environnement changeant. On peut affirmer aujourd'hui que l'industrie spatiale est un des secteurs de l'économie où l'esprit européen s'est imposé.

Conclusion
La notion de 'juste retour' a évolué fortement depuis la Conférence spatiale européenne de 1973 à aujourd'hui. Le renforcement des règles visant à garantir un retour d'au moins 95% du montant idéal qui refléterait exactement le pourcentage de contribution de chaque Etat et un retour supérieur à 90% dans chaque programme facultatif, a conduit l'Agence à réformer sa méthode de calcul du retour géographique en recherchant plus de précision et à mettre en place un système de prévision à long terme.

Cette évolution vers des règles plus contraignantes est d'une certaine façon la rançon du succès des programmes spatiaux.

En effet, le développement d'une industrie spatiale, qui n'est plus un secteur marginal de l'activité industrielle, a eu comme corollaire une augmentation des enjeux qui président à la passation des contrats par l'Agence. De plus, la croissance rapide des budgets spatiaux — croissance plus rapide que celle d'aucun autre grand domaine de la recherche financée par des fonds publics — a conduit les Etats à être de plus en plus exigeants en matière d'équité des retours géographiques, ce retour géographique étant une des justifications majeures données à l'augmentation des budgets consacrés à l'espace civil.

L'industrie s'est adaptée à ce nouvel environnement plus contraignant. Si le rôle des consortia, qui ont présidé au démarrage des activités spatiales européennes, a diminué, les groupements 'ad hoc' qui se créent pour chaque programme facultatif sont un facteur important de l'intégration de l'industrie spatiale européenne. Cette adaptation de l'industrie spatiale s'est également faite par un élargissement des capacités industrielles de nombreux pays. La sécurité en matière de plan de charge apportée par le 'juste retour' a été un des moteurs de cette évolution.

Toute médaille a bien entendu son revers et les règles de retour géographique diminuent dans une certaine mesure la compétition au sein de l'industrie. Cette approche a pu générer des coûts supplémentaires, mais dont l'ampleur n'a jamais pu être définie avec certitude. Ces coûts supplémentaires peuvent être envisagés comme le prix à payer pour assurer l'intégration européenne. En considérant les succès des programmes de l'ESA en regard des budgets dont elle dispose, on peut estimer que ce coût n'est pas excessif.

Au delà de cette considération financière, il ne faut pas perdre de vue que le rôle essentiel des activités de l'Agence et la raison fondamentale pour laquelle les Etats lui confient la gestion de fonds importants ne sont pas la garantie d'un 'juste retour' mais bien certainement la réalisation de programmes ayant des objectifs techniques ou scientifiques précis. Les considérations de retour géographique ne doivent pas s'exercer au détriment de cette responsabilité.

Les procédures d'actualisation de l'ESA — base possible pour la construction d'un indice de prix spatial européen

J. Vuagnat
Département des Finances, ESA, Paris

Lors des débats qui ont eu lieu ces dernières années sur les améliorations à apporter au système financier de l'Agence spatiale européenne, il est toujours apparu que la réforme essentielle à introduire serait celle d'une utilisation généralisée de l'ECU tant pour les recettes de l'Agence que pour ses paiements. Cést d'ailleurs l'objéctif à terme que s'est fixé le Conseil de l'ESA lors de sa 71ème session des 23 et 24 novembre 1985.

Dans une telle perspective, le besoin d'un indice européen unique de variations des prix dans le secteur de l'industrie aérospatiale se fait immédiatement sentir. Un tel indice n'existe malheureusement pas actuellement; on pourrait par contre songer à le construire à partir des procédures qu'utilise l'Agence depuis de nombreuses années pour actualiser ses prévisions de dépenses dans ses budgets annuels.

Quelles sont ces procédures d'actualisation?

Il est essentiel de noter que les procédures qui vont être schématiquement rappelées ci-dessous sont celles que l'Agence applique à ses budgets, c'est-à-dire à ses prévisions de dépenses, et non pas aux contrats qu'elle place auprès des industriels. Pour ces derniers, qui sont de types variés et couvrent différentes catégories de coûts, l'Agence utilise actuellement des formules de révision de prix convenues cas par cas en fonction de la structure des coûts de la firme et de la composition des coûts du contrat ou du produit particulier considéré. Une telle variété d'indices et de formules n'est pas nécessaire au stade prévisionnel de l'établissement des budgets. Cela ferait intervenir un nombre excessif d'indices élémentaires de variations des prix (dont certains ne seraient appliquées que sur des sommes marginales) pour un résultat dont la précision ne serait qu'apparente. Pour une fraction importante des dépenses prévues, d'autre part, il s'agit d'argent frais pour lequel on ignore quels types de contrats lui seront finalement associés. On ne traite donc ici que des procédures qu'applique l'ESA pour prendre en compte les variations de prix et de taux de conversion dans ses budgets.

Conformément au Règlement Financier de l'Agence, ces procédures peuvent être résumées comme suit: dans un premier temps, les dépenses prévisibles sont exprimées en monnaies nationales; ces dépenses sont ensuite actualisées au niveau des prix en vigueur au 30 juin de l'exercice au cours duquel les budgets sont établis. Pour ce faire, on utilise des coefficients de variations des prix spécifiques, par catégories de dépenses, des pays où les travaux ont lieu. Les dépenses actualisées sont enfin converties en unités de compte à l'aide des taux de conversion moyens du mois de juin de ce même exercice; ces taux de conversion sont ceux qui relient les monnaies nationales à l'ECU, puisque l'unité de compte utilisée par l'Agence est équivalente à l'unité de compte européenne (ECU) instituée par le Règlement du Conseil des Communautés européennes en date du 18 décembre 1978.

En ce qui concerne les coefficients de variations des prix, le Règlement Financier de l'Agence stipule que les calculs sont fondés sur l'application de coefficients d'indexation résultant de la variation d'indices de prix officiels élémentaires, représentatifs de l'évolution des coûts dans le domaine approprié.

Quels sont ces indices de prix officiels?

Il n'y a pas de lien direct en général entre les diverses catégories de dépenses de l'Agence et celles pour lesquelles les Etats établissent des indices de prix; à l'exception du Royaume-Uni, il n'y a pas, par exemple, d'indices officiels de l'évolution des salaires et des prix des produits dans l'industrie aérospatiale proprement dite, alors que de tels indices existent dans le secteur des industries mécaniques et électriques.

L'Agence a donc eu recours aux indices officiels, publiés par les divers services statistiques nationaux, qui lui paraissaient être les plus proches de l'évolution réelle des prix de ses dépenses. Ces indices lui sont fournis, pour chacun des principaux pays où elle effectue des dépenses, par l'Office statistique fédéral d'Allemagne, situé à Wiesbaden, d'où le nom d''indices de Wiesbaden' souvent donné à ces indices de prix nationaux.

Ces indices, en nombre limité, ont été choisis de façon telle que leur application à l'actualisation des dépenses de l'Agence soit suffisamment représentative de l'évolution économique dans le domaine aérospatial, tout en ne rendant pas la procédure trop complexe. Parmi ces indices, celui dit de la main-d'oeuvre a un poids prépondérant puisque l'ensemble des dépenses de l'Agence est constitué à près de 80% de salaires et de rémunérations dans l'industrie.

Dans le cas des dépenses de développement, on pondère cet indice 'main-d'oeuvre' en général avec des indices 'matière', voire avec d'autres indices tels que ceux de l'énergie, du coût de la construction, etc. Au total, le nombre d'indices élémentaires oscille actuellement entre 15 et 20 pour chaque pays où l'Agence effectue ses dépenses les plus importantes, et autour d'une dizaine pour les autres pays.

Peut-on réduire le nombre de ces indices?
La réponse à cette question est assurément oui.

Des simulations effectuées sur les dépenses de l'Agence ont montré que si on avait actualisé ces dépenses avec le seul indice 'main-d'oeuvre', quelle que soit la nature de la dépense, on aurait obtenu des résultats peu différents de ceux que l'on obtient actuellement avec pour chaque pays une quinzaine d'indices élémentaires et de nombreux indices pondérés.

Bien entendu, avant de retenir par pays un seul indice (tel que l'indice 'main-d'oeuvre' par exemple), il faudrait s'assurer que l'indice retenu est suffisamment représentatif de la réalité économique dans le domaine aérospatial du pays concerné.

Quel indice unique pourrait-on retenir?
Indice unique fait en général immédiatement penser à l'indice des prix à la consommation. Cet indice, représentatif de l'inflation

nationale, n'est par contre pas nécessairement représentatif de l'évolution des prix dans le secteur très spécifique de l'industrie aérospatiale. Ceci a été confirmé en comparant, pour les cinq dernières années, l'évolution de l'indice 'Wiesbaden' des prix de la main-d'oeuvre dans l'industrie aérospatiale avec celle de l'indice des prix à la consommation dans chacun des 13 Etats membres de l'Agence. L'étude a montré que bien que le rapport entre ces deux indices puisse être pour un pays donné soit supérieur à 1, soit inférieur à 1 suivant les années, il est en général très supérieur à 1 sur l'ensemble de la période étudiée de cinq ans (voir Tableau 1), seule la Suède faisant très légèrement exception à la règle; on constate également sur ce tableau que des pays à inflation voisine, tels que l'Allemagne et les Pays-Bas par exemple, n'ont pas nécessairement une évolution identique des

Tableau 1 — Evolution des prix (en %) dans les 13 Etats membres de l'ESA entre la mi-1983 et la mi-1988

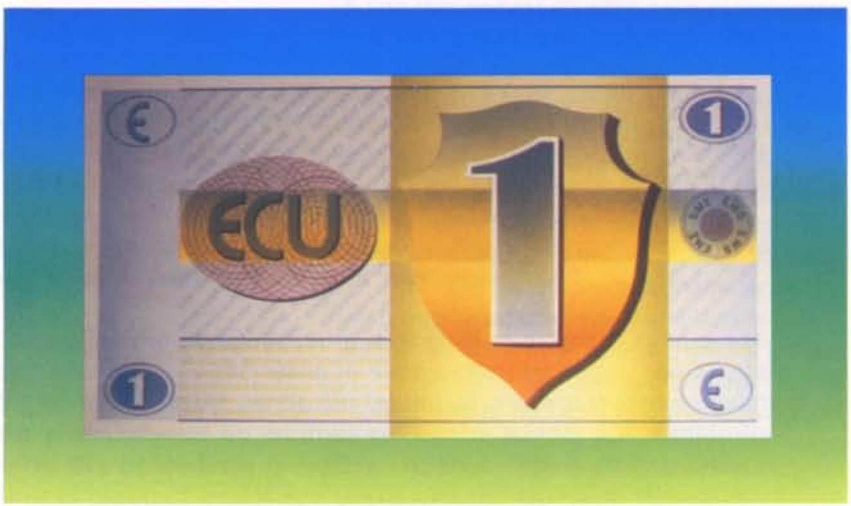
	Indice de la main-d'oeuvre dans l'industrie aérospatiale	Indice des prix à la consommation
Allemagne	+24,2	+ 5,8
Autriche	+24,6	+14,0
Belgique	+17,1	+16,0
Danemark	+28,8	+25,4
Espagne	+55,2	+44,7
France	+30,7	+23,4
Irlande	+41,4	+24,8
Italie	+46,8	+40,1
Norvège	+52,1	+40,1
Pays-Bas	+ 8,2	+ 6,1
Suède	+34,4	+34,8
Suisse	+18,6	+11,1
Royaume-Uni	+42,2	+26,7

salaires dans leurs industries aérospatiales respectives.

L'indice des prix à la consommation ne paraît par conséquent pas approprié, et il vaudrait mieux retenir un indice de prix tel que l'indice 'main-d'oeuvre' sélectionné par Wiesbaden (ou une pondération de cet indice et d'un indice 'matière'), conduisant pour chaque pays à un indice de prix 'spatial' unique.

Extension aux contrats placés en ECU
Ce qui précède s'entend pour des contrats placés en monnaies nationales, et ne conviendrait pas au cas de contrats en ECU, pour lesquels un indice 'spatial' européen devrait être subsitué aux divers indices 'spatiaux' nationaux mentionnés au paragraphe précédent.

Deux questions se posent alors:
— Quelle pondération faudrait-il retenir entre les divers indices nationaux pour déterminer l'indice européen ?
— Cet indice 'européen' prendrait-il suffisamment en compte les fluctuations, actuellement très différentes d'un pays à l'autre, des taux de conversion de l'ECU en monnaies nationales ?



Pondérations possibles pour l'indice de prix spatial européen
Première possibilité
Puisqu'il s'agit d'ECU, il apparaît logique d'utiliser la pondération des divers constituants du panier de l'ECU. Depuis le 17 septembre 1984, dix monnaies européennes entrent dans la composition de ce panier, avec les montants suivants:

0,719	mark allemand
+0,0878	livre sterling
+1,31	franc français
+140	lires italiennes
+0,256	florin néerlandais
+3,71	francs belges
+0,14	franc luxembourgeois
+0,219	couronne danoise
+0,00871	livre irlandaise
+1,15	drachme grecque

Deux autres monnaies (la peseta espagnole et l'escudo portugais) devraient en faire partie en septembre 1989.

La valeur de l'ECU dans les diverses monnaies nationales qui le composent permet de déterminer la part relative (ou poids) de chacune de ces monnaies dans le panier; ces parts relatives sont variables dans le temps, puisque le panier est constitué de quantités fixes des diverses monnaies, qui elles-mêmes fluctuent. Le Tableau 2 montre ce qu'a été l'évolution de ces parts relatives sur les cinq dernières années, en prenant à titre d'exemple les valeurs moyennes des taux de conversion de juin de chacune de ces années.

Tableau 2 — Poids des monnaies dans l'ECU (en %)

	Juin 1984	Juin 1985	Juin 1986	Juin 1987	Juin 1988
Allemagne	37,05	32,03	33,45	34,65	34,62
Belgique	8,04	8,20	8,45	8,63	8,54
Danemark	2,65	2,72	2,75	2,80	2,77
France	16,74	19,14	19,12	18,91	18,69
Grèce		1,15	0,85	0,74	0,69
Irlande	1,04	1,21	1,23	1,12	1,13
Italie	7,88	9,78	9,49	9,33	9,08
Luxembourg	0,31	0,31	0,32	0,33	0,32
Pays-Bas	11,35	10,11	10,58	10,95	10,96
Royaume-Uni	14,94	15,35	13,78	12,54	13,20
	100	100	100	100	100

Les poids qui y sont mentionnés ont été appliqués aux variations des indices des prix à la consommation et à celles des indices 'Wiesbaden' des prix de la main-d'oeuvre dans l'industrie aérospatiale des 10 pays dont les monnaies entrent dans la constitution du panier de l'ECU. (Faute de données disponibles, au moment de l'étude, pour les indices 'main-d'oeuvre' du Luxembourg et de la Grèce, on a supposé dans les calculs que les variations de ces deux indices étaient identiques à celles des indices des prix à la consommation dans ces deux pays. Cette hypothèse simplificatrice n'a pas d'impact sensible sur les résultats, compte tenu du poids très faible — 2% environ — des monnaies de ces deux pays dans le panier de l'ECU).

Les résultats obtenus ont été comparés à ceux qui résultent des procédures d'actualisation actuellement appliquées aux budgets de l'Agence: par rapport au pourcentage réel de variation des prix des dépenses globales de l'Agence, constaté pour chacune des cinq dernières années étudiées, l'utilisation des indices des prix à la consommation aurait donné des écarts trop importants avec la réalité (ce qui confirme à nouveau le caractère non approprié de cet indice dans le cas des dépenses aérospatiales). Par contre, l'emploi des indices main-d'oeuvre dits de Wiesbaden aurait pu convenir.

L'indice de prix spatial européen pourrait donc être constitué par les indices des prix de la main-d'oeuvre dans l'industrie aérospatiale, sélectionnés par l'Office statistique de Wiesbaden pour les Etats membres de la Communauté Européenne dont les monnaies entrent dans la composition du panier de l'ECU, avec comme pondération celle de ces monnaies dans ledit panier.

Deuxième possibilité
Une alternative pourrait être d'utiliser non pas la pondération des constituants du panier de l'ECU, mais celle (très différente) qui résulte des contributions des Etats membres de l'Agence aux dépenses globales de cette dernière. Une telle pondération, dont l'évolution sur les cinq dernières années est donnée dans le Tableau 3, montre en particulier le poids prépondérant du franc français (de l'ordre de 30%) et celui non négligeable de la lire italienne (de l'ordre de 15%) alors que ces poids se situent respectivement aux alentours de 19% et 9% dans le panier de l'ECU (la situation est inverse pour le mark allemand et le florin néerlandais).

Une telle pondération paraît à première vue plus appropriée puisqu'elle est par construction plus proche du panier des dépenses spatiales européennes. On l'a donc appliquée aux variations des indices des prix de la main-d'oeuvre dans l'industrie aérospatiale des 13 Etats membres de l'Agence. Les calculs effectués sur les cinq dernières années ont donné des résultats voisins de ceux obtenus avec la pondération des constituants du panier de l'ECU, sans être toutefois plus proches des variations réelles.

On pourrait donc aussi construire un indice de prix spatial européen qui serait défini comme étant constitué par les indices des prix de la main-d'oeuvre dans l'industrie

Tableau 3 — Contributions des Etats membres aux dépenses globales annuelles de l'ESA (en %)

	1984	1985	1986	1987	1988
Allemagne	22,29	23,36	24,78	23,23	25,40
Autriche	0,34	0,26	0,31	0,97	0,89
Belgique	4,32	4,16	4,17	3,86	4,22
Danemark	1,49	1,11	1,12	1,04	1,01
Espagne	3,30	3,34	3,30	3,40	3,79
France	28,32	30,23	29,71	30,29	31,44
Irlande	0,16	0,19	0,20	0,23	0,19
Italie	14,14	14,64	14,79	15,37	15,58
Norvège	0,34	0,27	0,40	0,90	0,91
Pays-Bas	4,72	4,12	3,72	3,55	2,87
Suède	2,26	2,15	2,48	2,92	2,54
Suisse	2,74	2,22	2,02	1,91	2,06
Royaume-Uni	15,58	13,95	13,00	12,33	9,10
	100	100	100	100	100

aérospatiale, sélectionnés par l'Office statistique de Wiesbaden pour les 13 Etats membres de l'ESA, avec comme pondération les pourcentages de contribution de ces Etats aux dépenses globales de l'Agence.

Une telle alternative ne semble cependant pas s'imposer puisqu'un indice construit sur ces bases ne donnerait pas des résultats meilleurs que ceux que l'on obtient en utilisant la pondération des constituants du panier de l'ECU.

Le risque de change serait-il couvert?
Avec un indice de prix unique, quels que soient le lieu et l'objet de la dépense, on peut se demander non seulement si les variations de prix nationales seront à chaque fois couvertes, mais aussi s'il en sera de même des variations des taux de conversion de l'ECU en monnaies nationales. Pour couvrir ses dépenses en monnaies nationales, l'industrie aura en effet à convertir la majeure partie des ECU qu'elle recevra de l'Agence.

On peut d'autant plus se poser la question que les pays à monnaie forte, malgré l'existence du Système Monétaire Européen, ont vu l'ECU se déprécier de façon sensible par rapport à leurs monnaies nationales au cours de ces cinq dernières années. Pour l'Allemagne, l'Autriche, les Pays-Bas et la Suisse, cette dépréciation a atteint presque 9% sur la période 1983-1988 (dans le même temps, certains autres Etats tels que l'Italie, la Norvège et le Royaume-Uni ont vu l'ECU s'apprécier de plus de 15% par rapport à leurs monnaies).

Pour tenter de répondre à la question, des calculs ont été effectués sur les cinq dernières années afin de déterminer ce qu'aurait été l'incidence d'une actualisation avec un indice de prix spatial européen (tel que défini au paragraphe précédent) appliquée à des contrats passés en ECU, convertis ensuite en monnaies nationales.

Les résultats des calculs ont montré que, sur une période d'un an, l'écart avec l'inflation nationale aurait pu être tantôt positif, tantôt négatif, suivant l'année considérée au sein de la période 1984-1988 étudiée. Par contre, sur l'ensemble de la période de cinq années, l'écart aurait toujours été nettement positif, à la seule exception non significative de l'Espagne (pour ce pays, les dépenses se seraient trouvées actualisées très légèrement au-dessous de l'inflation sur la période 1983-1988; ceci est dû au fait que durant cette période, l'inflation en Espagne s'est située au-dessus de la moyenne européenne, sans être compensée par une dépréciation suffisante de la peseta durant la même période). De tels résultats indiquent qu'une actualisation de contrats en ECU avec un indice de prix unique du genre de celui qui a été proposé dans ce document aurait bien couvert non seulement l'inflation mais aussi les variations de change.

Remarque finale
Les propositions qui précèdent pourront paraître à certains technocratiques, voire utopiques étant donné les disparités qui existent encore actuellement entre les économies des divers partenaires européens. Il ne faudrait pas cependant que ce soit un prétexte commode pour reporter dans un futur indéfini la mise en place d'une procédure d'actualisation utilisant un seul indice de prix en Europe pour l'industrie aérospatiale. Une telle attitude n'irait certainement pas dans le sens de l'harmonisation des politiques économiques et monétaires des pays européens que nous souhaitons tous.

Electronic Dissemination of Information by ESA Contracts Department

G. Dondi
Contracts Department, Directorate of Administration, ESA, Paris

The ESA Contracts Department records and updates all information concerning Agency procurement activities, and maintains a list of all firms having an interest in or currently undertaking contract work for ESA. In addition, a Contract Database is maintained, which records all contracts awarded to industry by the Agency since 1972.

This information is used for three main purposes:
- **to keep industry informed about ESA's procurement programme;**
- **to keep Member-State Delegations informed about contractual/industrial-policy matters discussed in the Agency's Industrial Policy Committee;**
- **to prepare statistical contract information, for both internal and external use.**

The value of this information, once collected and adaptated to meet specific requirements, is critically dependent on timely distribution. With conventional methods, such information takes the form of bulky documents and is therefore subject to the usual dissemination problems and delays.

Electronic dissemination

ESA first began exploiting the benefits of electronic mailing in its Contracts Department in 1984. The hub of this 'electronic data dissemination' is provided by a number of databases installed at ESRIN, in Frascati (Italy), to which interested users have access via public telephone lines.

Three systems have been put into operation there:
- EMITS (Electronic Mail Invitation to Tender System), for the dissemination of information concerning ESA Invitations to Tender (ITTs);
- DODIS (Documents Dissemination System), for the dissemination to Member States of official Industrial Policy Committee documents;
- SPIDAB (Space Industry Database), for the distribution, both inside and outside ESA, of information concerning space industry (company profiles, technical specialisations, space-programme funding, global contract awards, etc.).

These three information-dissemination systems have several characteristics in common:
- to keep development time and costs to a minimum, ESRIN's existing experience and infrastructure have been exploited in all cases;
- their reliance on public lines for information dissemination and the possibility of connecting the systems to a variety of receiving terminals;
- the ability to build a searchable archive of the disseminated information;
- in general, maximum commonality of equipment, software and support, in order to minimise costs and ensure an efficient operational service to users.

It is also important to keep in mind the different goals of the various systems:

Dissemination of ITTs
The main purpose of this system is to reduce the amount of paperwork involved, while at the same time speeding up distribution to users. The ESA Contracts Department issues several ITTs per day, and some document go to as many as 60 to 80 firms. Preparation and distribution of each of these relatively bulky documents by traditional means is arduous and time consuming.

Dissemination of ESA official documents to Delegations
The main purpose of this system is to speed up the dissemination, giving users the possibility of selective reproduction of documents as soon as they become available. Secondly, it provides an efficient searching facility for earlier documents.

Dissemination of statistical contract information
This service is very popular both inside and outside the Agency. The purpose of SPIDAB is to expand the scope and quality of service on the basis of user requirements, without

simultaneously increasing the resources needed to provide the service. To this end, Eurospace, as the inter-professional representative of European space industry, has been charged with organising the service, with Agency supervision and assistance. The understanding is that, after a two-year running-in period, the service should become self-financing, with ESA and its Delegations having free access to it.

Information dissemination to potential contractors (EMITS)

EMITS service characteristics

EMITS provides for the dissemination of the following information:

- planning information for the current year's ITTs. Each action is briefly described and an indication is given as to the value of procurement, the quarter in which the action will be initiated, the technical service responsible for the action, etc;

photo: picture report

Figure 1. ESRIN

- the full texts of actions currently open for tendering; both the technical and administrative documents are available on-line, together with an indication of the time span allowed to potential bidders for presenting their offers;
- standard contractual texts (general conditions for ESA contracts, general conditions for ESA tenders, etc.);
- information on ESA policies and procedures, and instructions for using EMITS.

The planning information is updated monthly and the texts of the current ITTs are updated on a daily basis. One very useful aspect of the EMITS system is that it remembers the date of the last contact with each user. When the user next calls on EMITS, information is immediately given as to which documents have been added since the last contact.

EMITS implementation and evolution

EMITS was the first of ESA's three information-dissemination systems to be developed and put into operation. As such, it is the system that has supported all the developmental work, and many of its features are easily recognisable in the other systems.

EMITS was first conceived in 1984, first implemented in 1985 (reported in ESA Bulletin No.43, August 1985), and has been fully operational since January 1987. The system has been expanding since that time and the Agency is currently in the process of introducing a new version that will allow the dissemination of drawings.

The elimination of paperwork has been more gradual than originally foreseen for two reasons:

- On the one hand, ESA has had to overcome several problems associated with the preparation of documents in computer-compatible form, including the standardisation of existing office equipment.
- On the other, the imposition of a reduced-paper system on industry had to proceed gradually, and could be fully exploited only when a representative number of ESA contractors and potential contractors had not only requested to be connected to EMITS, but had also become practical users of the system.

Since January 1989, all firms that request an ESA ITT have been informed by telex of the availability of the text in question on EMITS. Firms that intend to submit an offer can obtain a hard copy of the relevant documents free of charge on request. ESA does, however, reserve the right to invoke a fee for providing hard-copy documents if too many firms make use of this facility without submitting an offer.

EMITS current utilisation

During 1988, EMITS users were connected to the system for approximately 2000 h. There were more than 300 regular users, concentrated mainly in the United Kingdom and Germany. The main space contractors are, of course, the heaviest users in terms of connect time, but a fair amount of interest has also been shown by universities and research institutes.

The formal commencement of the reduced-paper system in January this year has caused a considerable increase in the number of requests for additional system passwords. A commensurate increase in the number of users is therefore expected to be reflected in the utilisation statistics for the second quarter of the year.

Information dissemination to Delegations (DODIS)

DODIS service characteristics

ESA decisions at policy level are taken by a series of committees composed of Member-State Delegation representatives. For contractual and industrial-policy matters, the relevant committee is the Industrial Policy Committee (IPC), the secretariat for which is provided by the ESA Contracts Department.

The main task of this secretariat is the production and dissemination of discussion papers, prepared on the basis of information supplied by the individual technical initiators. These papers have to be sent to Delegations at least 14 working days before each IPC meeting.

EMITS was obviously a system that could be easily adapted to the dissemination requirements for these documents. The principle was presented to the IPC in 1986, and an agreement was reached on the implementation of a pilot scheme at the end of 1987.

DODIS implementation and evolution

The DODIS system has only been operational since the end of 1988. On the technical side, there was the preoccupation of implementing a system that would ensure the selective dissemination of IPC documents, but could also easily be extended to provide a similar service for other committees of the Agency. On the document-preparation side, there were workload problems and the usual problems of adapting to new hardware and procedures. There was also a gradual redefinition of requirements on the part of the users, particularly with respect to the referencing and archiving functions.

Work is currently in progress, under ESRIN's guidance, on the extension of DODIS to provide a dissemination/archiving system incorporating all of the Agency's official documents. This initiative far exceeds the relatively limited aims of the original DODIS scheme, and clearly shows the potential of some of the new information technologies being used initially to solve specific problems, but capable of more ambitious and far-reaching applications.

DODIS current utilisation

Six ESA IPC Delegations are already benefitting from DODIS. It is expected that when the archiving/searching facilities, which are currently operational only on an experimental basis, become a standard feature, the majority of the ESA Delegations will utilise the system.

Dissemination of space-industry information (SPIDAB)

SPIDAB service characteristics

SPIDAB provides the following information and services:

- reference information on approximately 350 firms active in the space field in ESA's Member States;
- company specialisation database, containing a detailed description of company products, services, technologies and participations in past and current space projects;
- information on the flow of funds relating to space activities in the world, i.e. the global expenditure each year by official institutions on space activities in each country, and the global incomes to individual firms from ESA in various countries and in specific areas (e.g. technological research);
- participation by individual firms in recent important space projects and a forecast of their participation in current programmes.

This type of information is clearly of interest to various categories of users, both inside and outside the Agency, for a variety of applications (planning, presentations, visits, industrial-policy determination, etc.).

It is equally clear that to keep a database of this type reasonably up to date requires substantial resources, and in particular access to information concerning non-ESA activities. It is for these reasons that a commercialisation programme was devised and Eurospace was engaged for the scheme's implementation. Eurospace, which uses the ESA/IRS facilities on a cost-reimbursable basis to support SPIDAB, was given a contract by ESA in January 1988 to physically structure the database, validate the information, keep it up to date, and undertake promotion/commercialisation of the service.

SPIDAB implementation programme

Eurospace has already completed a number of steps in the implementation programme:

Figure 2. Computer room at ESRIN

photo: picture report

— the creation/validation of the database, with ESRIN's help;
— publication and commercialisation of a European Space Directory in book form; in particular, a Chinese translation of the 1988 edition has been widely distributed by the Chinese administration to the country's institutes and departments involved in space activities;
— the 1989 edition of the Directory is almost complete;
— a price list has defined by Eurospace for the electronic utilisation of SPIDAB.

Extensions to the current services

The implementation of the various dissemination systems has proceeded in parallel with a continuing redefinition of users' needs and of the characteristics of the systems themselves.

A number of requirements and ideas are currently under consideration for future implementation:
— For EMITS: the possibility of transmitting drawings and nonstandard documents by employing digitisers on the input side and offering the possibility of printing out improved-quality drawings, even with a simple dot-matrix printer; and the automatic registration of a firm' interest in the various procurement actions by electronic mail.

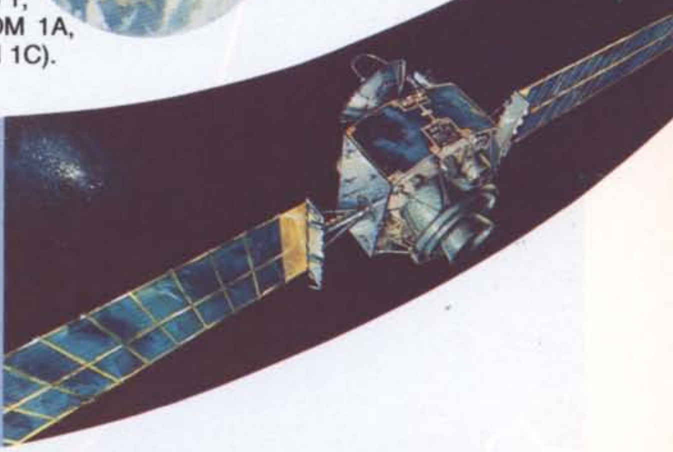
— For DODIS: the implementation of an archiving/searching facility; and the gradual extension of the DODIS system to other Committees of the Agency.

— For SPIDAB: recognition of the importance of the service industry for the support of space programmes; splitting of the European Space Directory into two separate volumes, in order to allow more comprehensive coverage of the capabilities of universities, research laboratories and service firms; and the introduction of a 'Business Opportunities' section dedicated to the presentation of forthcoming procurement actions by other International Organisations fostering advanced technology development or applications (Intelsat, Eutelsat, Inmarsat, CERN, etc.).

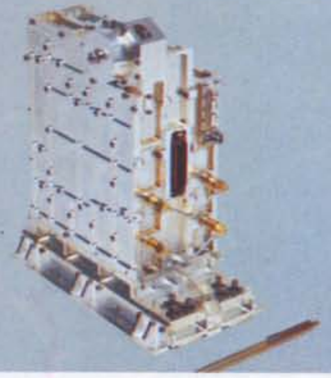
Conclusions

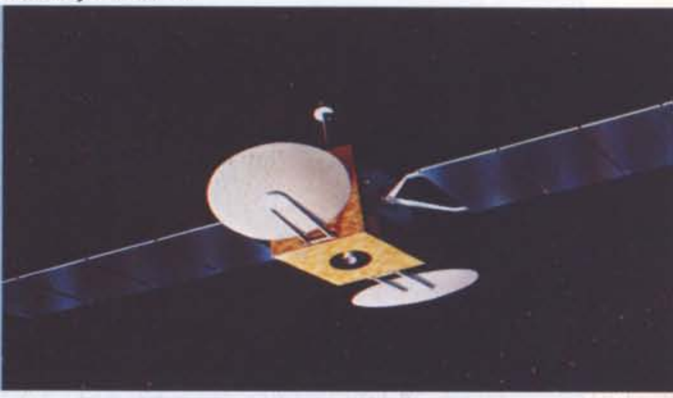
Information dissemination is a vital aspect of the ESA Contracts Department's work and one that has been greatly improved in recent years through the exploitation of modern information technologies. The systems developed — EMITS, DODIS, and SPIDAB — have drawn heavily on ESRIN's experience and capabilities in the field of information acquisition, analysis and dissemination, with the overall goal of limiting development costs and ensuring an affordable service to potential users.

Implementation has been gradual, due to the usual problems of equipment standardisation, acceptance of new procedures, user adaptation to new techniques, and ever-changing user requirements. However, the constant contact with users has also been a stimulating source for new ideas and improvements, and a number of new developments are currently under consideration for implementation in the near future as a result.



Courtesy TELESAT





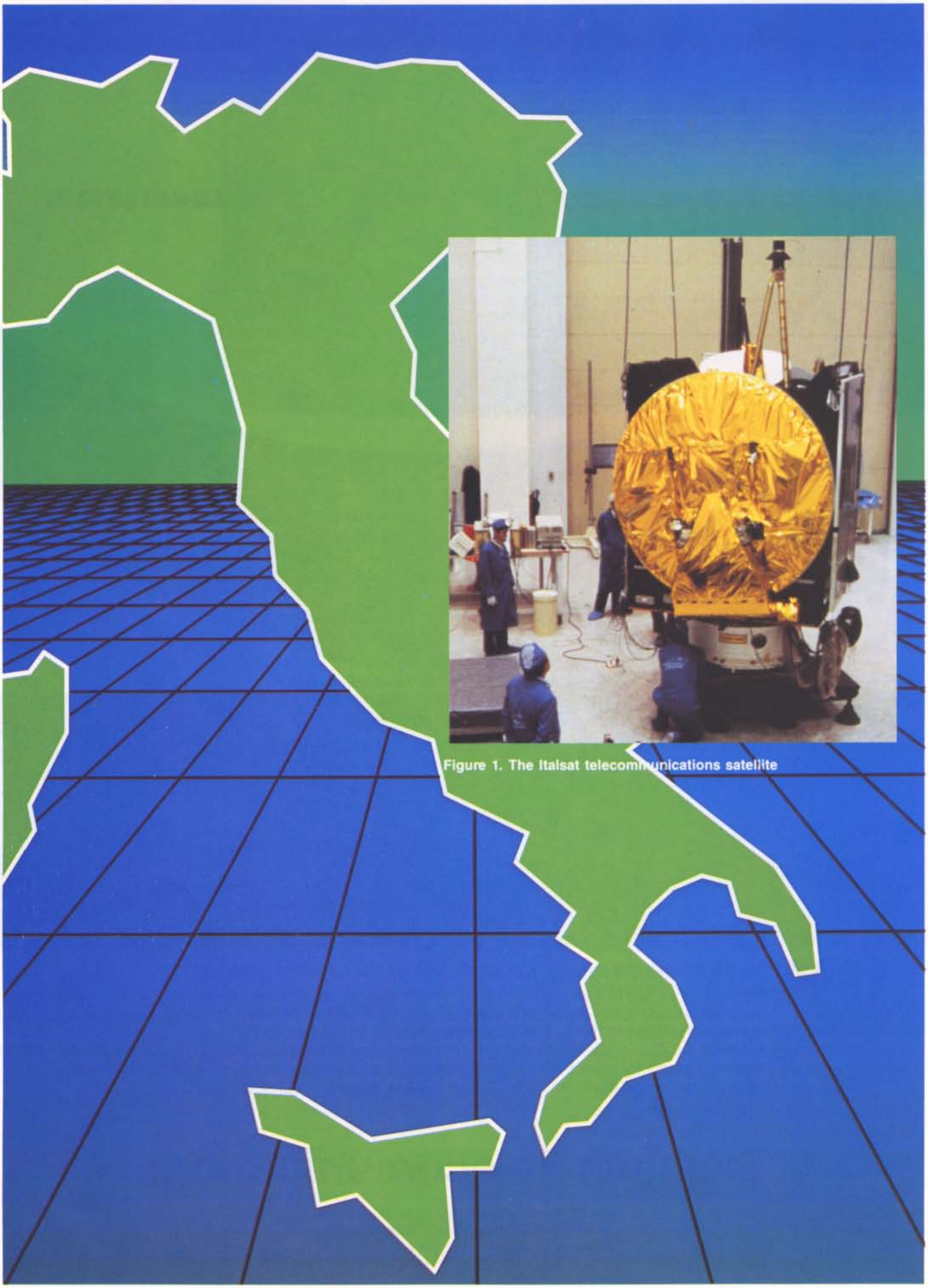


Figure 1. The Italsat telecommunications satellite

ESA Consultancy to the Italian Space Programme

L.M. Palenzona
Systems Engineering and Programmatics Department,
ESTEC, Noordwijk, the Netherlands

Almost nine years ago, ESA and the Italian Government signed a contractual agreement for the provision by ESA of technical and managerial support to the early programmes in the Italian Space Plan (PSN)*. The initial programmes involved were Italsat, a telecommunications satellite, and the Italian Research Interim Stage (IRIS), an 'orbit assist' propulsion unit.

New projects were subsequently introduced into the Italian programme and the consultancy services agreement was renewed and expanded to include support to these new projects: the Tethered Satellite System (TSS-S), Lageos-II (a laser retro-reflector facility), SAX (an X-ray astronomy satellite), and the DRB (a deployable/retrievable boom facility).

The contractual agreement has recently been extended until 1991.

The Italian projects receiving ESA support

Three ways in which ESA has been supporting the above-mentioned Italian projects are: through participation in project monitoring, including technical management and specialised engineering efforts; in the preparation and implementation of various environmental test programmes; and in flight-operations preparations, such as those for Italsat's launch and early-orbit operations.

Special attention has also been given to providing support in the areas involving the application of ESA specifications and standards, for instance telecommunications, where the ESA telemetry and telecommand standards are being implemented, and product assurance, where extensive support is provided in the areas of materials selection and testing, parts and components qualification and procurement, quality assurance, etc.

Italsat

Italsat is a domestic geostationary telecommunications satellite (Fig. 1, inset opposite page) designed to establish a pre-operational digital telephone exchange network, and carrying an on-board baseband switching facility for the first time. It will provide approximately 12 000 telephone circuits.

Multibeam coverage will be provided by six transponders and two 2 m-diameter antennas with a pointing accuracy of 0.03° provided by an auto-tracking control system. In addition to the multibeam payload, Italsat will carry a global-coverage payload for such applications as high-bit-rate computer connections, newspaper transmission, and video-conferencing. Three transponders operating at 20/30 GHz and a 1 m-diameter antenna covering the Italian territory will be used for these applications. A 40/50 GHz propagation payload covering Europe will gather data for the design of future systems.

The Italsat system includes a ground segment, consisting of 20/30 GHz communication stations, monitoring stations for the management, control and operation of the system, and a control centre for spacecraft and network-control purposes, as well as for the monitoring and control of the communication stations themselves.

Built by Selenia Spazio (prime contractor), which is also responsible for the communication stations and overall system integration, Italsat will be launched in mid-1990 by an Ariane vehicle from Kourou, in French Guiana.

ESA has been actively involved since June 1988 in preparations for Italsat's launch and early orbit phase (LEOP). Once launched, the satellite has to be controlled in the geostationary transfer orbit, the necessary orbital manoeuvres have to be effected, the apogee motor fired, and the satellite positioned in its final orbit. Control will then be handed over to the Italian authorities, once Italsat is in its geosynchronous operating orbit.

* Since August 1988, Italian space activities are being managed and coordinated by the newly formed Agenzia Spaziale Italiana (ASI), which has taken over the tasks and responsibilities of the old PSN (Piano Spaziale Nazionale), as well as the management of international agreements for space activities and Italy's participation in ESA.

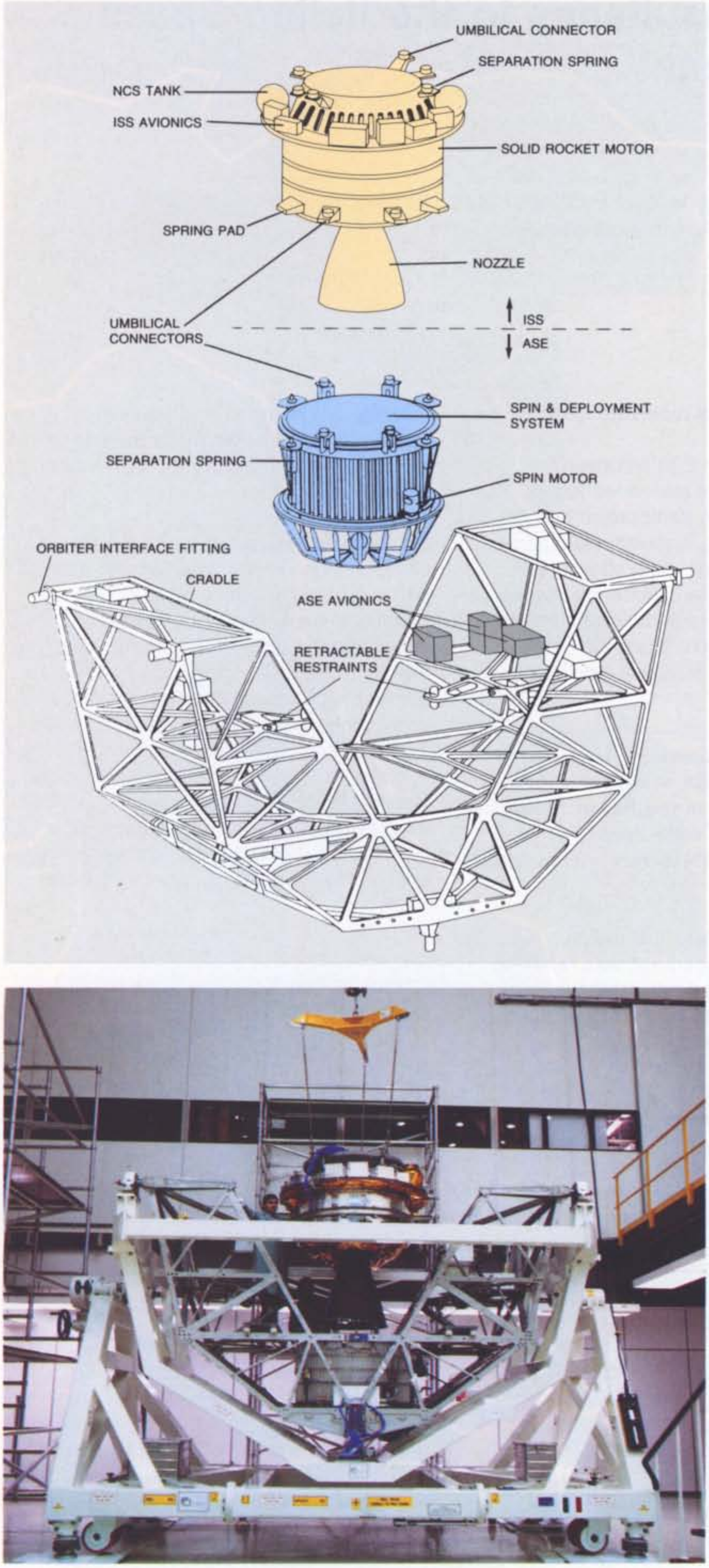


Figure 2. The Italian Research Interim Stage (IRIS) and its spaceborne launch platform

IRIS

IRIS, the Italian Research Interim Stage (Fig. 2), is a Shuttle-based orbital (perigee) propulsion system, similar to the American Payload-Assist Module (PAM). It consists of two major subsystems:

- a space-borne launch platform, called ASE (Airborne Support Equipment), which is to be installed in the Shuttle's cargo bay and can be reused for a minimum of five missions;
- a propulsion stage, called ISS (IRIS Spinning Stage), which provides the IRIS payload with the boost capacity needed to change the composite's orbital parameters after deployment from the Shuttle.

IRIS's performance allows a 900 kg payload to be placed into geostationary transfer orbit.

Aeritalia Space Systems Group is the prime contractor for IRIS, while SNIA-BPD is associate contractor, responsible for the ISS development. Several other industrial companies are involved at subsystem level.

ESA has been actively involved in the organisation, preparation and implementation of the environmental test programmes for both components of the IRIS system. Figure 3 shows the ISS structural/thermal model during thermal-balance testing in the Agency's HBF-3 facility at ESTEC, in Noordwijk. The dual-shaker facility at ESTEC was also used, to carry out vibration testing on the ISS plus payload combination, which weighs a total of 2.7 t (Fig. 4).

The mechanical- and thermal-qualification testing of the ISS have also been carried out at ESTEC (Fig. 5), the thermal-balance testing of the IRIS system being the inaugural test in ESA's Large Space Simulator (LSS) facility (Fig. 6). The preparations for these tests involved substantial effort on ESTEC's part in designing and procuring the large test adaptor needed to support the IRIS structural/thermal model in the LSS chamber during testing (Fig. 7). This same adaptor will be used for the thermal-vacuum testing of the IRIS flight unit, currently scheduled for early 1990.

The first flight of IRIS is scheduled for 1991, and its first payload will be the Lageos-II satellite.

TSS-S

The Tethered-Satellite System (TSS) a three-element orbiting facility consisting of a Shuttle-based deployer, a satellite (TSS-S),

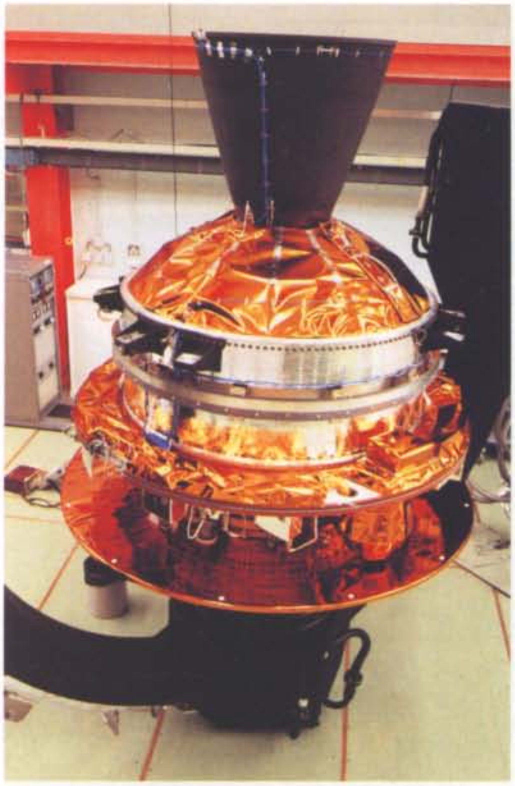


Figure 3. Structural/thermal model of the IRIS propulsion stage (ISS) under test at ESTEC

and a tether connecting satellite and deployer. It is a joint undertaking by the United States and Italy, the responsible agencies being Agenzia Spaziale Italiana (ASI) and NASA/Marshall Space Flight Center. The tethered satellite (Fig. 8) is being developed by Aeritalia Space Systems Group; Martin Marietta will provide the tether, the deployer and conduct overall system integration for NASA.

The first mission (TSS-1), which will carry out electrodynamic experiments, will use a conductive, insulated tether to deploy the satellite 20 km above the Shuttle, away from the Earth. As the conductive tether cuts through the Earth's magnetic field, a potential of up to 5 kV is expected to be electrodynamically induced between the tether's upper (satellite) and lower (Shuttle) ends. A variety of scientific investigations into the characteristics of magnetosphere/plasma interactions will be conducted using this system.

The satellite's spherical aluminium shell is 1.6 m in diameter. Instrument packages are located inside the spacecraft, within its payload module, and at the ends of two extendable booms. During operation, the satellite will be rotated about the tether axis at a speed of 1 rpm, to scan the instruments through a range of aspect angles with respect to the velocity vector.

ESA/ESTEC has been contributing to the TSS programme with the design and the procurement of the series of test adaptors, and with technical and management assistance to ASI and its contractors, particularly for the satellite system and the instrument packages.

Lageos-II

The Lageos-II satellite (Fig. 9) is a passive laser reflector that will be placed into a stable, 6000 km, circular orbit using a Space-Shuttle launch and Italian Research Interim Stage (IRIS). The launch, foreseen in 1991, will be the first to use IRIS as a perigee stage following a Shuttle deployment.

Lageos-II is basically identical to Lageos-I, launched by NASA in 1976, but will be manufactured and tested by Aeritalia. The satellite's spherical surface is covered with 426 corner-cube retroreflectors, to be used for ranging with ground-based lasers. The scientific objective of the mission is to make high-precision measurements of the Earth's surface to allow accurate study of such geophysical phenomena as plate tectonics, regional fault motions, Earth rotation rate and pole motion, ocean tides, etc.

Due to the special launch and mission characteristics, Lageos-II will be provided with an apogee motor of the MAGE series, developed by ESA, for the circularisation of its final orbit.

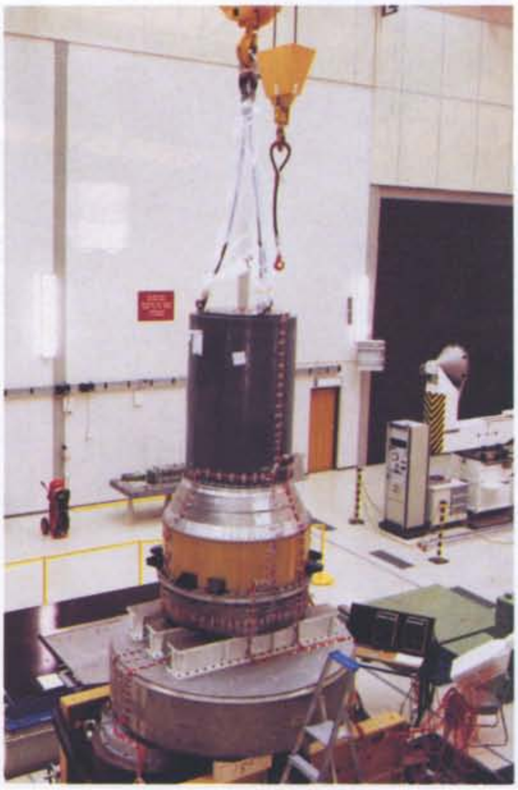


Figure 4. Vibration testing of the IRIS propulsion stage (ISS) and payload at ESTEC

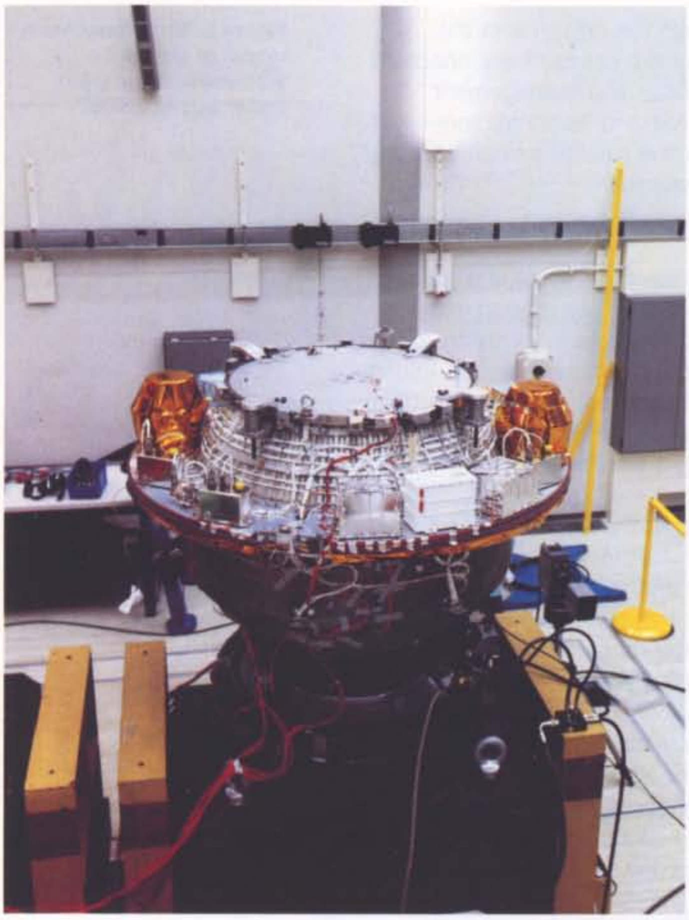


Figure 5. The IRIS ISS undergoing mechanical testing at ESTEC

Figure 6. IRIS undergoing thermal testing in ESTEC's Large Space Simulator (LSS)

Figure 7. The large test adaptor constructed to support the IRIS structural/thermal model in the LSS at ESTEC

SAX

The SAX X-ray astronomy satellite (Fig. 10) is being developed with contributions from the Netherlands Instituut voor Ruimtevaart (NIVR), the Dutch Organisation for Space Research (SRON), and the Astrophysics Division of ESA Space Science Department. Its task will be to make systematic observations of celestial X-ray sources in the 0.1—200 keV energy range, with emphasis on spectral and timing measurements. The SAX programme also involves the establishment of a ground segment to support the scientific mission.

The three-axis-stabilised SAX platform, developed by Aeritalia Space Systems Group, provides the essential services for the mission, such as attitude control, power supply, data handling both for housekeeping and scientific data, etc., and supports the satellite's six scientific instruments.

The SAX programme also includes the development of a ground segment, including a ground station, a control centre, and a scientific data centre.

ESOC staff have already served in the ground-segment support team throughout the Phase-B activities. Compatibility with the ESA ground-station network is a requirement for the SAX programme. It will allow the Agency to provide operational support during the orbital lifetime of the SAX satellite if required.

The SAX satellite is presently planned to be launched into a near-equatorial, circular orbit (inclination approximately 2°, altitude 600 km) in 1993 by an Atlas-Centaur vehicle.

DRBS

The Deployable/Retrievable Boom System (DRBS) is a telescopic structure capable of deploying a given unit, such as a sensor, at a variable distance from the surface of a space vehicle or satellite. It was introduced in the framework of the TSS-S programme, to support diametrically opposed measuring probes 2.5 m from the tethered satellite's skin. However, it can, in principle, be used for a variety of other space missions.

The DRBS is being developed by Rinaldo Piaggio SpA, in collaboration with FIAR.

The unit for the TSS-S mission consists of seven telescopic tubes, which slide concentrically during deployment and retrieval (Fig. 11). Neighbouring tubes are connected by steel cables mounted on pulleys and the worm-gear drive mechanism is actuated by an electrical stepper motor. A latching mechanism secures the moving parts against accidental deployment and/or ejection during launch and landing. If the DRBS should fail to retract for reentry, a pyrotechnically operated mechanism allows the complete stack of tubes and associated drive to be jettisoned by means of spring actuators.

The DRBS flight hardware is planned to be acceptance-tested and integrated into the tethered satellite in the first half of 1989, to be compatible with the scheduled launch in January 1991.

Figure 8. The Tethered Satellite TSS-S

Figure 9. The Lageos-II satellite

Extensive support has been provided to ASI and its contractors by ESA during preparation and implementation of the DRBS environmental test programme, at qualification as well as flight-acceptance level (Fig. 12). A DRBS development unit was subjected to functional and thermal-balance testing in the HBF-3 facility at ESTEC, followed by the qualification model, which completed vibration, thermal and jettison testing in February 1989. Flight acceptance tests, including experiment integration operations, have also taken place at ESTEC, in June 1989.

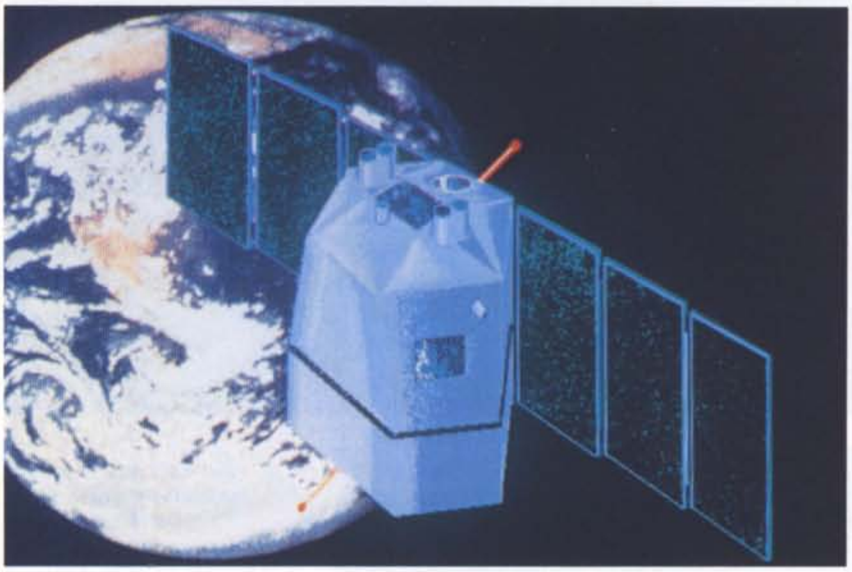


Figure 10. Artist's impression of the SAX X-ray astronomy satellite

In addition, the DRBS project has received considerable dedicated effort from ESTEC's metrology laboratory.

Standards

Check-out standards

The Agency is assisting the Italian Space Agency in implementing ESA Electrical Ground-Support Equipment (EGSE) standards within the Italian space programme. European Test Operations Language (ETOL) software packages have been transferred to ASI, training courses have been given, and assistance has been provided in the development and acceptance testing of checkout stations. This effort is continuing in step with the evolution in ESA's own facilities.

Telecommunications

The ESA TT&C standards for telemetry and telecommunications systems have been passed to ASI and to their contractors during project implementation.

On-board data handling (OBDH)

Support is provided in maintaining ESA-developed standards for the design of on-board data systems, including the ESA-standard OBDH design configuration, the OBDH data bus, etc.

Ground-station and control-centre interfaces

ESA support is provided for ground-based systems to maintain compatibility, as far as possible, between the ESA ground network and the future ASI ground network.

Product-assurance standards

The ESA product-assurance standards for components, materials and processes are being passed to ASI and their contractors for reference and implementation on a regular basis, together with the necessary documentation (e.g. ESA PSS documents and SSC specifications for electronic components).

The ESA/ASI contractual agreement

In Article IX of the ESA Convention - 'Use of Facilities, Assistance to Member States, and Supply of Products' - it is stated that:

'.....the Agency shall make its facilities available, at the cost of the State concerned, to any Member State that asks to use them for its own programmes.'

'If.....one or more Member States wish to engage in a project, the Council may decide ..... to make available the assistance of the Agency'.

The first agreement with Italy for consultancy services was made by ESA, on this basis, in August 1980, and was limited to the support requested by PSN for the Italsat Programme. In September 1980, an additional agreement for consultancy services was made with PSN for the IRIS programme, and in the following years these services were extended to include other PSN space programmes also.

The first three-year contract, covering all the programmes, was signed in April 1982 for the period 1982—1985. It was based on a statement of work to be renewed on a yearly basis, to enable the planning of the support tasks on a shorter-term basis, based on more up-to-date information. The second three-year contract was issued in 1985, covering the period 1 October 1985 until 30 September 1988.

The particular technical disciplines for which ASI contracts the Agency's support are:
- project control
- systems engineering, and assembly, integration and verification (AIV) activities

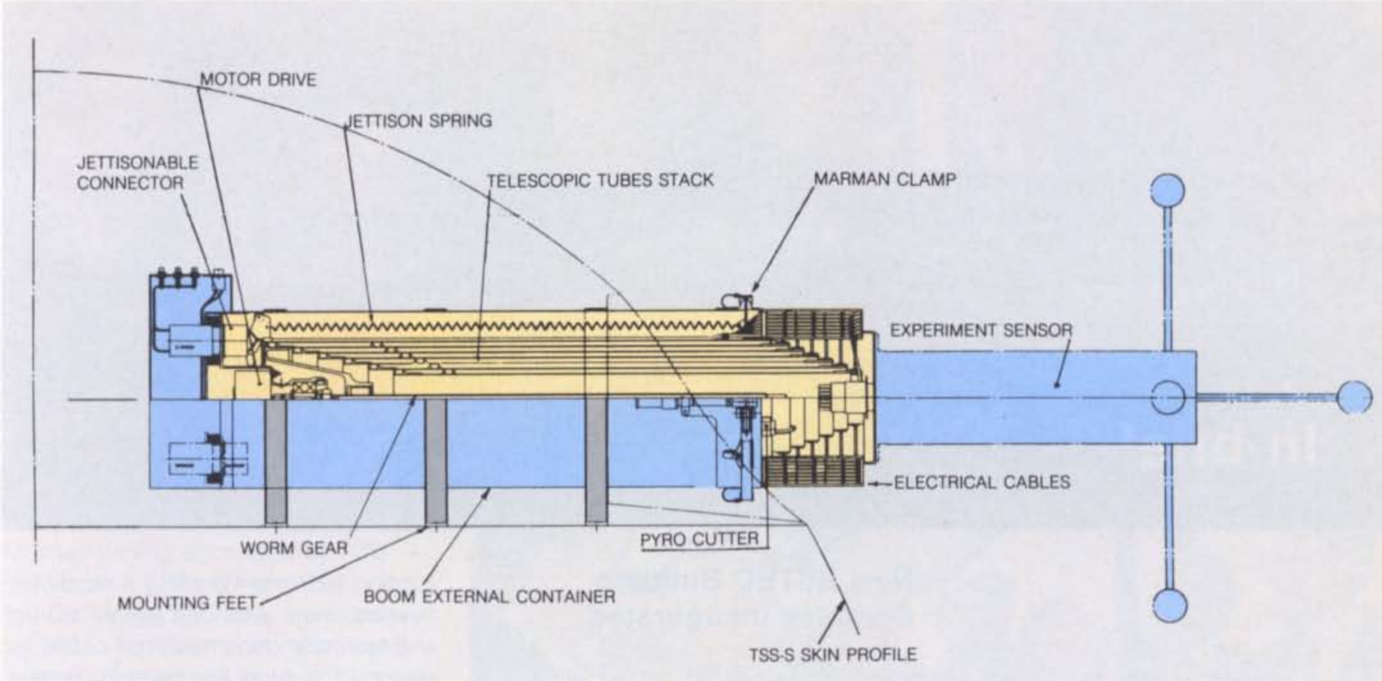


Figure 11. The Deployable/Retrievable Boom System (DRBS) for the Tethered Satellite (TSS-S)

Figure 12. DRBS qualification tests in progress in ESTEC's HBF-3 facility

- product assurance
- structural assurance
- thermal control
- propulsion
- data handling
- power supplies
- telemetry, tracking and control (TT&C)
- attitude and orbit control systems
- satellite to experiment interfacing
- ground and flight operations
- ground-support equipment (hardware and software)
- mission analysis.

In addition, ESA also provides the necessary managerial support, and assists ASI in acquiring licenses for the use of ESA software. The contract also has provision for utilisation, on behalf of ASI, of ESA 'facilities, equipment and/or other services', which includes the Agency's environmental test facilities, and direct technical assistance, for example in assessing technology options.

Many tasks are centred around support to Design Review activities, including the critical evaluation of the applicable documentation, the issuing of comments, usually in the form of RIDs (Review Item Discrepancy), attendance of ESA personnel at Design Review panel and board meetings, etc.

Conclusion

The support that ESA is providng to ASI acts as a stimulus for both organisations in terms of mutual collaboration and shared experience. ESA's experts are involved in design and development activities for ASI projects that, in many cases, enable them to broaden and complement the working experience that they acquire within the Agency's own programmes.

The good links that have been established between ESA and ASI also serve to foster future collaboration on European space projects. The implementation of ESA standards in the areas of telecommunications, product assurance, software, ground support, etc. in the Italian programmes will make that future collaboration that much easier.

Acknowledgements
I wish to express my sincere thanks to the ASI Management, whose courtesy and support in providing both advice and information have facilitated the writing of this article.

New ESTEC Building Complex Inaugurated

On 29 June 1989 Mr. Pieter van Vollenhoven officially inaugurated ESTEC's new offices and Conference Centre. The new complex is unique in its architectural design and building philosophy. It includes more than 200 new offices to accommodate the additional engineering manpower required to prepare, monitor and manage the new space programmes such as Columbus, Ariane-5 and Hermes, which will carry Europe as a leading space power into the 21st century.

The new Conference Centre, with its three large meeting areas close to the support facilities, including a much needed, more spacious staff restaurant and technical documentation centre, is designed to serve the need for greater international communication between European specialists active in the highly specialised fields of space research and technology.

The design of the new building was entrusted to the prominent Dutch architect, Prof. Aldo van Eyck, whose brief was 'to create a communications heart for ESTEC'. His solution was the creation of a Conference Centre and five office towers based on intertwined circular patterns. Soft-bent steel-beam structures, light-shaded woods, and pagoda-style roofs have been used to blend the futuristic new complex

Mr Pieter van Vollenhoven opening the new ESTEC complex

1

2

into the surrounding dune landscape.

After welcoming addresses by Prof. Reimar Lüst, ESA's Director General, and Mr. Marius Le Fèvre, the Director of ESTEC, Mr. Pieter van Vollenhoven ceremonially opened the main entrance to the new complex and unveiled a small commemorative plaque.

Honoured guests attending the inauguration ceremony included Dr R.W. de Korte, Dutch Vice Prime Minister and Minister of Economic Affairs, Mr. S. Patijn, the Queen's Commissioner for the Province of South Holland, Mr. J.M. Hoffmann, the Mayor of Noordwijk, and Mrs. G.W. Montfrans-van Hartman, the Mayor of Katwijk. Her Royal Highness Princess Margriet of the Netherlands, for whom Mr. van Vollenhoven was deputising, was unfortunately unable to attend due to illness.

3

1. *Left to right: Mr Marius Le Fèvre, Prof. Reimar Lüst, Mr Henrik Grage, and Mr Pieter van Vollenhoven*

2. *Mr Pieter van Vollenhoven receives a bouquet from Miss Annalisa Lo Galbo, daughter of an ESA staff member*

3. *Left to right: Mr Marius Le Fèvre, Prof. Aldo van Eyck, Prof. Massimo Trella, Mr Robert Veldhuyzen, Mrs Hannie van Eyck, Minister Rudolf de Korte, and Mr Pieter van Vollenhoven*

4. *Interior of the new restaurant*

4

ESA Council in Session at ESTEC

In the last week of June, the new Conference Centre at ESTEC was the venue for the 87th Meeting of the ESA Council (28 and 29 June). This was, in fact, the first time that the Council had met at ESTEC since ESA officially came into being in 1974.

The main results of this 87th Council, the agenda items for which included a number of important items relating to major programmes that form part of the Agency's Long-Term Plan, included:

1. A unanimous decision on the Agency's proposed astronaut policy, including the setting up under the ESA Director General's authority of a single European Astronaut Corps. This astronaut policy will form the basis for future operations in the Agency's Columbus and Hermes manned programmes.
2. A vote to proceed with the detailed definition of the Agency's proposed In-Orbit Infrastructure Ground Segment.
3. Approval of the Implementing Rules for the Hermes and Columbus Programmes.
4. Adoption of the Agency's proposed strategy for the immediate implementation of telecommunication projects, with a view to making an early start with specific programmes in the areas of Telecommunications Technology and Data-Relay Systems, with maximum harmonisation between these two elements.

Left to right: Mr George van Reeth (ESA's Director of Administration), Prof. Reimar Lüst (ESA's Director General), and Mr Henrik Grage (Chairman of ESA Council)

The 87th Council Meeting in session in the new ESTEC Conference Facilities (below and top of facing page)

5. Unanimous approval of the Draft Agreement between ESA and CNES, the French national space agency, concerning the Ariane-5 Development Programme.

6. Unanimous approval of Sweden's request to join the Columbus Programme with a contribution of 1%.

7. Unanimous approval of Switzerland's proposal to increase its contribution to the Hermes Programme from 1.5 to 2.0%.

The Council's next Meeting is scheduled to take place on 18/19 October 1989.

Scientific Instruments Selected for XMM

ESA's Science Programme Committee has selected the scientific instruments for the Agency's X-ray Multi-mirror Mission (XMM) to be launched in 1998, the second major Cornerstone mission in the Long-Term Scientific Programme known as 'Horizon 2000'.

This sensitive X-ray observatory will provide a large array of mirrors in a deep Earth orbit with which to examine the X-ray emissions of faint stars and the nuclei of distant galaxies. The Earth's atmosphere strongly absorbs X-rays, so that observations of X-ray sources have to be made from above 200 km. XMM will carry an array of telescopes to image celestial X-ray sources, and measure luminosity and spectral energy distribution.

The instruments selected at the meeting in Paris on 12 June 1989 include:

— very advanced X-ray cameras for the prime-focus positions of the three telescopes
— two reflection-grating spectrometers to measure the spectra of X-ray sources
— a telescope operating at visual wavelengths to allow the study of both X-ray and optical emissions simultaneously.

Provision of these instruments will be a massive effort involving some 70 scientists from 29 institutes in seven European countries, supported by five groups from the USA.

The three Principal Investigators for the instruments selected are: Dr G.F. Bignami, from Milan (I); Dr A.C. Brinkman, from Utrecht (NL); and Dr K.O. Mason from London (UK). Development of the X-ray telescope optics will be supported by Dr B. Aschenbach, from Munich (D).

ESA's Programmes on Display at Le Bourget

This year the Agency's programmes were presented at the Le Bourget Air Show (8—18 June 1989) in a complex of three pavilions and a tower element, giving a total exhibiting area 1600 m^2. It was thus the largest ever display mounted by ESA at the Paris Show.

The main entrance was through Pavilion A, where large display panels presented an overview of the Agency's main fields of activity.

Present and future ESA programmes were presented in Pavilion B, where full-scale models of ESA's scientific and applications satellites were displayed: Hipparcos, the first astrometry satellite, to be launched in the coming weeks, and Ulysses, due for launch next year, which will be the first satellite to orbit the poles of the Sun. Also on display was the Faint Object Camera destined for the Hubble Space Telescope, and full-scale models of the Agency's ECS-2 and Olympus communications satellites.

Pavilion C was dedicated to space transportation and manned spaceflight, with full-scale models of Europe's Hermes spaceplane, the Columbus Free-Flying Laboratory and the Columbus Attached Laboratory, the last two items representing ESA's contribution to the International Space Station.

The tower element of the stand (20 m high with glass walls) contained an Ariane-4 fairing housing a full-scale model of ESA's first remote-sensing satellite, ERS-1.

The ESA Press Conference on 13 June, which was chaired by ESA's Director General, Prof. Reimar Lüst, was attended by some 70 media representatives. Moreover, the number of visitors to ESA's pavilion this year was approximately 15% higher than at the previous Paris show two years ago.

The ESA Press Conference in progress at Le Bourget (below): from left to right, Dr. Fredrik Engström (Director of Space Station and Platforms), Prof. Reimar Lüst (Director General), Mr George van Reeth (Director of Administration), and Prof. Roger Bonnet (Director of Scientific Programmes)

Mr Jörg Feustel-Büechl (second from right), ESA's Director of Space Transportation Systems, flanked by Mr Yu. P. Semyenov (left) and Mr B.I. Gubanov (right) — 'founding fathers' of the Soviet shuttle 'Buran' and Energia heavy-launcher programmes, respectively — and Mr Jean Capart of ESA's Hermes Department (far left)

Crew-Safety Workshop at Le Bourget

Crew safety and rescue were the primary topics at a jointly sponsored Workshop at Le Bourget (F) on 7 June 1989. The Association Aéronautique et Astronautique de France (AAF), the American Institute of Aeronautics and Astronautics (AIAA), and ESA joined together to provide a forum for more than 150 space professionals from all over the World who gathered to discuss these important aspects of manned space travel.

All participants underlined the necessity of undertaking a common effort towards inter-operability of rescue systems in view of the increasing complexity of space missions and the prospect of future joint missions. Representatives reported on their experiences in achieving safety and rescue during space transportation and orbital activities. They also discussed to what extent it is desirable and possible to achieve inter-operability between the various systems.

This Workshop will be followed up by an international workshop on docking systems at the end of this year in the United States.

ESA/FAO Agreement to Fight Hunger

Agreement has been reached between ESA and the UN Food and Agriculture Organisation (FAO) to coordinate action in sub-Saharan Africa in combatting locust plagues and crop failures, in an excellent example of the way in which space-age technology can be used to fight hunger in less-developed nations.

Mr. Giorgio Salvatori, ESA's Director of Telecommunications, and Mr. C.H. Bonte-Friedheim, FAO's Assistant Director General for Agriculture, signed the Agreement on 16 June. It commits ESA to provide three free Diana high-speed satellite data-reception stations, plus one hub-station to be installed at FAO Headquarters in Rome.

ESA is developing Diana as a derivative of its Apollo and Spacemail document-delivery systems. These systems can transmit large quantities of data at variable speeds, depending on the error-rate tolerance of the user's system. For FAO's purposes, this means that vital situation reports can be relayed in near-real time. ESA's system concept is designed with maximum user-friendliness in mind, and will employ standard personal-computer hardware and simple menu-driven software at the FAO ground stations in Africa. Some of these stations will be mobile, giving FAO's home-base in Rome maximum flexibility in directing field operations.

Olympus Launched — A Stepping Stone in the Construction of the Single European Market

12 July 1989 was an important day for the future of telecommunications in Europe, with the launch of ESA's Olympus satellite marking the beginning of a new era.

The highly advanced Olympus-1 communications satellite, built by a consortium of European aerospace companies led by British Aerospace, was successfully launched by the last of the Ariane-3 launchers (flight V32) from the Guiana Space Centre in Kourou at 00.14 a.m. UT on 12 July. Olympus-1, weighing 2612 kg at launch and measuring 25.7 m across (between tips of solar arrays), is the World's largest and most powerful civil, three-axis-stabilised communications satellite, and it employs a range of innovative satellite and payload technologies. (A detailed description appeared in ESA Bulletin No. 58.)

It is 11 years since ESA launched OTS, its first experimental communications satellite. The objective then was to give the PTT administrations of Europe an opportunity to learn how they could apply satellites to various types of intra-European communications problems. Until then, satellites had been used only for linking European countries with other continents. The results of the OTS Programme proved very positive and tangible, as demonstrated by the successful growth of the Eutelsat and Telecom-1 systems.

Olympus, on the other hand, has not been built primarily for the PTTs, but rather with the end users of telecommunications services in mind. It will give them the opportunity to discover for themselves how satellites can satisfy their needs as vehicles for a wide range of new services.

For most of this century, the word telecommunications has been synonymous with telephony and telegraphy. Only recently has the field expanded to include numerous new concepts that were practically unknown 20 years ago; videoconferencing, computer communications, electronic mail, data dissemination, video distribution, tele-education, and high-speed facsimile transmission are just some examples. All those interested in either offering or using such services on a truly Europe-wide scale will be able to experiment with Olympus. To have access to the satellite, they will need only very small stations (VSAT), with antenna reflectors less than 2 m in diameter.

The Olympus-1 launch

The Olympus Programme was initiated in the early eighties, at a time when the prospects for communications satellites in Europe looked much more limited than they are now. Today, telecommunications are going through a period of intense expansion, particularly in Europe, where the wind of deregulation is beginning to blow across the whole continent. The Commission of the European Communities (CEC) is proposing to change the overall institutional environment fundamentally in order to realise the 'single market' objective by 1992. Very recently it issued a directive with the goal of opening the provision of all of these new services to competition, leaving only telephony and telex to the care of the government-appointed operating organisations.

Olympus has therefore been launched at a most opportune time. It will provide Europe with an ideal tool with which to implement the strategy being put forward by the CEC. For ESA, it is very gratifying to see that, having invested so much in Olympus, this Programme is now able to make a substantial contribution to the development of European telecommunications.

Olympus-1 will arrive at its final geostationary orbital position at 19°W, some 21 days after launch. Once on station, the satellite will undergo extensive in-orbit testing, with the completion of the commissioning phase expected some 90 days after launch.

Olympus Conference in Austria

The Olympus Utilisation Conference, held at the new Austria Centre in Vienna, from 12 to 14 April, provided a forum for experimenters to discuss and reinforce their ideas for the use of ESA's large telecommunications satellite Olympus (launched on 12 July).

The Conference, which was of great interest to engineers and managers concerned with the commercial and educational uses of Olympus, was organised with the cooperative support of: Eutelsat, Canada's Department of Communications, Telespazio, British Telecom, the Technical University of Graz, Politecnico di Milano, the University of Surrey, Plymouth Polytechnic, the British National Space Centre, and the Technical University of Eindhoven.

An exhibition of equipment and information relevant to Olympus utilisation accompanied the Conference and was provided by various industrial representatives.

Sessions of the Conference addressed such areas as: small terminal systems; earth-station technology; fade countermeasures; SS-TDMA;

internetworking; scientific applications; Eutelsat signatories' activities; propagation studies; distance learning by satellite; and video conferencing.

The launch of Olympus presents a unique opportunity for scientific, technical, educational and business organisations to explore the potential of satellite communications on an experimental basis. The Vienna Conference provided the wider technical community with information about ESA's latest telecommunications satellite and its utilisation programme, thereby establishing sound channels of communication for the ensuing operational phases.

Above right: Chairman (left) and speakers at the final session of the Olympus Utilisation Conference

Right: Transportable satellite earth stations installed for demonstrations outside the Austria Centre in Vienna

Mr James Arnold-Baker (left) and Mr Giorgio Salvatori

ESA and BBC Sign Agreement on Use of Olympus

ESA's Director of Telecommunications, Mr. Giorgio Salvatori, and Mr. James Arnold-Baker, the Chief Executive of BBC Enterprises Limited, a wholly-owned subsidiary of the British Broadcasting Corporation, signed an Agreement at Le Bourget on 14 June 1989 for a five-year commitment for the use of the Agency's recently launched Olympus satellite.

Olympus is the largest civil communications satellite developed so far and is designed to demonstrate several new communication and broadcasting applications, with the aim of promoting space telecommunications and paving the way for operational services.

One of its four payloads is a direct-broadcasting transponder with a European footprint on which BBC Enterprises will provide prime-time transmissions between the hours of 17.00 and 01.00, starting this autumn. This European channel will have a very powerful, steerable beam so that television transmissions can be received across Europe with antennas as small as 30 cm in diameter.

The terms of the Agreement between ESA and the BBC allow BBC Enterprises to use Olympus capacity to develop new television sound- and data-broadcasting applications free of charge for an initial period of experimentation and demonstration, with the costs of satellite operations being reimbursed to ESA once the service becomes operational.

ISU Press Conference at ESA's Le Bourget Pavillion

ISU Board Member, and Director of the Austrian Space Agency, Dr Johannes Ortner hosted a Press Conference on 15 June in the ESA Pavilion at the Paris Air Show to discuss the goals and objectives of the 1989 Summer Session of the International Space University (ISU), taking place at the Louis Pasteur University (ULP) in Strasbourg from 30 June to 31 August 1989.

Representatives from ESA and from the University were present to explain their roles and involvements as supporter and host site, respectively, for this year's ISU Summer Session.

From left to right: Mr M. Pouliquen, Mr K. Madders (ESA), Prof. R. Bonnet (ESA), Dr. J. Ortner, Prof. G. Laustriat, and Ms M. A. Perrino

ISU Delegation Meets President Gorbachev

An International Space University (ISU) delegation, which included Prof. Reimar Lüst, ESA's Director General, met the President of the Soviet Union in Strasbourg (F) on 6 July. The students, faculty and administration of ISU presented Mr. Gorbachev with a letter carrying a message of international cooperation for space exploration and development. They also invited Mr. Gorbachev to deliver the Keynote Address at the opening ceremonies of the 1991 ISU Summer Session, which will be hosted by the Moscow Aviation Institute (MAI).

The letter to Mr. Gorbachev, which was drafted by the students of the 1989 ISU Summer Session currently in progress at the Louis Pasteur University in Strasbourg, was signed by students, faculty members and staff representing 28 nations. 'When we each return to our homelands, we will carry with us much more than the technical expertise we gain here', stated the letter, 'we will return with the knowledge that international cooperation in the venue of space is not only feasible, but viable.'

President Mikhail Gorbachev in discussion with Prof. Reimar Lüst

Sweden Becomes 10th Country to Join Columbus Programme

Sweden has become the tenth ESA Member State to join in the Columbus Development Programme and will be subscribing 1% of the Programme's budget.

The request to participate in the Programme was presented by the Swedish Delegation during the ESA Council Meeting at ESTEC (NL) at the end of June.

The Columbus Programme is ESA's contribution to the International Space Station, a joint venture by the United States, Europe, Canada and Japan.

Sweden also intends to sign the Intergovernmental Agreement between the so-called 'Four Partners' on cooperation in the design, development, operation and utilisation of the Space Station.

New Communications Facility Inaugurated at ESTEC

A new satellite communications facility was inaugurated at ESTEC, by Mr. Giorgio Salvatori, Director of ESA's Telecommunications Programmes, on 27 June. The new 'Satellite Communications Building' (SCB) will provide a base for ESTEC satellite communications activities in general, and will support the Olympus Utilisation Programme in particular.

Many new earth stations established for Olympus utilisation, plus several refurbished existing stations will form the backbone of Olympus, ECS, and Marecs tests. The support and maintenance of these earth stations have been centralised in the new SCB.

In addition to Mr. Salvatori, those on hand to celebrate the completion of the new facility, included Prof. Reimar Lüst, Director General of ESA, members of the Agency's Joint Communications Board, representatives of the various companies involved, and ESA staff involved in earth-segment matters.

At the inauguration ceremony, Mr. Salvatori spoke of the important role that Olympus Utilisation Programme will play in providing the means for scientific and technical bodies to make measurements and develop new systems for satellite communications. He also pointed out that the new facility forms part of extensive ground facilities encompassing over 50 earth stations owned by more than 30 organisations, including ESA.

In future, television reception for launch events, reception of telemetry from the Agency's telecommunication satellites, experiments using the Apollo system and In-Orbit Testing as well as the demonstration of Olympus' capabilities, will all be possible from the various earth stations located in and mounted on the SCB. The SCB will also act as a support base for transportable stations that are deployed in various parts of Europe and Canada.

Mr Giorgio Salvatori opening the new Satellite Communications Building (SCB), pictured below

HST Observers Selected

The Guest Observers who have been selected to make use of the new Hubble Space Telescope (HST), which will be the first permanent optical observatory to be placed in orbit above the Earth's atmosphere, have recently been notified by Dr Riccardo Giancconi, Director of the Space Telescope Institute in Baltimore (USA).

The 162 selections were made from 556 proposals submitted by astronomers from 30 countries, 20% of the proposals being from ESA Member States. Observing time on the HST may well prove to be the most highly valued professional asset for today's astronomers.

The final selections completed an intensive review process that involved 62 scientists, 10 of whom were from ESA Member States.

The HST, which is a joint ESA/NASA project, is scheduled for launch in March 1990. It is the largest and most expensive spacecraft ever built. ESA's contributions to the project are the Faint-Object Camera, and the large solar arrays that will power this unique observatory (see detailed article in ESA Bulletin No. 58, pp. 90—100).

The new telescope will be capable of resolving accuracies approaching 0.007 arcseconds — good enough to recognise a human face from a distance of more than 100 km. The high-resolution cameras will be able to pinpoint objects 50 times weaker, with details ten times smaller, than Earth-based telescopes. This means that it will soon be possible to study celestial objects 14 billion light years away from Earth.

Meteosat-4 Officially Handed Over to Eumetsat

Dr. John Morgan (right) receives the first Meteosat-4 image from Prof. Reimar Lüst

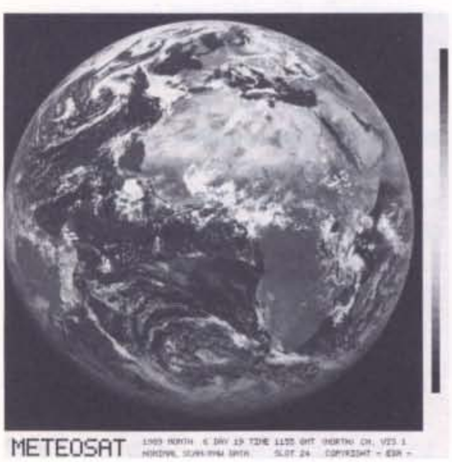
In a ceremony at the Akademie für Tonkunst in Darmstadt (D) at which Eumetsat celebrated its Third Anniversary on 19 June 1989, ESA handed over official responsibility for the Meteosat-4 meteorological satellite to Eumetsat.

Prof. Reimar Lüst, ESA's Director General, symbolically presented Dr. John Morgan, Director of Eumetsat, with a model of the spacecraft and a copy of the first operational picture taken by Meteosat-4 on 19 June. Prof. Lüst took this opportunity to underline that Darmstadt is one of the places where efficient European cooperation in space is demonstrated through spectacular projects like Meteosat, the pictures from which are seen every evening by millions of television viewers throughout Europe.

Meteosat-4 (MOP-1) is Eumetsat's first European meteorological satellite. It follows three pre-operational satellites, also launched by ESA, which have become indispensable tools for modern meteorology in Europe. The spacecraft was built by Aerospatiale in Cannes (F) as prime contractor, with MBB, MSS, Selenia Spazio, ETCA, Matra, IGG, ANT and SEP as the main contractors.

Meteosat-5 will follow about 12 months later and Meteosat-6 in the 1992—1994 time frame. This launch schedule has been selected to provide sufficient in-orbit backup to guarantee uninterrupted data availability.

While Eumetsat funds and administers this programme, ESA continues to execute and supervise the building of the satellites and to operate and control them via its European Space Operations Centre (ESOC) in Darmstadt. ESOC also acquires and processes the images for Eumetsat and distributes them, together with other special meteorological products, via the satellite to the users.



Exosat Database Goes On-Line

On 10 April 1989, the preliminary version of ESA's Exosat-results database was made available to the scientific community by remote access. The database has been developed in the three years since the satellite's orbital mission came to an end, by the Exosat Observatory Team.

The database contains the results, data products and analysis programs from the Exosat Observatory and allows them to be remotely accessed via SPAN (the Space Physics Analysis Network). It provides: a listing of the key results from each observation; plots of light curves, spectra and images; extraction of data products; and possibilities for further analysis. Analysis application software can be supplied to users and installed on request.

The following are currently available from Exosat's observation programme:
- all targets detected in the inner 6 arcmin of the low-energy telescope; outside this region there are many spurious sources arising from extended sources, use of the diamond filter and background uncertainties;
- for the medium-energy telescope, about 60% of the observations; the remainder are being carefully checked and are being put on line at a rate of about 10% per month;
- for the gas scintillator, 100% of the observations.

European Centre for Space Law Inaugurated

The European Centre for Space Law (ECSL) was officially inaugurated on 12 May 1989 by the Agency's Director General, Prof. Reimar Lüst, at ESA Headquarters in Paris.

ECSL, supported by representatives of ESA's Member States, academics, space organisations, industry and private practitioners, has been established because ESA saw the need to strengthen Europe's space law profile. The centre will 'bridge the gap' between the important technological progress made over the past years and the need for legal means to control it.

As an example, major projects such as the Hermes spaceplane and the Columbus contribution to Space Station Freedom are presenting legal questions that need addressing. Also, the complexities of regulating transnational aspects of telecommunications satellites in Europe require careful legal consideration.

ECSL will function via an administrative unit at ESA Headquarters and a network of national points of contact.

The groundwork has already been laid by ESA with the setting up of an electronic space-law database (ESALEX) to serve legal academics and practitioners across Europe via IRS (ESA's Information Retrieval Service), and the publication in April by ESA Publications Division of the first ECSL newsletter (ECSL News).

ECSL is a European organisation in which membership is open to interested persons within any ESA Member State's territory who are ESA Member-State nationals or are permanently resident in an ESA Member State and who are not employed by non-European firms or other entities.

Application Forms for membership and other information are available from:

Mrs. E. Vermeer, ECSL, 8—10 rue Mario Nikis, 75738 Paris 15, France.

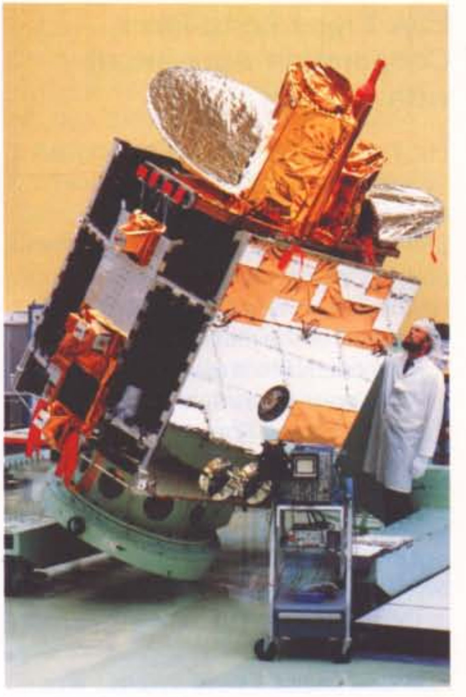
Ariane-4 Launch (V31) Total Success

The first launch of the most powerful version of Europe's Ariane launcher took place on Monday 5 June 1989 from Kourou, in French Guiana, putting into orbit two satellites.

With the successful launch of this Ariane-44L vehicle, with its four strap-on liquid boosters, the German telecommunications satellite DFS Kopernikus, and the Japanese communications satellite SCS-1 Superbird were placed safely into geostationary transfer orbit.

DFS Kopernikus 1 is a telecommunications spacecraft built for the German PTT which will provide the Federal Republic of Germany and West Berlin with multiple services. Superbird-A is a telecommunications satellite for the Space Communications Corporation of Japan which will provide national telecommunications service and video coverage for the Japanese main islands and Okinawa.

The two satellites weighed a total of 3907 kg at launch. The new Ariane vehicle is in fact capable of launching payloads weighing up to 4200 kg into geostationary transfer orbit. By comparison, Ariane-3 that it supercedes could carry up to 2700 kg.



The DFS Kopernikus-1 spacecraft

ESA Meets with NASDA

ESA had its 14th Meeting with the National Space Development Agency of Japan (NASDA) in Tokyo on 30 May/1 June 1989, with discussions taking place on both the current space activities of the respective agencies and their future programmes.

As a result of the Meeting, many areas of cooperation between the two organisations will be strengthened, such as:

- manned spaceflight, particularly between the Japanese Experiment Module and the Columbus Programme
- earth observation, including the mutual exchange of data on major environmental concerns and pollution monitoring
- use of satellite earth stations, with the cooperation established in 1987 for MOS-1 being extended to include MOS-1B (1990) and JERS-1 (1992)
- space science, developed in the framework of the Inter-agency Consultative Group (IACG)
- telecommunications, with the exchange of information on communications and broadcasting satellite programmes and the exploring of possibilities for compatibility of data relay satellite systems.

The Meeting also reinforced collaboration in the framework and planning of activities for the International Space Year (1992).

A staff-exchange programme will serve as an additional tool for strengthening cooperation between ESA and NASDA. Engineers from each organisation will spend a year in the other's establishments to further understanding and the exchange of information between the two agencies.

ESA Signs Long-Term Cooperation Agreement with Canada

For the first time, Canada has signed a ten-year Cooperative Agreement with the Agency, extending until 1998. Canadian Minister of Industry, Science and Technology, the Honourable Harvie Andre, and ESA's Director General Prof. Reimar Lüst signed the Agreement in Montreal on 31 May. Dr. Larkin Kerwin, President of the Canadian Space Agency was also present.

Canada has been an ESA 'Observer' since the early 1970s and has signed two five-year Cooperative Agreements in the intervening years.

ESA and Canada have several important common interests, particularly remote sensing and communications. Canada is therefore taking a key role in major ESA programmes such as Olympus, where it is the third largest participant and will be involved in the post-launch experiment phase, and ERS-1, for which a Canadian company is the prime contractor for the ground segment (including a planned station at Gatineau in Quebec).

The new extended agreement is comparable to the previous ones in that:
- Canada is represented on the ESA Council
- Canada will contribute annually to the ESA General Budget on a progressive basis
- Canada's participation in optional programmes is in accordance with detailed arrangements concluded in each case between Canada and the Agency.

Space Commerce 90: Greater Involvement of Industrial Users

The third meeting of Space Commerce 90, the biennial International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, will take place from 26 to 29 March 1990, in Montreux, Switzerland.

The Steering and Advisory Committees met for two days at ESA Headquarters in Paris on 7 and 8 June to finalise the Conference Programme and arrangements.

After two successful events in 1986 and 1988, Space Commerce is now recognised worldwide as an essential link in the chain of events that contribute to the rapid and appropriate dissemination of information on commercial opportunities to the potential space user.

Further information can be obtained from:
Space Commerce 90
PO Box 97
CH-1820 Montreux

Tel. 41 21 963 23 54
Fax 41 21 963 78 95

Space Commerce '90 Steering and Advisory Committee Members, who met at ESA Headquarters on 7/8 June

SAFISY Meeting Hosted by ESA

Prof. Reimar Lüst, ESA's Director General, welcomed participants to the second meeting of the Space Agency Forum on the International Space Year (SAFISY) 1992, hosted by ESA on 2 and 3 May 1989 at ESRIN in Frascati (I). The SAFISY members represent some 20 industrialised and developing countries, as well as a number of international and national agencies and organisations conducting civil space activities.

The concept for the International Space Year (ISY) was launched by the United States in 1985 and became a reality last year at the 'ISY Mission to Planet Earth Conference'.

The representatives of the space agencies and national governments, together with the International Council of Scientific Unions (ICSU), and the International Astronautical Federation (IAF), were addressed in Frascati by SAFISY's Chairman Prof. Hubert Curien, French Minister of Research and Technology. They in turn presented their plans for ISY 1992 and discussed possible means of coordinating ISY activities.

There was a common concern, voiced by all speakers, that much more scientific information is needed concerning the Earth and its environment, especially those phenomena that can seriously affect human habitation. The use of satellite remote-sensing methods for gathering data and monitoring events was strongly encouraged. There was agreement that this is a global problem requiring global resources and international collaboration if the fullest possible knowledge is to be gained on which to base remedial action for such potential hazards as the greenhouse effect, changes in land coverage, ozone-layer degradation, and deforestation.

The thirteen winners in ESA's Essay Competition who received their prizes during the ESA Council Dinner on 28 June 1989 were, from left to right: J. Aase (Norway), A. Lopez (Spain), Ch. Domain (France), S. Sauter (Germany), T. Siegfried (Switzerland), M. Nielsen (Denmark), Th. Posch (Austria), P. Buist (Netherlands), K. Gantois (Belgium), J. Cunniffe (Ireland), M. Hagvall (Sweden), S. de Agostini (Italy), L. Backfolk (Finland).

A. Gentles (UK), the fourteenth winner, was unable to attend the Dinner due to a previously scheduled examination.

With the winners, in the front row, are: Prof. R.M. Bonnet, Director of the ESA Scientific Programme, Prof. R. Lüst, ESA's Director General, Mr H. Grage, Chairman of the ESA Council, and Dr. M.C.E. Huber, Head of ESA's Space Science Department.

Essay Competition Winners Visit ESTEC

Fourteen young space-interested Europeans visited ESTEC in Noordwijk (NL) at ESA's invitation during the days of the recent Council Meeting on 28 and 29 June 1989. They were there to receive their awards as the national winners of the Agency's Essay Competition based on the theme 'Astronomy from Space' — chosen because of the impending launches of two astronomical missions: ESA's Hipparcos astrometry satellite and the ESA/NASA Hubble Space Telescope (HST).

Over 300 entries were submitted in the 14 countries that participate in ESA's Scientific Programme and a national winner was selected in each. From these 14, a jury (consisting of the Chairman and a Member of the Agency's Space Science Advisory Committee, and three ESA staff members) selected three winners who will be invited by the Agency to visit the Space-Telescope Science Institute (Baltimore) and the HST Scientific Operations Center (Greenbelt) in the United States, and two winners to travel to Kourou in French Guiana to attend the Hipparcos launch.

The winners were presented with their prizes by Mr. H. Grage, Chairman of the ESA Council, during the formal Council Dinner on the evening of 28 June.

Earlier that day they had attended the Opening Session of the 87th Council, thereby gaining some first-hand experience of the workings of the Agency. In the afternoon, they visited some of the specialised laboratories and test facilities at ESTEC and looked over the Columbus Test Bed.

On 29 June, they attended a presentation on scientific and technical writing, where they were asked as an exercise to briefly describe their impressions of ESTEC. Aside from their comments on the novel technical installations, many remarked on the multinational European atmosphere. One of the winners wrote:
'I was impressed by the working atmosphere, in particular the international collaboration. I discovered that scientists are people of flesh and blood, friendly and enthusiastic. Above all, I was impressed by the European spirit that is evident in all aspects of the work done at ESTEC. Here, in ESTEC, you can already find a small piece of a united Europe!'

Later this year, all the national winners will be invited to visit the Space-Telescope European Coordinating Facility, located at the European Southern Observatory in Garching, Germany, where they will see what is involved in supporting and exploiting a modern space observatory.

The two top winners of ESA's Essay Competition, who were invited to attend the Hipparcos launch, are seen here being congratulated by Minister R.W. de Korte of The Netherlands. Sabine Sauter's (Germany) essay was entitled 'The Supernova SN 1987A' and Christophe Domain's (France) 'L'astronomie spatiale'.

ESA Establishments

In recent weeks, staff at the ESA Establishments in the other European countries (the celebrations in Paris were reported in the last issue of ESA Bulletin) have been celebrating the Agency's Silver Jubilee with a combination of formal functions, and less formal activities coordinated by staff and the sports and special-interest clubs at the various sites.

The accompanying brief reports and photographs record a selection of the main events that took place at ESTEC in Noordwijk (NL) on Friday 30 June and Saturday 1 July, at ESOC in Darmstadt (D) on 5 June, and at ESRIN in Frascati (I) on 27/28 May and 8 June.

at ESOC

Following what the local Darmstadt press had described as the 'Agency's Official Silver Jubilee Celebration via satellite on 19 April', ESOC staff celebrated this event in more relaxed style on 5 June.

The highlight of the day was the presentation of the 'ESOC 25 Years Revue' by the ESOC Theatre Group, which parodied events that have punctuated the years of the Agency's development in general, and those at ESOC in particular, in a series of humorous sketches, songs and dances, reflected in the accompanying selection of photographs.

▲ *Silver Jubilee Revue, by ESOC Theatre Group* ▼

Staff party

Celebrate Silver Jubilee

at ESRIN

ESA's Silver Jubilee celebrations started early in the year at ESRIN with the celebration of the 25th Anniversary of the NASA/ESA Information Exchange Agreement. This Agreement, which came into force in 1964, first gave Europe access to an important source of space information for the rapidly developing European space community. Through the building up of the necessary infrastructure to provide online access to this information, and the subsequent addition of other new databases, the ESRO/ELDO Space Documentation Service was able to become a forerunner in Europe in online information retrieval technology, and develop into the well-known ESA/IRS service that it is today.

NASA was represented at the celebration by Mr P. Thibideau, its Manager of International Scientific and Technological Information Activities. Other speakers included Mr Y. Demerliac, representing Eurospace, Mr J.M. Czermak, Chairman of the ESA Documentation Advisory Group, and Dr. H. Strub, Chairman of the ESA Administrative and Finance Committee (AFC).

During this gathering, a NASA Distinguished Public Service Medal was presented to Irene Mader, Head of the Aerospace Data Office at ESRIN, for her long-standing dedication to the smooth execution of the Exchange Agreement.

The second Silver Jubilee celebration took the form of a weekend of staff activities organised by the local staff association. Early on the morning of Saturday 27 May, ESRIN joggers and superjoggers gathered on the shores of Lake Albano for a 5 km and an 11 km competition, respectively, to be followed by a canoe race. The afternoon was spent at the ESRIN sports club with tennis, football and ping-pong tournaments, and specially organised games for the children. A baking competition resulted in the cakes being eaten before they could be judged! Dancing went on late into the night.

Sunday 28 May was dedicated to a visit to the Fucino satellite-receiving station, where satellite-tracking demonstrations and a presentation on space-imagery applications were particular highlights for the participating staff and their families..

A formal dinner to celebrate ESA's Silver Jubilee took place on 8 June, to coincide with the holding at ESRIN of the 111th Meeting of the Agency's Administrative and Finance Committee (AFC). A pleasant restaurant in the Frascati area provided the backdrop for an evening of good food, music and dancing.

The Silver Jubilee celebrations at the Agency's Italian Establishment will be rounded off during the last week of September with an exhibition with the theme '25 Years of Europe in Space', with the main accent on ESRIN's contributions.

Children's party

Canoeing on Lake Albano

Irene Mader receives her award from Mr P. Thibideau

at ESRIN

Staff gather for the formal dinner...

...and dancing

at ESTEC

ESTEC celebrated ESA's Silver Jubilee on the afternoon of Friday 30 June and on Saturday 1 July 1989. Most of the ESTEC Clubs organised sports and entertainment activities for staff and their families.

One of the main sporting events was the 3rd ESTEC Fun-Run, which was supported by a substantial turnout of teams representing the numerous divisions, sections and projects at the Establishment, each striving to make the most laps of the site in an hour.

On Friday night, members of the ESTEC Music and Theatre Clubs entertained guests with a potpourri of music and sketches.

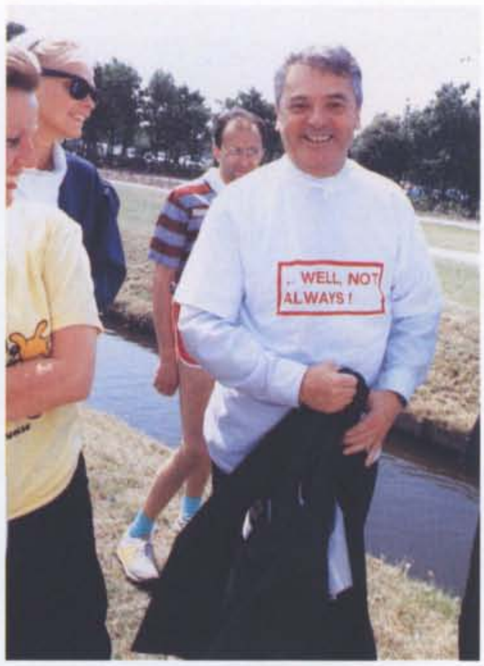
On Saturday, canoe racing, football, golf, volleyball, simulated sailing and windsurfing, aerobics, martial arts and scuba diving demonstrations and competitions were the order of the day.

Other staff-organised activities included an international food fair and an exhibition of photographs by staff documenting 25 years of ESTEC.

For those family members who wanted to find out how satellites are tested or what the Columbus Attached Laboratory will look like, small guided tours of the ESTEC Spacecraft Environmental Test Facilities and the Columbus Crew Work Station Test Bed were organised.

The more formal highlight of the ESTEC celebrations was a mid-summer-night party on the Saturday evening.

The Fun-Run



The sports prize-giving by Mr. Marius Le Fèvre, Director of ESTEC

ESTEC Martial Arts Club demonstration

Scuba-diving lessons

The International Food Fair

The International Food Fair

Visitors to the ESTEC Test Facilities

The musical potpourri

Late News Item

ESA's Hipparcos Scientific Satellite Launched

Hipparcos, ESA's new scientific astrometry satellite, was successfully launched from Kourou, French Guiana, on 8 August.

An Ariane-4 launcher (V-33) placed Hipparcos (weighing 1130 kg), and the German direct-television-broadcast satellite TV-Sat 2, into a geostationary transfer orbit (GTO) with perigee 200.5 km, apogee 35 894 km and inclination 6.89°.

Real-time data analysis began at the European Space Operations Centre (ESOC) in Darmstadt (W. Germany) 24 mins after launch, when the Centre assumed control of the Hipparcos mission and its Malindi ground station acquired the first telemetry data.

Within the first hour of operations, some forty commands were uplinked to the satellite and five ranging measurements were successfully completed. In addition, the initial reconfigurations of the spacecraft's telecommunications, attitude and orbit control, heater, and active nutation damping systems was completed. Sensor measurements showed that Hipparcos was spinning at 6.91 rpm, and its solar aspect angle was 110°, both parameters being close to nominal.

The Hipparcos satellite has been developed by ESA to track and measure the positions of the stars in our Galaxy with previously unachievable accuracy. The final product of the mission will be a unique Star Catalogue, which it is planned to make available to the scientific community in 1995.

A detailed description of the Hipparcos mission can be found in the May 1989 issue of ESA Bulletin (No. 58).

The successful dual launch of Hipparcos and TV-Sat 2 means that Arianespace has now launched a total of 24 satellites in just 23 months.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 13, No. 1:

MOBILE COMMUNICATIONS BY SATELLITE — RESULTS OF FIELD TRIALS CONDUCTED IN EUROPE WITH THE PRODAT SYSTEM
ROGARD R, JONGEJANS A & LOISY C

ARIANE-5 STRUCTURAL DESIGN AND DEVELOPMENT
GONZALEZ BLAZQUEZ A L

SPACELAB-D1 OFFGASSING EXPERIMENT (SOGS)
JUDD M D, QUEMENER J A & SCHUERMANNS H

HELIOCENTRIC RADIO-RELAY LINKS — THE FUTURE SYSTEM FOR RELIABLE COMMUNICATIONS INSIDE THE SOLAR SYSTEM?
MERCADER DEL RIO L

PULSE-WIDTH-MODULATION (PWM) CONDUCTANCE CONTROL
O'SULLIVAN D, SPRUIJT H & CRAUSAZ A

ESA Special Publications

ESA SP-285 // (VOL. I) XII + 402 PAGES
INTERNATIONAL SCHOOL AND WORKSHOP ON PLASMA ASTROPHYSICS (JANUARY 1989)
GUYENNE T D & HUNT J J (EDS)

ESA SP-285 // (VOL. II) X + 324 PAGES
INTERNATIONAL WORKSHOP ON RECONNECTION IN SPACE PLASMA (JANUARY 1989)
GUYENNE T D & HUNT J J (EDS)

ESA SP-292 // XXXXII + 488 PAGES
OLYMPUS UTILISATION CONFERENCE (MAY 1989)
SLIWA R & BATTRICK B (EDS)

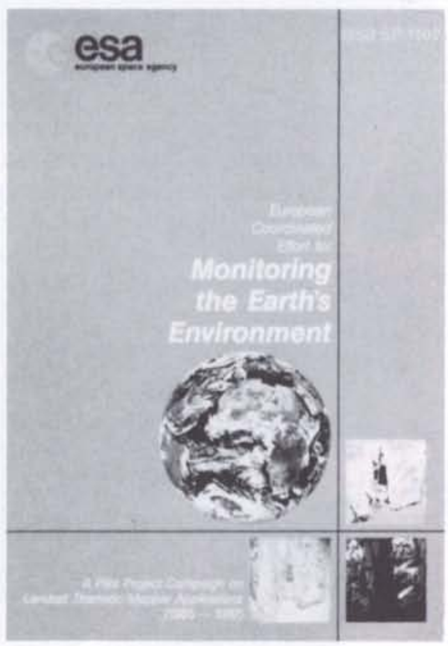
ESA SP-298 // IX + 188 PAGES
WORKSHOP ON FLIGHT OPPORTUNITIES FOR SMALL PAYLOADS (MAY 1989)
DAVID V & GUYENNE T D (EDS)

ESA SP-1102 // 343 PAGES
EUROPEAN COORDINATED EFFORT FOR MONITORING THE EARTH'S ENVIRONMENT: A PILOT PROJECT CAMPAIGN ON LANDSAT THEMATIC MAPPER APPLICATIONS (1985-1987)
GUYENNE T D & CALABRESI G (EDS)

ESA SP-1104 // 84 PAGES
THE SOHO MISSION — SCIENTIFIC AND TECHNICAL ASPECTS OF THE INSTRUMENTS (NOVEMBER 1988)
GUYENNE T D (COMPILER)

ESA SP-1106 // 63 PAGES
POTENTIAL CONTRIBUTIONS BY SPACE SYSTEMS TO SOCIO-ECONOMIC ADVANCEMENT IN DEVELOPING COUNTRIES (JUNE 1989)
LONGDON N (ED)

ESA SP-1110 // 127 PAGES
REPORT ON ESA'S SCIENTIFIC SATELLITES (MAY 1989)
TAYLOR B G, BATTRICK B & SLIWA R (EDS)



ESA SP-1111 // (VOL. I) 354 PAGES
THE HIPPARCOS MISSION — PRE-LAUNCH STATUS. VOL. I: THE HIPPARCOS SATELLITE (JUNE 1989)
PERRYMAN M A C & HASSAN H (PUBL. MGR. B BATTRICK)

ESA SP-1111 // (VOL. II) 290 PAGES
THE HIPPARCOS MISSION — PRE-LAUNCH STATUS. VOL. II: THE INPUT CATALOGUE (JUNE 1989)
PERRYMAN M A C & HASSAN H (PUBL. MGR. B. BATTRICK)

ESA SP-1111 // (VOL. III) 515 PAGES
THE HIPPARCOS MISSION — PRE-LAUNCH STATUS. VOL. III: THE DATA REDUCTIONS (JUNE 1989)
PERRYMAN M A C & HASSAN H (PUBL. MGR. B. BATTRICK)

ESA Brochures

ESA BR-58 // 16 PAGES
ESRIN (MARCH 1989)
DAVID V & LONGDON N (EDS)

ESA BR-59 // 40 PAGES
ASTRONOMY FROM SPACE — WINNING ENTRIES FROM AN ESSAY COMPETITION (JUNE 1989)
LANDEAU J (ED)

ESA Newssheets

EARTH OBSERVATION QUARTERLY // 16 PAGES
AVAILABLE IN ENGLISH AND FRENCH (MARCH 1989)
GUYENNE T D & LONGDON N (EDS)

MICROGRAVITY NEWS FROM ESA, VOL. 2, NO. 1 // 24 PAGES
AVAILABLE IN ENGLISH AND FRENCH (MARCH 1989)
DAVID V (ED)

ESA Training Manuals

ESA TM-02 // 141 PAGES
BIOLOGY IN MICROGRAVITY — A GUIDE FOR EXPERIMENTERS (MAY 1989)
BRIARTY L G & KALDEICH B (EDS)

ESA Technical Translations (issued in 1988)

MARCH

ESA TT-1076 // 79 PAGES
COMPARISON OF DIFFERENT KINDS OF COMPACT CROSSFLOW HEAT EXCHANGERS
SIEMENS W, DFVLR, GERMANY

ESA TT-1077 // 79 PAGES
THEORETICAL INVESTIGATIONS OF THREE TURBINE CASCADES USING A 2-D TIME MARCHING PROCEDURE
GIESS P-A, DFVLR, GERMANY

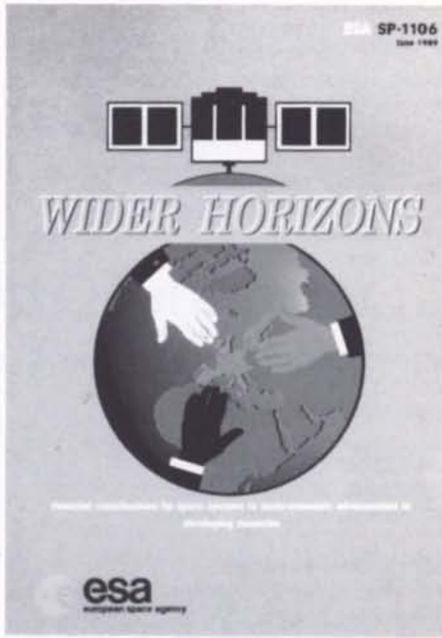
ESA TT-1078 // 142 PAGES
THE EXPERIMENT NAVEX ON SPACELAB MISSION D1 — PLANNING AND EXECUTION
STARKER S, NAU H & HAMMESFAHR J, DFVLR, GERMANY

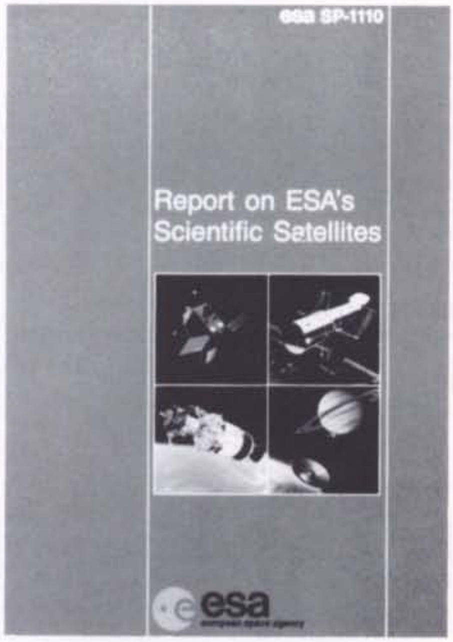
ESA TT-1080 // 58 PAGES
STANDARDIZED ICE ACCRETION THICKNESS AS A FUNCTION OF CLOUD PHYSICS PARAMETERS
HOFFMANN H-E, ROTH R & DEMMEL J, DFVLR, GERMANY

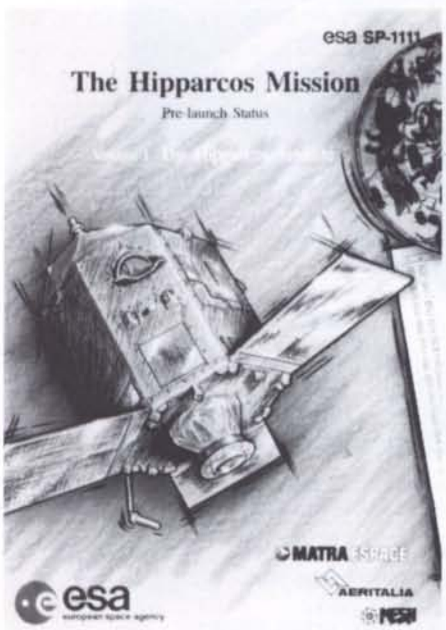
ESA TT-1094 // 56 PAGES
DIGITAL PROCESSING OF FLIGHT TEST DATA OF A HELICOPTER WITHOUT USING ANTI-ALIASING FILTERS
HOLLAND R, DFVLR, GERMANY

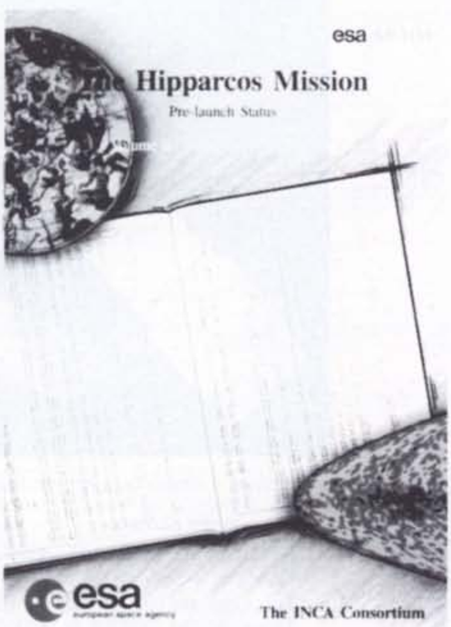
JUNE

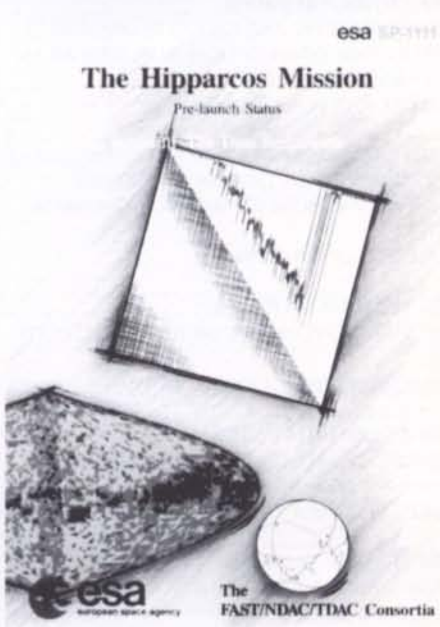
ESA TT-1085 // 43 PAGES
ON EXPERIENCES WITH TWO HOT WIRE INSTRUMENTS FOR MEASURING THE LIQUID WATER CONTENT IN CLOUDS
HOFFMANN H-E, DEMMEL J & LOEBEL H, DFVLR, GERMANY











ESA TT-1087 // 173 PAGES
INVESTIGATION OF LARGE-SCALE IMPACT OF AIR POLLUTION COMPONENTS ON FOREST ECOSYSTEMS IN BAVARIA
PAFFRATH D & PETERS W, DFVLR, GERMANY

ESA TT-1088 // 74 PAGES
LA RECHERCHE AEROSPATIALE, BIMONTHLY BULLETIN, 1987-4
ONERA, FRANCE

ESA TT-1089 // 102 PAGES
NUMERICAL SIMULATION OF THE INTERACTION OF PRESSURE WAVES WITH LAMINAR AND TURBULENT BOUNDARY LAYERS
REISTER H, DFVLR, GERMANY

ESA TT-1090 // 150 PAGES
MODELLING OF PULSED GAS FLOW LASERS
OFFENHAUSER F, DFVLR, GERMANY

ESA TT-1091 // 95 PAGES
THE VISCOUS FLOW ON SURFACES WITH STREAMWISE RIBLETS
BARTENWERFER M & BECHERT D W, DFVLR, GERMANY

ESA TT-1095 // 75 PAGES
LA RECHERCHE AEROSPATIALE, BIMONTHLY BULLETIN, 1987-5
ONERA, FRANCE

ESA TT-1099 // 75 PAGES
ADDITIONAL INVESTIGATIONS IN LANDING PROCESS OF AIRCRAFT — TEST DISTRIBUTIONS
PETERS H-J, DFVLR, GERMANY

ESA TT-1100 // 99 PAGES
INVESTIGATION OF LARGE-SCALE STRUCTURES IN THE NEAR WAKE OF A PARALLEL FLAT PLATE
STRUNCK V, DFVLR, GERMANY

JULY

ESA TT-902 // 123 PAGES
NONLINEAR CONTROL OF A H2/O2-STEAM REACTOR
WOLFMUELLER K, DFVLR, GERMANY

ESA TT-1004 // 38 PAGES
CONSIDERATIONS AND CALCULATIONS FOR APPLICATION OF AN OPTICAL AMPLIFIER AS AN END- AND PRE-AMPLIFIER
MALOTA F, DFVLR, GERMANY

ESA TT-1005 // 90 PAGES
CALCULATIONS OF THE SNR OF A LASER DOPPLER ANEMOMETER WITH A CASSEGRAIN LENS
MALOTA F, DFVLR, GERMANY

ESA TT-1060 // 148 PAGES
INVESTIGATIONS ON THE ENTROPY OF CLOUDY AIR
HAUF T & WEIDNER J, DFVLR, GERMANY

ESA TT-1082 // 315 PAGES
HISTORY OF AEROELASTICITY IN GERMANY FROM THE BEGINNING UNTIL 1945
BUBLITZ P, DFVLR, GERMANY

ESA TT-1102 // 51 PAGES
LA RECHERCHE AEROSPATIALE, BIMONTHLY BULLETIN, 1987-6
ONERA, FRANCE

ESA TT-1103 // 53 PAGES
BEAM QUALITY OF STABLE AND UNSTABLE RESONATORS — A THEORETICAL APPROACH
HALL T, DFVLR, GERMANY

AUGUST

ESA TT-1106 // 92 PAGES
DETERMINATION OF CHARACTERISTIC RADIATION PROPERTIES OF A TORUS ANTENNA
ZINK M, DFVLR, GERMANY

ESA TT-1111 // 65 PAGES
SECURING THE TIME SCALE OF THE NAVEX REFERENCE CLOCK AND RATE DETERMINATIONS BY TIME COMPARISONS WITH THE HELP OF THE GLOBAL POSITIONING SYSTEM (GPS)
NAU H, DFVLR, GERMANY

SEPTEMBER

ESA TT-881 // 46 PAGES
NUMERICAL PREDICTION OF MULTIREACTIVE TURBULENT FLOWS BY AN EULERIAN-LABRANGIAN METHOD
POURBAIX E, ONERA, FRANCE

ESA TT-1030 // 47 PAGES
NUMERICAL SIMULATION OF COMPRESSIBLE HOMOGENEOUS TURBULENCE
DELORME P, ONERA, FRANCE

ESA TT-1086 // 199 PAGES
CONCEPTION AND DISCUSSION OF A MODEL DESCRIBING ICE FORMATION ON VARIOUS OBSTACLES
BRUNET L, ONERA, FRANCE

ESA TT-1093 // 246 PAGES
DAMAGE MECHANICS OF GRAPHITE/EPOXY LAMINATES DURING FATIGUE
PRINZ R ET AL., DFVLR, GERMANY

ESA TT-1097 // 123 PAGES
EXPERIMENTAL INVESTIGATION OF SHOCK-INDUCED DISTURBANCES ON TRANSONIC AIRFOILS
BASLER D, DFVLR, GERMANY

ESA TT-1105 // 175 PAGES
AEROSOL LIDAR FOR ENVIRONMENT PROTECTION AND METEOROLOGY
WERNER C & STREICHER J, DFVLR, GERMANY

ESA TT-1133 // 73 PAGES
LA RECHERCHE AEROSPATIALE, BIMONTHLY BULLETIN, 1988-1
ONERA, FRANCE

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

In Orbit / En orbite

	PROJECT	1989 – 1995	COMMENTS
SCIENT. PROG.	IUE		OPS. FUNDED UNTIL END 1989
APPLICATIONS PROGRAMME	MARECS-A		LEASED TO INMARSAT FOR 10 YEARS
	MARECS-B2		LEASED TO INMARSAT FOR 10 YEARS
	METEOSAT-3		LIFETIME 3 YEARS
	METEOSAT-4		LIFETIME 3 YEARS
	ECS-1		LIFETIME 7 YEARS
	ECS-2		LIFETIME 7 YEARS
	ECS-4		LIFETIME 7 YEARS
	ECS-5		LIFETIME 7 YEARS

Under Development / En cours de réalisation

	PROJECT	1989 – 1995	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
	ULYSSES		MISSION DURATION 4.5 YEARS
	SOLAR TERRESTRIAL SCIENCE PROG. (STSP)		LAUNCHES: SOHO MARCH 1995 CLUSTER DEC. 1995
	HIPPARCOS		LIFETIME 2.5 YEARS
	ISO		LIFETIME 1.5 YEARS
TELECOM. PROGRAMME	OLYMPUS-1		LIFETIME 5 YEARS
	DATA-RELAY SATELLITE (DRS)		SYSTEM OPERATIONAL 1996
	PSDE/SAT-2		READY FOR LAUNCH END 1993
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	ERS-1		
	EARTH OBS. PREPAR. PROG. (EOPP)		
	METEOSAT OPS. PROG.	MOP-1, MOP-2, MOP-3	MOP-3 LAUNCH TO BE DECIDED
	MICROGRAVITY	IML-1, D2, IML-2	
SPACE ST. & PLATF. PROG.	EURECA		
	COLUMBUS	PHASE-1, PHASE-2	3 YEAR INITIAL DEVELOPMENT PHASE
SPACE TRANSPORTATION PROGRAMME	ARIANE-2/3	V28 V30 V32	
	ARIANE-4	V29 V31 V33 V34 V35 V36 V37	OPERATIONAL UNTIL END 1998
	ARIANE-5		FIRST FLIGHT APRIL 1995
	HERMES		3 YEAR INITIAL DEVELOPMENT PHASE
TECH. PROG.	IN-ORBIT TECHNOL. DEMO. PROG. (PH-1)		SEVERAL DIFFERENT CARRIERS USED

= DEFINITION PHASE — > PREPARATORY PHASE — ▨ MAIN DEVELOPMENT PHASE — ▪ STORAGE — ◇ HARDWARE DELIVERIES

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

Météosat

Programme préopérationnel
Pendant le premier semestre, Météosat-P2, rebaptisé Météosat-3, a continué à jouer le rôle de satellite principal. P2 deviendra le satellite de réserve après le lancement de MOP-1 prévu pour le 19 juin 1989.

On prépare actuellement la désorbitation de Météosat-2 qui n'a plus besoin d'être maintenu en réserve.

Expérience LASSO
Les tirs de stations laser travaillant individuellement en direction de l'expérience LASSO ont continué et ont permis de mesurer la distance du satellite géostationnaire avec une précision de 5 à 10 cm.

Les préparatifs de tirs de stations travaillant par deux se poursuivent.

Programme opérationnel
Le satellite géostationnaire MOP-1 a été lancé de Kourou le 6 mars, placé sur orbite quelques jours plus tard et mis en service le 27 avril 1989. Il a transmis d'excellentes images dans le visible, l'infrarouge et le canal vapeur d'eau. Aucune anomalie n'a été détectée lors des essais de recette. Conme cela a déjà été indiqué, MOP-1 (aujourd'hui dénommé Météosat-4) doit prendre les fonctions de satellite principal à partir du 19 juin 1989.

La fabrication de MOP-2 s'achève à l'Aérospatiale (Cannes). Les essais de recette acoustique devraient commencer en août; la revue d'aptitude au vol est prévue pour novembre/décembre et le lancement pour mars 1990.

FIRST OPERATIONAL IMAGE TAKEN BY METEOSAT-4 ON 19 JUNE 1989 AT 08:55 GMT.
ON THE SAME DAY ESA HANDED OVER TO EUMETSAT THE RESPONSIBILITY FOR THE SATELLITE.

First operational image taken by Meteosat-4, on 19 June 1989

Télescope spatial

Le lancement du Télescope spatial Hubble (HST) a été reporté de décembre 1989 à mars 1990 suite à des retards de lancement de la Navette; un vol entre Sunnyvale (Californie) et le centre spatial Kennedy est désormais prévu pour octobre 1989.

Le programme d'essais de recette des panneaux du réseau solaire est arrivé à son terme. L'examen de recette pour le vol a eu lieu début avril et les panneaux ont été expédiés et montés sur le HST à la mi-avril. La puissance de sortie mesurée des générateurs solaires est parfaitement conforme aux spécifications (4,9 kW en début de vie et 4,5 kW en fin de vie).

Chaque mois, on vérifie la chambre de prise de vues pour objets faibles (FOC) déjà montée sur le télescope spatial. Son fonctionnement ne montre aucune modification. Les travaux de validation du logiciel sol de la NASA pour l'exploitation de la FOC se poursuivent.

Ulysse

En 1989, les activités relatives à Ulysse ont repris; on prépare le véhicule spatial pour son lancement prévu pour octobre 1990 à bord de la Navette lors de la mission STS-41. L'accident de Challenger ayant entraîné la dispersion des équipes de l'ESA et de l'industriel ainsi que le report du lancement d'Ulysse, il a fallu recruter de nouveaux ingénieurs pour de nombreux postes-clés dans les secteurs du véhicule proprement dit et dans celui de son exploitation. Pour réduire les incidences de ce changement de personnel sans précédent, il a été décidé de réintégrer le modèle de qualification d'Ulysse, non seulement pour la formation du personnel mais aussi pour vérifier la compatibilité 'système' de tous les unités de vol de réserve. La réintégration et les essais 'système' subséquent, qui se sont déroulés entre janvier et mai 1989, ont été terminés exactement à la date prévue et sans incident majeur. Le modèle de vol du satellite a été déstocké et sa réintégration se poursuit de manière satisfaisante.

A l'ESOC également, les travaux se sont intensifiés pour préparer l'exploitation d'Ulysse après son lancement. L'équipe en place (ESA et industriels) a également souffert de la dispersion du personnel et il a fallu recruter et former de nouveaux ingénieurs. En outre, le calculateur prévu à l'origine pour l'exploitation d'Ulysse sera obsolète avant la fin de la mission en 1995; il a donc été décidé de le remplacer dès maintenant par un

Meteosat

Pre-operational programme

The Meteosat-P2 spacecraft (now re-named Meteosat-3) has continued to be used as the primary satellite during the first half of the year. The scheduled changeover to MOP-1 is planned for 19 June 1989, after which the P2 spacecraft will become the reserve satellite.

Plans are currently being made for de-orbiting Meteosat-F2, which is now no longer required to be on standby.

Lasso experiment

Firings from individual laser stations to the LASSO experiment have continued, enabling the range to the geostationary spacecraft to be measured with an accuracy of 5 to 10 cm.

Preparations for firings from pairs of stations are continuing.

Operational programme

The MOP-1 spacecraft was successfully launched from Kourou on 6 March this year and achieved geosynchronous orbit a few days later. The spacecraft's commissioning was completed on 27 April 1989. Excellent images were produced in the visible, water-vapour and infrared channels. No spacecraft anomalies were found during the commissioning tests. As mentioned above, MOP-1 (now renamed Meteosat-4) is planned to become the operational satellite as of 19 June 1989.

The manufacture of MOP-2 is currently being completed at Aerospatiale in Cannes. Acoustic acceptance tests are expected to be started in August, with the Flight Acceptance Review foreseen for November/December, and launch in March 1990.

Space Telescope

The launch of the Hubble Space Telescope (HST) has been postponed from December 1989 to March 1990 due to Shuttle launch delays, which have resulted in a re-issuing of the Shuttle launch manifest. Shipment of the flight hardware from Sunnyvale (Calif.) to Kennedy Space Centre (Fla.) is now planned for October 1989.

The solar-array wings have successfully completed their acceptance-test programme. The Flight Acceptance Review was held in early April and the wings were shipped and fitted to the HST in mid-April. The array's power output was measured and found to be well within specification (4.9 kW beginning-of-life; 4.5 kW end-of-life).

The Faint-Object Camera, which is already installed in the ST, continues to be checked out each month and shows no variation in performance. Work is continuing on validating the NASA ground software for FOC operation.

Ulysses

1989 has seen a resurgence in activity on the Ulysses spacecraft as preparations have got under way for the launch, in October 1990 on Space Shuttle mission STS-41. The dispersal of the ESA and industrial teams that occurred following the 'Challenger' accident, and the consequent delay in the Ulysses launch, have meant that new engineers were needed for many of the key posts in both the spacecraft and operations areas.

To reduce the impact of this unprecedented change of staffing, it was decided to re-integrate the qualification model of the Ulysses spacecraft. In addition to providing training for the staff, this enabled all the flight-spare units to be checked out for system compatibility. The re-integration and subsequent system testing took place between January and May 1989 and was completed exactly on schedule and without major incident. The flight spacecraft has now been taken out of storage and its re-integration is under way and progressing satisfactorily.

At ESOC also, work has now intensified on preparing for the post-launch operation of Ulysses. The team there (ESA and industrial) has also suffered from redeployment of personnel and some new engineers have needed to be introduced and trained. In addition, the operations computer originally foreseen for Ulysses will be obsolete before the mission is completed in 1995, and it has been decided to replace it now with a more modern machine. This has now been delivered and the modifications needed to both the operational and flight-dynamics software are well advanced.

In the United States, activities are also proceeding smoothly and the successful launch of the Magellan spacecraft to Venus, the first planetary mission for twelve years, has intensified thinking about the Galileo and Ulysses missions, both of which are due for launch before the end of 1990. After some minor perturbations, work is now proceeding smoothly on both the qualification testing and flight production of the PAM-S vehicle, which will perform the final boost towards Jupiter. Similarly, production of the IUS and the necessary modifications to the 'Atlantis' Orbiter, designated to carry the Ulysses payload, are all proceeding on schedule.

Finally, the experiments, which are the reason for all of the other activities, have all been tested and the flight-spares successfully integrated into the qualification-model spacecraft. All of the flight units are prepared and delivery to the Ulysses Prime Contractor for integration into the flight spacecraft starts on 12 June. At the present time, therefore, all seems to be on course for a successful launch on 5 October 1990.

ISO

All satellite design activities are geared to freezing the system and subsystem design baseline for the System Design Review (SDR), to be completed in early July. The SDR is being preceded by all the usual lower-level reviews: successful reviews for all mechanical subsystems allowed release for manufacture, while those for the payload module allowed release for integration of its structural/thermal model. Most design reviews of the electrical subsystems have to be completed in June to allow release for manufacture of the qualification-module units. The most critical items requiring a special effort are: to ensure satellite pointing performance with an adequate margin; to ensure an adequate mass margin; and to ensure that the satellite has no critical single-point failures. Doubts about the maturity of the design for the complex attitude-control subsystem remain.

système plus moderne. Le nouvel ordinateur a été livré et les modifications à apporter aux logiciels d'exploitation et de dynamique de vol ont bien progressé.

Aux Etats-Unis, les travaux progressent normalement et le lancement réussi de la sonde Magellan vers Vénus a suscité un regain d'intérêt pour les missions Galileo et Ulysse qui doivent toutes deux être lancées avant la fin 1990. Après quelques problèmes d'ordre mineur, les essais de qualification et la construction du modèle de vol du PAM-S, qui assurera la propulsion finale vers Jupiter, se poursuivent de manière satisfaisante. Il en va de même pour la fabrication de l'IUS et des modifications nécessaires à la Navette Atlantis pour qu'elle puisse emporter la charge utile Ulysse. Enfin, les expériences qui sont la raison d'être de toutes les autres activités ont bien entendu été toutes vérifiées et les réserves de vol ont été intégrées au modèle de qualification du véhicule spatial. Toutes les unités de vol sont prêtes et les livraisons au Maître d'oeuvre d'Ulysse pour intégration dans le modèle de vol du véhicule spatial ont débuté le 12 juin. Pour l'heure, tout semble donc en ordre en vue du lancement fixé au 5 octobre 1990

ISO

Toutes les activités liées à la conception du satellite ont pour objectif de figer la conception de référence du système et des sous-systèmes en vue de la Revue de conception du système (SDR) qui doit être terminée début juillet. Celle-ci est précédée par toutes les revues de niveau inférieur: pour ce qui concerne tous les sous-systèmes mécaniques, les bons résultats ont permis d'en engager la fabrication; quant au module de charge utile, autorisation a été donnée de passer à l'intégration de son modèle structurel/thermique. Les revues des sous-systèmes électriques doivent pour la plupart être terminées en juin pour que puisse commencer la fabrication des unités du modèle de qualification. Un effort particulier doit être fait sur les points les plus délicats, à savoir: assurer le pointage du satellite avec une marge adéquate, obtenir une marge de masse suffisante et veiller à ce que le satellite n'ait pas de points critiques de défaillance. On reste préoccupé par la complexité de la conception du sous-système d'orientation. Les activités liées au matériel vont en s'accélérant en préparation du démarrage de l'intégration du modèle structurel/thermique. L'ensemble du matériel mécanique du module de charge utile subit les derniers essais avant son intégration en juin. La structure du module de service est en cours de fabrication; de nombreux sous-ensembles, comme la structure de l'écran solaire et le réservoir d'hydrazine du sous-système de commande à réaction, ont été livrés. La livraison des équipements mécaniques de soutien sol est en cours. La conception de tous les sous-systèmes électriques est soumise aux essais sur des modèles de laboratoire.

Le problème le plus délicat à résoudre a été celui de la réalisation du miroir primaire du télescope dont le polissage a été une opération très difficile et longue pour obtenir la qualité de surface recherchée; il a ensuite fallu l'étalonner à une température de 6 K proche du zéro absolu. La transformation de l'installation d'étalonnage optique pour atteindre des températures aussi basses et pour limiter les déformations du miroir à moins de 0,05 μ a posé de nombreux problèmes de mise au point. Les premiers résultats des essais menés en mai sont satisfaisants. Parallèlement, il fallait modifier la conception de l'interface de montage du miroir pour réduire les contraintes dans le miroir même. Ce changement de conception est en cours de validation. Ces deux problèmes ont retardé considérablement les travaux de développement du télescope.

Le calendrier d'ensemble du projet est très critique et tous les efforts sont faits pour rattraper les retards. Il a donc fallu renoncer à intégrer dans le module de charge utile le modèle structurel/thermique du télescope et passer directement à l'intégration du modèle de qualification. Une maquette du télescope de masse identique sera donc integrée dans le modèle structurel/thermique du module de charge utile. Toutes les activités de conception ont souffert d'un retard de plusieurs mois. La date de lancement reste inchangée mais la marge de calendrier a déjà été pratiquement entièrement utilisée. Le calendrier général du programme est à l'examen, l'objectif étant de recréer le volant de manoeuvre nécessaire.

Instruments scientifiques

Les travaux relatifs à tous les instruments scientifiques progressent normalement.

Les maquettes inertes pour essais thermiques, d'alignement et de simulation de masse sont presque prêtes pour la livraison. Les résultats des revues de conception de tous les instruments ont permis d'engager la fabrication de modèles d'identification et de qualification. Dans tous les cas, le calendrier est critique et le fournisseur commun de plusieurs types de détecteurs spéciaux à infrarouge de trois instruments est surchargé de travail.

Il est très préoccupant que trois groupes 'instruments' n'aient pas confirmé la fourniture pour le télescope de certaines unités de rechange au plan focal. En cas de défaillance d'une unité de vol, l'absence de ces rechanges augmenterait considérablement les risques de retards et aurait pour conséquence d'accroître le coût total du projet. Les discussions se poursuivent avec les chercheurs principaux.

Secteur sol

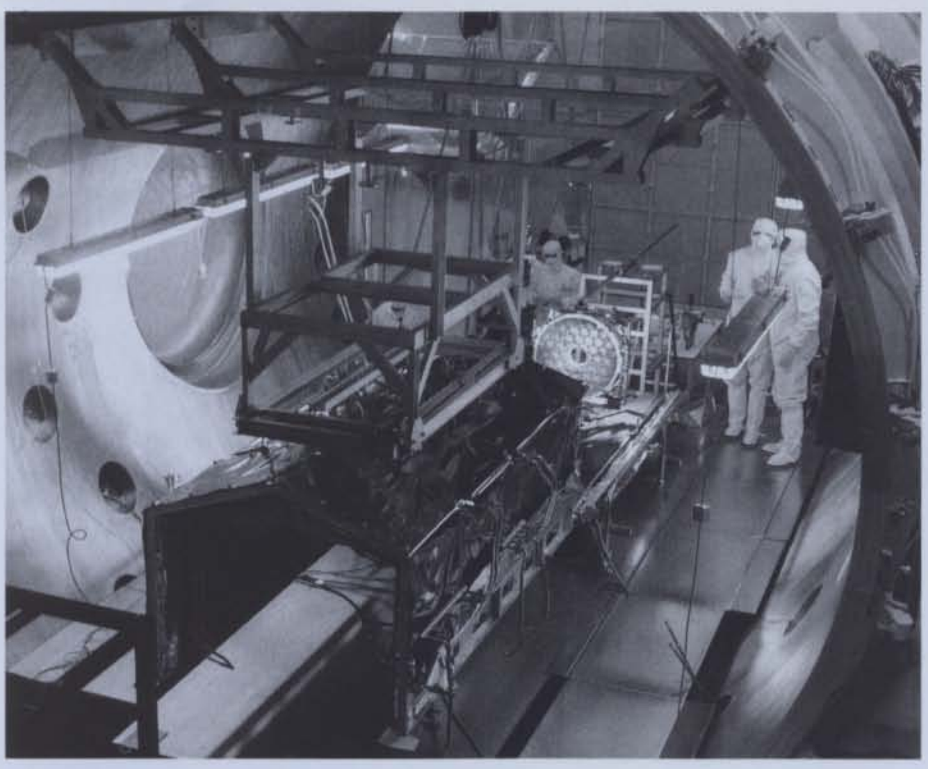
En février, la revue de définition du secteur sol a confirmé la faisabilité du concept global de l'observatoire et la compatibilité de tous les éléments fournis par l'ESOC à Darmstadt pour l'exploitation du satellite ainsi que par le Département 'Science spatiale' de l'ESA et les chercheurs principaux pour la conduite de l'observatoire. La forte incitation à introduire une harmonie entre tous les éléments a porté ses fruits et on peut désormais passer au niveau suivant de la définition détaillée des impératifs. Un prototype de logiciel commun a été réalisé avec succès; il sera utilisé pour les essais d'instruments, puis pour ceux du satellite et pour les opérations en vol.

On recherche actuellement des moyens qui permettraient d'augmenter considérablement le rendement scientifique en mettant à la disposition de la mission une deuxième station sol.

ERS

Après avoir subi tous les essais de recette, le modèle de vol de la plate-forme a été livré fin 1988.

Après la livraison du modèle de



Test set-up at Institut d'Astrophysique de Liège (B) for the ISO satellite's primary mirror

The hardware activities are proceeding with strong momentum in preparation for the start of integration of the structural/thermal model. All mechanical hardware for the payload module is in final testing prior to starting module integration in June. The structure of the service module is being manufactured, and many subassemblies, including the sunshield structure and the hydrazine reaction-control-subsystem tank, have been delivered. Delivery of mechanical ground-support equipment items is now starting. All electrical subsystem designs are in breadboard testing.

The most challenging development problem was that of the telescope primary mirror. It proved extremely difficult and time-consuming to polish the mirror to the required surface quality and then to calibrate it at a temperature of 6 K, close to absolute zero. The conversion of the optical calibration facility to provide such low temperatures and to limit physical movement of the mirror to less than 0.05 micron involved many teething problems. The test conducted in May gave good preliminary results. In addition, there was a parallel problem in that the design of the mirror mounting interface had to be modified to reduce stresses in the mirror itself; this design change is being validated. Together, these two problems have caused considerable delay in the telescope's development.

The overall project schedule is very critical and stringent efforts are being made to recover delays whenever they occur. The long delay in the telescope forced a decision to delay its integration into the payload module from its structural/thermal model to its qualification model. A mass dummy of the telescope will therefore be built into the structural/thermal model payload module. All design activities have suffered a delay of several months. The launch date remains unchanged, but the schedule buffer has virtually been consumed. The overall programme schedule is under review, the aim being to re-create the necessary contingency.

Scientific instruments
Progress on all scientific instruments is good.

The alignment/thermal/mass dummies are almost ready for delivery. Design reviews for all instruments have permitted release for manufacture of the engineering/qualification models. Two concerns are that the schedule is critical in all cases, and that the common supplier of a wide variety of special infrared detectors for three instruments is overloaded.

A major concern is that three instrument groups have not confirmed the supply of dedicated-spare focal-plane units for the telescope. The absence of such spares to replace a possible failed flight unit would considerably increase risk to the schedule and hence the total cost of the project. Discussions are continuing with the Principal Investigators.

Ground segment
The ground-segment definition review held in February confirmed the feasibility of the observatory's overall concept, and compatibility of all the elements provided by ESOC in Darmstadt for spacecraft operations, and by ESA Space Science Department and the Principal Investigators for observatory operations. The strong drive to introduce commonality for all the elements was successful and the stage is now set for the next level of detailed requirements definition. Prototyping of common software development for instrument testing and for re-use during satellite testing and flight operations was highly successful.

Methods are being explored for considerably increasing the scientific return by adding a second ground station for the mission.

ERS

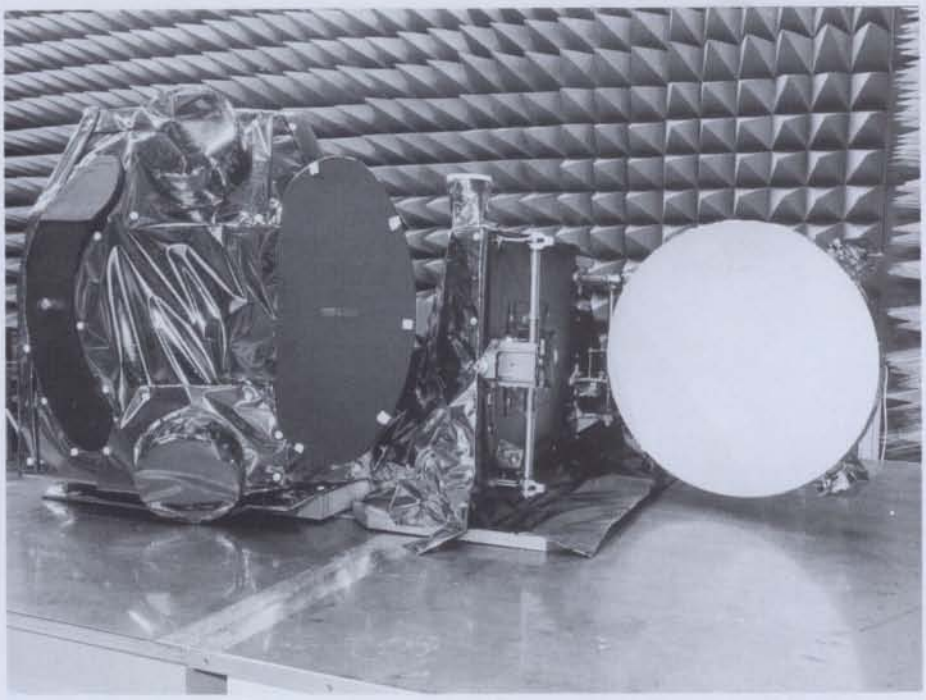
The flight-model platform has passed all its acceptance tests and was delivered at the end of 1988.

Following the delivery of the engineering model of the Active Microwave Instrument (AMI), payload integration and functional testing have progressed well. Thermal-balance and thermal-vacuum testing at ESTEC, using the Large Solar-Simulation facility, is expected to take place in June/July 1989.

Flight-model instruments are progressing, with deliveries, including that of the AMI, expected between June and September 1989.

The Qualification Results Review is foreseen for June 1989.

Work on the ground-segment facilities is



Flight-model Along-Track Scanning Radiometer (ATSR) and microwave sounder (right) for ERS-1 during EMC testing at ESTEC (NL) in February 1989

qualification du détecteur actif à hyperfréquences (AMI), l'intégration de la charge utile et les essais fonctionnels ont progressé de manière satisfaisante. Les essais d'équilibrage de température et les essais sous vide thermiques menés dans le grand simulateur solaire de l'ESTEC sont prévus pour juin/juillet 1989.

Les modèles de vol des instruments, y compris l'AMI, devraient être livrés entre juin et septembre 1989.

La revue des résultats de qualification est escomptée pour juin 1989.

Les travaux sur les installations du secteur sol se déroulent conformément au calendrier. Une étape importante a été franchie avec l'achèvement des essais de recette et la livraison, en mai 1989, de la station ERS de Kiruna.

Earthnet

Toutes les stations sol du réseau ont poursuivi l'acquisition, l'archivage, le traitement et la distribution des données Landsat, MOS-1 et Tiros. Les activités des stations de Kiruna et Fucino peuvent être désormais suivies directement de Frascati au moyen de liaisons terrestres.

Les services Landsat viennent d'être augmentés avec l'introduction de nouveaux produits de l'instrument de cartographie thématique (TM) comme la visualisation rapide et les scènes à recadrage variable à haute résolution. En outre, le catalogue est désormais actualisé tous les jours.

Les chercheurs principaux ont désormais accès aux données MOS-1, brutes et corrigées des erreurs de système au moyen d'un prototype installé à Frascati. Des chaînes complètes de traitement de données conçues pour que les stations fassent elles-mêmes le traitement sont en cours de fabrication.

L'antenne de la station de Maspalomas a été dotée d'un dispositif de basculement pour les passages au zénith. La chaîne de traitement des données Spot (financée par la CEE) a été installée. Elle peut fournir des produits à visualisation rapide, des informations 'catalogue' et des produits jusqu'au niveau standard Spot-1A et 1B. L'acquisition de données se fait dans le cadre d'un accord avec la CEE.

ERS-1

Les études de conception architecturale des services centraux des utilisateurs et de consultation rapide ERS-1 à Frascati étant terminées, les contrats de réalisation des sous-systèmes de télécommunications et d'interfaces vers l'extérieur ont été passés. Les études d'évaluation de la qualité du radar à synthèse d'ouverture (SAR) et du diffusiomètre ainsi que du suivi des performances à long terme sont terminées. Des progrès satisfaisants ont été accomplis en ce qui concerne l'approvisionnement des chaînes de traitement des produits à livraison rapide pour les stations de Gatineau, Maspalomas et Fucino et le développement des installations de traitement et d'archivage ERS-1. Les modulateurs et démodulateurs des stations ERS-1 ont subi avec succès les essais de recette. Le contrat de définition du système de distribution des produits ERS-1 à livraison rapide vient d'être lancé.

Des contrats ont été passés pour l'exploitation des installations de Fucino, Kiruna, Tromsø, Farnborough, Oberpfaffenhofen et Frascati qui sont intégrées au réseau.

EOPP

Programme d'étude du solide terrestre 'Aristoteles'

Une étude additionnelle consacrée à Aristoteles a débuté en mai 1989. Elle est faite par une équipe industrielle européenne de 17 sociétés sous la conduite de Dornier, Aeritalia, Matra et l'ONERA en étant les principaux acteurs. Elle porte pour l'essentiel sur un certain nombre d'arbitrages au niveau système et sur des options d'instruments et de missions. Les travaux de prédéveloppement technologique de gradio-accéléromètres de grande précision se sont terminés en janvier 1989 avec la fabrication et les essais d'un premier modèle de laboratoire; ils se poursuivront tout au long de l'étude additionnelle.

L'étude sur l'analyse des données de gradiométrie s'est terminée en avril 1989 avec la livraison d'un logiciel qui modélise la réduction des données de gradiométrie en une trame à référence terrestre. Les résultats des premières simulations sont satisfaisants; le logiciel sert à d'autres arbitrages au niveau 'système' ainsi qu'à des analyses de sensibilité menées par l'ESA et par l'industrie.

proceeding according to plan. A major milestone has been achieved with the successful completion of the acceptance testing and delivery in May 1989 of the ERS Kiruna Station.

Earthnet

Acquisition, archiving, processing and distribution of Landsat, MOS-1 and Tiros data have continued at all network ground stations. Station activities at Kiruna and Fucino can now be monitored directly in Frascati through land-line connections.

As a further extension to Landsat services, Thematic-Mapper (TM) quick-look and full-resolution floating-scene products have been introduced, and the catalogue is now updated daily.

Both raw and system-corrected MOS-1 products are now available to Principal Investigators via a prototype system in Frascati. Full data-processing chains to deliver these products at the stations themselves are currently being manufactured.

At the Maspalomas Station, the antenna has been refurbished with the incorporation of a tilting device to cope with overhead passes. The Spot data-processing chain (funded by the EEC) has been installed. It can generate quick-looks, catalogue information, and products up to the standard Spot level-1A and 1B. Data acquisition is carried out within the framework of an agreement with the EEC.

ERS-1
With the completion of the architectural design of the Frascati ERS-1 Central User and Browse Services, contracts have now been awarded to realise the telecommunications and the interface-functions subsystems. Studies on Synthetic-Aperture Radar (SAR) and Scatterometer quality assessment and long-term performance monitoring have now been successfully completed.

Good progress has been made in the procurement of the fast-delivery processing chains for the Gatineau, Maspalomas and Fucino stations, and in the development of the ERS-1 processing and archiving facilities. The modulators and demodulators for the ERS-1 ground stations have been accepted. The contract for defining the ERS-1 fast-delivery product-distribution system has now commenced.

Contracts have also been placed for the operation of the Fucino, Kiruna, Tromsø, Farnborough, Oberpfaffenhofen and Frascati facilities that are integrated into the network.

EOPP

'Aristoteles' Solid-Earth Programme
An 'additional study' on Aristoteles commenced in May 1989. It is being carried out by a European industrial team of 17 companies led by Dornier and with major involvement by Aeritalia, Matra and ONERA. The study is concentrating on a number of system-level trade-offs and instrument/mission options. The technological pre-development of highly accurate gradio-accelerometers was completed in January 1989 with the successful manufacture and testing of a first laboratory model. These pre-developments will be continued through the additional study.

The Gradiometer Data-Analysis Study was completed in April 1989 with the delivery of software that models gradiometer data reduction in an earthbound reference frame. First simulations were successfully performed and the software is being used for further system-level trade-offs and sensitivity analyses by ESA and industry.

In the context of the General Assembly of the European Geophysical Society, a Workshop on Solid-Earth Satellite Programmes centred around 'Aristoteles' was held in Barcelona in March 1989 and attracted a great deal of interest from a wide community.

A two-day workshop dedicated to Aristoteles was organised by the Italian authorities at Trevi in May 1989. A broad cross-section of the scientific and technical communities from Italy, from other European countries, and from the USA participated in this workshop and confirmed their interest in and support for this ambitious proposed mission.

Meteosat Second Generation (MSG)
A series of studies of new instruments for MSG and of alternative three-axis-stabilised satellite configurations will commence shortly. The new instruments are:
— a high-resolution visible imager
— an enhanced infrared sounder
— an enhanced visible and infrared imager, which includes 'sounding-type' capabilities.

These instruments will be considered as elements of two different missions in the satellite system-level study. The requirements for these instruments and missions have been elaborated in close consultation with Eumetsat.

The new 15 metre antenna at ESA's Maspalomas ground station (Canary Islands)

L'Assemblée générale de la Société européenne de géophysique a servi de cadre à un atelier sur les programmes de satellites 'Solide terrestre' organisés autour d'Aristoteles qui s'est tenue à Barcelone en mars 1989 et qui a suscité un vif intérêt de la part d'une large communauté.

Les autorités italiennes ont organisé à Trevi en mai 1989 un atelier de deux jours consacré à Aristoteles. Des chercheurs et des techniciens d'Italie, d'autres pays européens et des Etats-Unis y ont participé; ils ont confirmé leur intérêt pour cette mission et leur soutien à ce projet ambitieux.

Météosat de seconde génération (MSG)
Une série d'études sur de nouveaux instruments pour le MSG et sur d'autres configurations possibles de satellites à stabilisation trois axes est sur le point d'être lancée. Ces nouveaux instruments sont les suivants:
- *un imageur à haute résolution dans le visible*
- *un sondeur infrarouge optimisé*
- *un imageur amélioré dans le visible et l'infrarouge disposant de capacités du type 'sondeur'.*

Dans l'étude de satellite au niveau 'système', ces instruments pourront constituer les éléments de deux missions différentes. Les impératifs relatifs à ces instruments et à ces missions ont été formulés en collaboration étroite avec Eumetsat.

En outre, pour élaborer une option de coût minimal pour le MSG également, on étudiera aussi un système de satellite stabilisé par rotation ayant une capacité d'imagerie nettement améliorée comparativement aux Météosat de première génération.

Les conceptions de mécanismes de têtes de balayage pour instruments optiques ainsi que la simulation de la mission de sondage à hyperfréquences ont fait l'objet d'une étude technologique qui vient de débuter.

La communauté météorologique envisage l'utilisation d'un instrument de sondage à haute résolution spectrale basé sur des techniques d'interférométrie; il pourrait être étudié au niveau du modèle d'identification.

L'étude d'un ensemble scientifique MSG composé d'un instrument géostationnaire de cartographie de la luminescence atmosphérique et d'un moniteur de l'ultraviolet à rétrodiffusion a bien progressé et est en voie d'achèvement.

Plate-forme polaire
Un certain nombre d'études de préfaisabilité relatives aux futurs systèmes sur orbite polaire ont été menées à bien; elles traitent des domaines suivants:
- *analyse des missions et évaluation de leur déroulement*
- *aspects 'système' y compris le traitement de bout en bout des données de charge utile ainsi que les systèmes de commande et de contrôle associés*
- *mise en oeuvre de scénarios multi-missions*
- *instruments de l'installation du noyau affectés spécialement à la première mission.*

Ces études de préfaisabilité ont permis d'alléger les impératifs d'observation de la Terre pour la conception de la plate-forme polaire Columbus et ont ouvert la voie à l'étude de phase-A de la première mission d'observation de la Terre en orbite polaire.

Cette étude doit être lancée fin juin 1989; elle portera non seulement sur les aspects mission, système et traitement des données de la première mission d'observation de la Terre en orbite polaire mais aussi sur les instruments candidats de l'installation du noyau, à savoir:
- *Altimètre radar*
- *Diffusiomètre 'vents'*
- *Radar à synthèse d'ouverture*
- *Détecteur actif à hyperfréquences à caractéristiques améliorées*
- *Radiomètre imageur à multi-hyperfréquences*
- *Spectromètre imageur à moyenne résolution*
- *Lidar atmosphérique.*

Deux études parallèles seront menées pour chaque instrument à l'exception de l'un d'entre eux.

Les instruments de l'Avis d'offre de participation (AO) à prendre en compte dans l'étude de phase A ont été choisis. Il s'agit des sondeurs, des radiomètres, des spectromètres et des instruments de localisation. Les domaines d'application couverts sont les suivants:
- *la chimie et la dynamique de la haute atmosphère*
- *la surface de la Terre*
- *le solide terrestre.*

Un large éventail d'études technologiques sont en cours; elles sont destinées au soutien de futures missions en orbite polaire et portent sur des instruments à hyperfréquences (radar à synthèse d'ouverture, altimètre radar, par exemple), des instruments optiques (évaluation de détecteurs matriciels dans le visible pour spectromètres imageurs à moyenne et haute résolution) et équipements pour usages généraux (systèmes de refroidissement actifs, par exemple).

Microgravité

Les travaux se poursuivent sur les projets de charges utiles de microgravité qui utiliseront des occasions de vol nombreuses et diverses.

Missions Spacelab
Mission D-2 (décembre 1991)
Deux installations multi-utilisateurs de l'ESA participeront à cette mission: le Module de physique des fluides amélioré (AFPM) et l'Anthrorack. Le modèle d'identification de l'AFPM est en phase d'intégration finale; les activités d'essais et de vérification se déroulent conformément à un calendrier très serré. Au terme de la revue de conception critique de l'Anthrorack, qui a donné toute satisfaction, priorité a été donnée aux travaux sur le modèle d'entraînement.

Mission IML-1
Deux installations multi-utilisateurs de l'ESA participeront à cette mission: le Biorack et le dispositif d'étude des phénomènes de point critique (CPF). La remise en état du Biorack, qui a déjà volé une fois, est terminée. La préparation des expériences et l'entraînement de l'équipage ont commencé. Le CPF qui à l'origine devait être embarqué lors de la mission Spacelab D-2 est en cours d'adaptation pour satisfaire aux impératifs d'interface d'IML-1.

Mission IML-2
La NASA a accepté pour cette mission quatre charges utiles de l'ESA: le four à gradients de haute technologie (AGHF),

In addition, in order to establish a minimum-cost option for MSG also, a study will also be made of a spin-stabilised satellite system, but providing much improved imaging compared with first-generation Meteosat.

A technology study has been started of the scanning-head-mechanism designs for the optical instruments, as well as simulation of the microwave-sounding mission.

A high-spectral-resolution sounding instrument employing interferometric techniques is under consideration by the meteorological community and is expected to be studied at engineering level.

The study of a scientific package for MSG (consisting of a geostationary airglow mapper and a backscatter ultraviolet monitor) has progressed well and is nearing completion.

Polar Platform

A number of pre-feasibility studies have now been successfully completed which are relevant to future polar-orbiting systems, covering the following areas:
- mission analysis and mission-performance assessment;
- system aspects, including the end-to-end payload-data handling and associated command and control;
- multi-mission-scenario implementation;
- Core Research Facility instruments earmarked for the first polar mission.

These pre-feasibility studies have allowed streamlining of the Earth-observation requirements for the Columbus Polar Platform's design, and have paved the way for starting the Phase-A study of the first Polar-Orbit Earth-Observation Mission.

This Phase-A study is expected to commence by the end of June 1989. It will not only cover mission, system and data-handling aspects of the first Polar-Orbit Earth-Observation Mission, but will also study the candidate Core Research Facility instruments, namely:

- Radar Altimeter
- Wind Scatterometer
- Synthetic-Aperture Radar
- Enhanced Active Microwave Instrument
- Multifrequency Imaging Microwave Radiometer
- Medium-Resolution Imaging Spectrometer
- Atmospheric Lidar.

In all but one case, two parallel studies will be conducted for each instrument.

The selection of the Announcement of Opportunity (AO) instruments to be considered in the Phase-A study has been successfully completed. Those retained include sounders, radiometers, spectrometers, and location instruments. The fields of application covered encompass:
- the chemistry and dynamics of the upper atmosphere
- the surface of the Earth
- the solid Earth.

A wide range of technology studies are being conducted to support future polar-orbiting missions. These cover microwave instrumentation (e.g. Synthetic-Aperture Radar, Radar Altimeter), optical instrumentation (e.g. evaluation of Visible Matrix Detectors for Medium- and High-Resolution Imaging Spectrometers), as well as general-purpose items (e.g. active cooling systems).

Microgravity

Work on the microgravity-payload projects, which will utilise a range of flight opportunities, is continuing.

Spacelab missions

D-2 mission (December 1991)

Two ESA multi-user facilities — the Advanced Fluid-Physics Module and Anthrorack — will be flown on this mission. The engineering model of the AFPM is in the final stages of integration, and testing/checkout is proceeding to a very tight schedule. After successful completion of the Anthrorack Critical Design Review, work on the training model is proceeding with high priority.

IML-1 mission

Two ESA multi-user facilities, i.e. Biorack and the Critical-Point Facility, will be on board this flight. The refurbishment of Biorack, which has already been flown once, is complete. Experiment preparation and crew training have started. The Critical-Point Facility, originally foreseen to be flown on the Spacelab D-2 mission, is being adapted to meet the IML-1 interface requirements.

IML-2 mission

Four ESA payloads were accepted by NASA as candidates for this mission: the Advanced Gradient Heating Facility; the Bubble, Drop and Particle Unit; Biorack (re-flight); and the Critical-Point Facility (re-flight). The development of the AGH Facility and BDP Unit had already been initiated by ESA and the initial design phases completed.

Eureca-1 mission

Development of the five ESA multi-user facilities for this mission is nearly complete. Two facilities, the Automatic Mirror Furnace (AMF) and the Exobiology Radiation Assembly (ERA), have been accepted and are ready for integration. The work in support of experiment preparation and flight operations at the Microgravity User Support Centre (MUSC) in Porz (W. Germany) is increasing in importance. Experience in operating the available engineering models of the multi-user facilities is being acquired.

Biocosmos-9

Five biological experiment packages will be flown on the Biocosmos-9 satellite on a cooperative basis by the Institute for Biomedical Problems (Moscow) and ESA. The experiments were defined in detail last year and launch is foreseen for August 1989. Recovery of the satellite and the experiment package is planned to take place after a two-week flight.

Sounding rockets

Eight ESA microgravity experiments have been successfully flown on sounding rockets: six on the Maser-3 rocket (10 April 1989) and two on the Texus-21 rocket (26 April 1989), giving approximately five minutes of weightlessness (microgravity conditions) per flight. Preparations for flying further experiments on sounding rockets are underway.

Parabolic flights

A Caravelle aircraft managed by CNES has been used for parabolic flights providing approximately twenty seconds of microgravity. ESA took part in the first demonstration flight by providing two experiments. The first operational campaign (three flights, each including 30 parabolas) was dedicated solely to ESA experiments and was conducted *l'équipement pour l'étude du comportement des bulles, des gouttes et des particules (BDPU), le Biorack (nouvel emport) et le CPF (nouvel emport). L'ESA a déjà commencé les travaux de développement de l'AGHF et du BDPU dont les phases de conception initiale sont terminées.*

Mission Eureca-1
La réalisation des cinq installations multi-utilisateurs de l'ESA destinées à cette mission est presque terminée. Deux d'entre elles, le four automatique à miroir et le dispositif d'étude de l'exobiologie et de l'effet biologique des rayonnements, ont été acceptées et sont prêtes à être intégrées. Les activités de soutien de la préparation des expériences et des opérations en vol s'intensifient au Centre de soutien des utilisateurs de la microgravité à Porz en Allemagne où l'on acquiert l'expérience de l'exploitation des modèles d'identification disponibles des installations multi-utilisateurs.

Biocosmos-9
Cinq ensembles d'expériences biologiques seront embarqués sur le satellite Biocosmos-9 pour la mission menée en coopération avec l'Institut de recherche biomédicale de Moscou et l'ESA. Ces expériences ont été définies dans le détail l'an dernier et le lancement est prévu pour août 1989. Le satellite et les expériences devraient être récupérés après un vol de deux semaines.

Fusées-sondes
Huit expériences de recherche en microgravité de l'ESA ont été exécutées avec succès sur des fusées-sondes: six à bord de la fusée Maser-3 tirée le 10 avril 1989 et deux à bord de la Texus-21 le 26 avril; la période d'impesanteur a été d'environ 5 minutes par vol. D'autres tirs de fusées-sondes emportant des expériences sont en préparation.

Vols paraboliques
Une Caravelle exploitée par le CNES a servi à des vols paraboliques comportant une période d'impesanteur de quelque vingt secondes. L'ESA a participé au premier vol de démonstration avec deux expériences. La première campagne opérationnelle (Trois vols de 30 paraboles chacun) a été réservée exclusivement à des expériences de l'ESA; elle s'est déroulée avec succès en février et mars 1989. La deuxième campagne ESA est prévue pour septembre/octobre 1989.

Eureca

Fin décembre 1988, l'assemblage composé de la structure de vol et du sous-système de propulsion intégré d'Eureca a quitté SNIA-BPD (Colleferro, Italie) pour MBB/ERNO (Brême, RFA) où les travaux d'intégration se sont poursuivis, portant en particulier sur les sous-systèmes électriques et de traitement des données.

En parallèle, et toujours à Brême, on a procédé aux essais de charges utiles.

Trois des quinze charges utiles de vol ont été livrées à MBB/ERNO pour être intégrées sur le porte-instruments; neuf autres sont attendues dans les trois mois et les trois dernières seront livrées avant la fin de l'année.

Les essais de qualification des équipements et des sous-systèmes sont pratiquement achevés à l'exception de ceux du sous-système de commande d'orientation qui doivent se terminer plus tard dans l'année.

Station spatiale 'Freedom'/Columbus

Les activités de Phase C-Zéro relatives au secteur spatial de Columbus se sont poursuivies dans l'industrie parallèlement à la préparation de la proposition industrielle de la Phase-C/D (Phase de développement principale). La Phase C-Zéro a été prolongée de fin juin à fin septembre 1989 pour tenir compte du ralentissement des activités industrielles pendant la période de pointe de la préparation de la proposition de la Phase-C/D. L'ESA a également continué ses travaux avec la NASA pour élaborer la première édition des impératifs techniques et de gestion qui seront applicables conjointement aux programmes 'Station spatiale Freedom' et Columbus.

La revue No. 1 des impératifs préliminaires de la Phase C-Zéro (PRR-1) s'est déroulée de décembre 1988 à avril 1989, après un remaniement de calendrier à la suite d'un retard dans la réception de données industrielles. La dernière réunion du Conseil Directeur de l'ESA est prévue pour la fin juin 1989. La préparation de la PRR-2, qui couvre la plate-forme polaire Columbus et le laboratoire autonome, sera définitivement mise au point conjointement avec l'évaluation de la proposition de Phase-C/D.

L'industrie ayant proposé une nouvelle configuration pour le laboratoire raccordé Columbus à la fin de 1988, celle du laboratoire autonome a dû être réaménagée à la lumière de ces modifications. L'industrie met un point final à un certain nombre d'arbitrages de configurations pour remédier à quelques lacunes au niveau des impératifs.

Les études sur le concept de plate-forme menées par l'industrie (Options A et B) sont achevées depuis la fin janvier 1989. Les résultats et recommandations ont été présentés à une réunion conjointe des Conseils directeurs des programmes Columbus et Observation de la Terre, en février, et au Conseil de l'ESA en mars. Ce dernier a décidé de remettre le choix définitif du concept à sa réunion d'octobre 1989 en attendant la soumission et l'évaluation des propositions complètes de Phase-C/D pour les deux options.

Le planning de la proposition industrielle de la Phase-C/D a été modifié deux fois à la suite de retards dans la diffusion de la demande de prix du Maître d'oeuvre et dans la demande par le Conseil de deux propositions complètes pour la plate-forme polaire; d'autres retards sont imputables, pour l'essentiel, à quelques propositions soumises au niveau 'sous-système' qui dépassent de loin les prix-objectifs établis. La présentation de la proposition globale a été fixée par le Maître d'oeuvre à la mi-août 1989. Elle couvrira les propositions complètes des deux options de plate-forme polaire.

Après examen approfondi avec le CNES et le Maître d'oeuvre d'Hermes, le Document des impératifs d'interface Columbus/Hermès (CHIRD) a été officiellement remis aux consortiums industriels Columbus et Hermès en décembre 1988 avec l'approbation conjointe de ces deux programmes.

L'appel d'offres pour le contrat de soutien de la cohérence Columbus/Hermès a été lancé en décembre 1988; après une réunion d'information des soumissionnaires potentiels en janvier 1989, quatre offres ont été reçues avant la date de clôture. La réunion de démarrage avec Sener (E) successfully during February/March 1989. The second ESA campaign using the Caravelle is planned for September/October 1989.

Eureca

The assembled Eureca flight structure and integrated propulsion subsystem were transported from SNIA-BPD at Colleferro (I) to MBB/ERNO in Bremen (D) at the end of December 1988. Integration has continued in Bremen, with the emphasis on the electrical and data-handling subsystems.

Payload testing has continued in parallel at the payload-test facility in Bremen.

Of the fifteen flight payloads, three have been delivered to MBB/ERNO for integration onto the carrier, a further nine are due in the next three months, and the remainder will be delivered by the end of the year.

Qualification testing of equipment and subsystems has been largely completed, with the exception of the attitude-control subsystem, testing of which is due to be completed later this year.

Space-Station 'Freedom'/Columbus

Columbus Space-Segment Phase C-Zero activities have continued in industry in parallel with the preparation of the Phase-C/D (main development phase) industrial proposal. The C-Zero phase has been extended from end-June to end-September 1989 to accommodate a period of reduced industrial effort during the peak Phase-C/D proposal-preparation period. ESA has also continued to work with NASA in establishing the first issue of technical and management requirements to be jointly applicable to the Space-Station 'Freedom' and Columbus Programmes.

The Phase C-Zero Preliminary Requirements Review No. 1 (PRR-1) was conducted during the period December 1988 to April 1989, after some rescheduling due to late receipt of industrial data. The final ESA Board is planned for end-June 1989. Planning for PRR-2, covering the Columbus Polar Platform and the Free-Flying Laboratory, will be finalised in conjunction with the Phase-C/D proposal evaluation.

As a result of the introduction by industry of a new Columbus Attached Laboratory configuration in the latter part of 1988, the Free-Flying Laboratory configuration has also been updated to reflect this new design. Industry is still finalising a number of configuration trade-offs to overcome certain requirements deficiencies.

The industrial Polar-Platform concept studies, covering Options-A and B, were completed by the end of January 1989. The results and recommendations were presented to a joint session of the Columbus and Earth-Observation Programme Boards in February, and to the ESA Council in March. The Council decided to defer final concept selection to its meeting in October 1989, pending submittal and evaluation of full Phase-C/D proposals for both options.

The industrial Phase-C/D proposal planning has undergone two rescheduling exercises due to some delays in the release of the Prime Contractor's Request for Quotation (RFQ), the Council's request for two full Polar-Platform proposals, and further delays due primarily to a number of proposals being submitted at subsystem level that far exceed the established target prices. The overall proposal submittal has now been set by the Prime Contractor for mid-August 1989. This proposal will fully incorporate proposals for both Polar-Platform options.

Following completion of a comprehensive review with CNES and the Hermes Prime Contractor, the Columbus/Hermes Interface Requirements Document (CHIRD) was formally released to the Columbus and Hermes industrial consortia in December 1988, under the joint approval signatures of the Columbus and Hermes Programmes.

The Invitation to Tender (ITT) for the Columbus/Hermes Coherence Support Contract (CSC) was released during December 1988 and, following an industrial briefing for potential bidders in January 1989, four industrial offers were received by the closing date. The kick-off meeting with Sener (E) took place at the end of March 1989, immediately after the Agency's Industrial Policy Committee (IPC) had approved the contract proposal.

A comprehensive presentation addressing Columbus/Hermes coherence was made to the Columbus and Ariane Programme Board delegations at ESTEC on 25/26 April 1989. This presentation focussed on the current level of technical and managerial coherence between the two programmes and with other infrastructure programmes.

Establishment of the ESA/NASA joint technical-requirements documentation has continued, with a number of meetings both in Europe and the USA. In April, the Level-2 Joint Requirements Document achieved the status of 'ad referendum' ESA/NASA approval, and formal approval at Programme Manager level is now tentatively planned for June 1989.

In close cooperation with ESA's User Directorates and other user sponsors, the Utilisation Department has further elaborated the payload requirements, but the baseline issued with the RFQ in August 1988 has not been changed. The Department is also maintaining an intensive dialogue with NASA's utilisation organisation on payload accommodation and user integration. The main channel of communication has been through the Multilateral Utilisation Study, which for the first time has established a model outfitting of all Space-Station 'Freedom' laboratory modules.

Ariane

First hot tests on Ariane-5's Vulcain engine

On 23 February 1989, there was an important step forward in the development of the cryogenic Vulcain engine intended for the central stage of Ariane-5: the first hot testing of the thrust chamber at nominal pressure was performed on the new test stand at Lampoldshausen (D). This test was 100% successful and was followed by two similar tests before the nozzle divergent was introduced in May. Two short-duration tests (2 s) on the chamber with its divergent in place have since been accomplished and a third is underway. The primary aim in the coming tests will be to achieve a burn time of about 20 s.

s'est tenue à la fin mars 1989, dès que le Comité de la Politique industrielle de l'Agence (IPC) eut approuvé la proposition de contrat.

Les 25 et 26 avril 1989, à l'ESTEC, la cohérence Columbus/Hermès a fait l'objet d'une présentation détaillée aux délégations aux conseils directeurs des programmes Columbus et Ariane. L'accent a été mis sur le niveau actuel de cohérence technique et gestionnelle entre les deux programmes ainsi qu'avec d'autres programmes d'infrastructure.

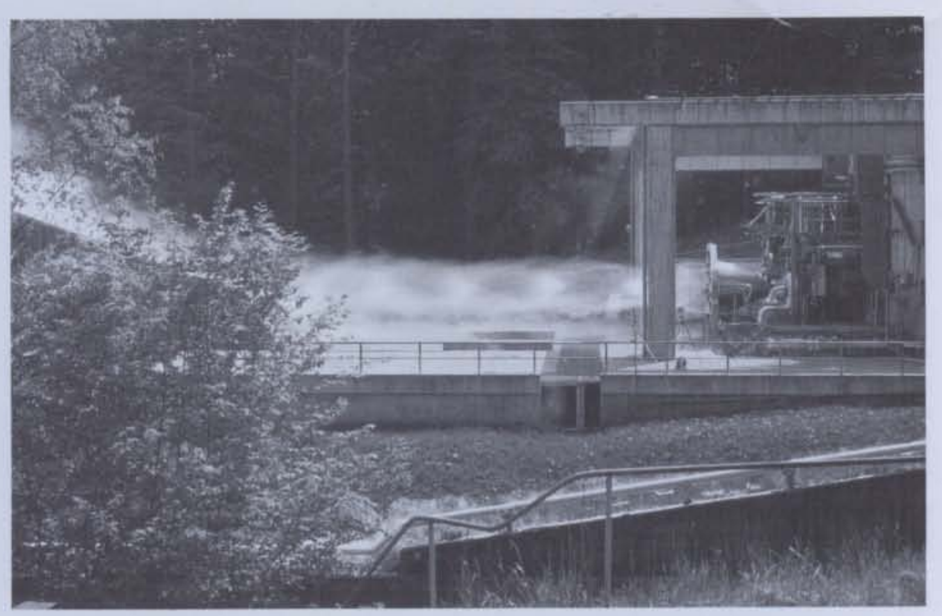
La préparation de la documentation commune ESA/NASA sur les impératifs techniques s'est poursuivie, les deux parties s'étant rencontrées plusieurs fois en Europe et aux Etats-Unis. En avril, le document des impératifs conjoints de niveau 2 a reçu l'approbation 'ad referendum' des deux agences. L'approbation officielle au niveau des responsables de programmes devrait intervenir en juin 1989.

En collaboration étroite avec les directions des programmes utilisateurs et d'autres utilisateurs commanditaires, le Département 'Utilisation' a affiné les impératifs de charges utiles mais le concept de référence indiqué dans la demande de prix d'août 1988 n'a pas été modifié. Il maintient également en permanence le dialogue avec les responsables de l'utilisation de la NASA sur l'installation des charges utiles et l'intégration des utilisateurs. Le principal support de ce dialogue a été l'étude multilatérale sur l'utilisation qui, pour la première fois, a établi un modèle d'équipement de tous les modules laboratoires de la Station spatiale 'Freedom'.

Ariane

Premiers essais à chaud du moteur Vulcain d'Ariane-5

Le 23 février 1989, date importante du programme de développement du moteur cryotechnique Vulcain, a vu les premiers essais de mise à feu réelle de la chambre de combustion à la pression nominale sur le nouveau banc d'essai de Lampoldshausen (Allemagne). Ce succès total a été suivi par deux essais similaires avant la mise en place du divergent de tuyère en mai. Deux essais de courte durée (2 s) ont ensuite été exécutés sur la chambre équipée de son divergent et un troisième est en préparation. L'objectif des prochains essais est de parvenir à une durée de combustion de l'ordre de 20 s.



Testing of the combustion chamber for the Ariane-5 Vulcain engine at Lampoldshausen (D)

Hermès

L'industrie a terminé son analyse détaillée de la configuration d'Hermès retenue en septembre 1988; elle doit être examinée lors de la Revue de la définition préliminaire de l'avion spatial qui a commencé début juin. Parmi ses caractéristiques principales, on notera la cabine éjectable de type-A (décision à confirmer) et un module de ressources Hermès comportant des radiateurs montés sur le corps de l'avion, un sas intégré à la baie pressurisée et une porte d'amarrage axiale.

Dans le domaine de la technologie, les travaux vont bon train et progressent plus particulièrement pour ce qui concerne les piles à combustible, la protection thermique et les matériaux de la structure. Les groupes 'Technologie' mis en place par l'ESA et le CNES examinent actuellement les progrès réalisés dans six domaines critiques.

La revue des exigences préliminaires au niveau 'système' s'est terminée avec l'actualisation des principaux documents qui régissent le développement de l'avion spatial, du bras manipulateur (HERA), des EVA, du secteur sol, etc. Cette revue portait également sur les documents de définition des interfaces avec Ariane et Columbus. Les négociations avec la NASA sur les interfaces dans le cadre des visites d'Hermes à la Station spatiale 'Freedom' ont repris et le premier document consacré à ce sujet devrait être diffusé prochainement.

Enfin, les charges utiles, l'entraînement et l'utilisation sont des domaines qui ont été marqués par des progrès notables. En particulier, le Programme a défini sa politique pour la phase d'utilisation et pour la sélection et l'entraînement des astronautes.

TDP

Expériences

Du fait du report de l'occasion de lancement, l'unité de vol du générateur solaire à l'arséniure de gallium (GaAs) et deux plaquettes de piles ultrafines ne seront achevés qu'en juin. L'appel d'offres relatif à la phase-2, qui porte principalement sur un panneau solaire de 4 × 20 photopiles a été envoyé aux industriels en mai.

La fabrication de l'unité de vol du microaccéléromètre à l'état solide est terminée. Les essais 'système' se feront en juin.

Hermes

Industry has completed its detailed analysis of the Hermes configuration, as selected in September 1988. This analysis is to be reviewed during the spaceplane's Preliminary Definition Review, which started in early June. Its main features include the 'type-A' ejectable cabin (decision to be confirmed), and a Hermes Resource Module with body-mounted radiators, an airlock integrated into the pressurised cargo volume, and an axial docking port.

The technology effort is being actively continued, with major progress in the areas of fuel cells, thermal protection and structural materials. The Technology Panels appointed by ESA and CNES are now reviewing progress in six critical areas.

The system-level Preliminary-Requirements Review has been completed, with the updating of major requirements documents governing the development of the spaceplane, the robotic arm (HERA), EVA, ground segment, etc. The documents defining the interfaces with Ariane and Columbus also formed part of this review. The interface negotiations with NASA for a visit by Hermes to Space-Station 'Freedom' have resumed and issue of the first interface document is expected shortly.

Finally, important progress has been achieved in the payload, training and utilisation areas. In particular, the Programme has defined its policy for the utilisation phase and for astronaut selection and training.

Technology Demonstration Programme

Experiments

The flight-unit Gallium-Arsenide Solar-Array (GaAs) panel and two patches of ultra-thin cells will be completed in June, due to the shift in the launch opportunity. The Invitation-to-Tender (ITT) for Phase-2, focussing on a solar-array panel of 4 × 20 cells, was sent out to industry in May.

Manufacture of the flight-unit Solid-State Microaccelerometer has been completed, and system testing will be carried out in June.

The Phase-B final presentation for the Collapsible-Tube Mast took place in March. However, more work was required to complete the experiment definition, expected in June. A Safety Review undertaken in Houston in April showed no major problems, although the experiment was confirmed to be very complex.

The Transputer and Single-Event Upset flight unit has been completed and it is now ready for integration into Uosat-E.

The In-Space Aluminium Coating experiment's objectives are in the process of being reviewed.

The Liquid-Gauging Technology ITT has been released in May, after extensive review.

The ITT for a newly proposed Two-Phase Flow experiment has been released in April.

The ITT for the Inflatable Space-Rigidised Antenna is awaiting a final launch agreement. Alternative flight opportunities are under investigation.

The first operational unit of the Hitchhiker-G simulator is being manufactured at the industrial contractor. Manufacture of the flight-representative hardware (prototype) for the Payload Control Unit is in progress, with completion is foreseen in the summer.

ESA/NASA cooperative experiments

ESA's Phase-B work on the In-Flight Contamination Experiment (IFCE) has been successfully completed with the final presentation in March 1989, held at ESTEC. The NASA Phase-B completion is expected in July.

The proposed NASA Phase-C/D Draft Agreement for the CTM/IFCE experiment is under discussion.

Finalisation of the ESA/NASA Letter of Agreement for the Solar-Array-Module Plasma Interaction Experiment (SAMPIE) Phase-B is awaiting funding agreement. This study forms part of the preparatory activities for Phase-2 of the Technology Demonstration Programme.

Flight opportunities

The Hitchhiker experiments have been manifested for launch: the Attitude-Sensor Package on Space-Shuttle flight STS-44 on 31 January 1991, and the Collapsible-Tube Mast with the IFCE on STS-65 on 11 January 1993. The pricing policy for the Attitude-Sensor Package is still pending.

The final safety-review cycle for the GAS experiment solid-state microaccelerometer (G-21) has started and is expected to be completed in June. Only when this safety-review cycle is complete will the GAS enter the launch queue.

Integration of the Uosat-E experiments (Transputer and Single-Event Upset and Gallium-Arsenide Solar Panel with two cell patches) is now planned to begin in June 1989. The spacecraft's launch, as a piggy-back payload on the Spot-2 satellite's Ariane-4 launch, has been delayed until November 1989.

The final choice of carrier for the Gallium-Arsenide Panel with larger cells (Phase-2) is in progress.

Work is continuing on the Ariane Technology Experiment Platform (ARTEP). Issue of the ITT for the procurement of the ARTEP-1 platform is foreseen for the second half of 1989.

Preparation of TDP Next Phase

In the framework of the preparatory activities for Phase-2 of the Technology Demonstration Programme, the closing date for proposals responding to the Announcement of Opportunity for small/medium-sized experiments was extended from mid-March until the end of April. The evaluation process started in May. Several preparatory studies to define complex experiments have been initiated.

C'est en mars qu'a eu lieu la présentation finale de la phase-B du mât à tube enroulable. Des travaux complémentaires sont cependant nécessaires pour achever la définition de l'expérience escomptée en juin. Une revue de sécurité s'est tenue en avril à Houston; aucun problème majeur n'a été relevé bien qu'il ait été confirmé que cette expérience était très complexe.

L'unité de vol de l'expérience 'Transordinateur et perturbations sous l'effet de particules élémentaires', achevée, peut être intégrée à Uosat-E.

On examine actuellement les objectifs de l'expérience d'aluminiage dans l'espace.

L'appel d'offres de l'expérience de jaugeage des liquides a été lancé en mai après un examen approfondi.

Celui d'une expérience d'écoulement à deux phases récemment proposée a été lancé en avril.

L'appel d'offres relatif à l'antenne gonflable et rigidifiable est lié à l'accord définitif sur le lancement. On envisage actuellement d'autres occasions de vol possibles.

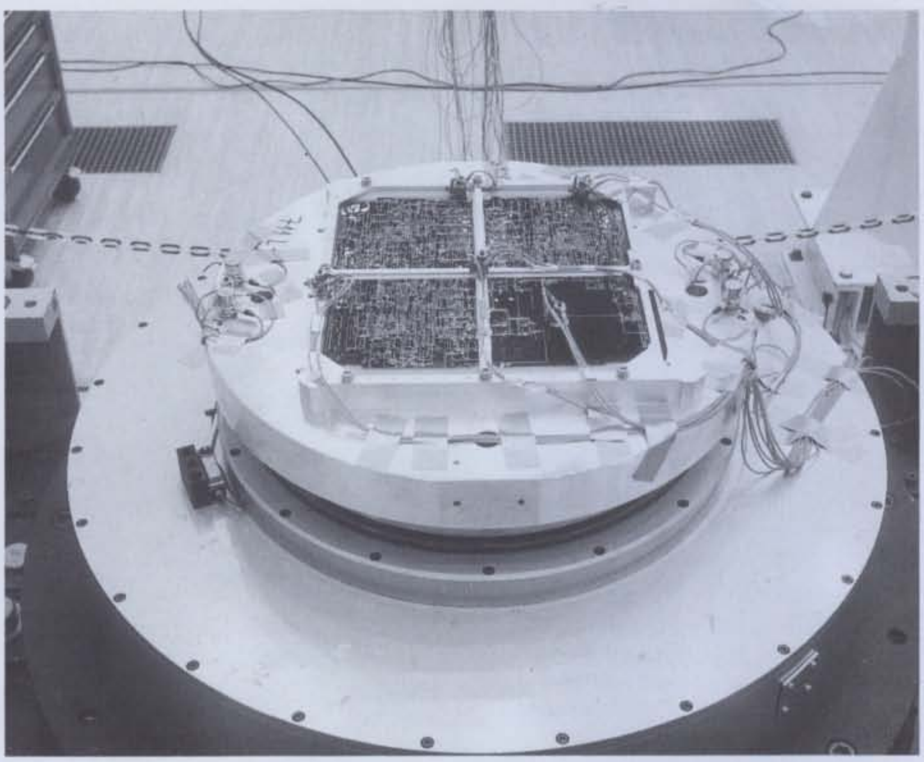
La première unité opérationnelle du simulateur Hitchhiker-G est en fabrication chez le contractant. La fabrication du matériel représentatif de vol (prototype) de l'unité de conmande de la charge utile progresse et devrait s'achever dans le courant de l'été.

Expériences en coopération ESA/NASA

L'ESA a terminé ses travaux sur la phase-B de l'expérience de contamination en vol (IFCE) dont la présentation finale a eu lieu en mars 1989 à l'ESTEC. La fin des travaux de phase-B de la NASA est attendue pour juillet.

On examine actuellement le projet d'accord proposé par la NASA et relatif à la phase-C/D de l'expérience CTM/IFCE.

La rédaction définitive de la lettre d'accord NASA/ESA sur la phase-B de l'expérience d'interactions entre le module de générateur solaire et le plasma (SAMPIE) est suspendue dans l'attente de l'accord de financement. Cette étude fait partie des activités préparatoires de la phase-2 du TDP.



Transputer Experiment flight unit for the Technology Demonstration Programme under test at ESTEC (NL)

Occasions de vols

Les expériences Hitchhiker ont été inscrites sur le manifeste des vols suivants: Ensemble de détection d'orientation sur le vol STS-44 de la Navette le 31 janvier 1991 et mât à tube enroulable avec l'IFCE sur le vol STS-65 le 11 janvier 1993. La politique de prix de l'ensemble de détection d'orientation n'est pas encore fixée.

La revue finale de sécurité du microaccéléromètre à l'état solide des expériences GAS (G-21) a commencé et devrait se terminer en juin. Ce n'est qu'à l'issue de ce cycle que l'on pourra donner une date de lancement des expériences GAS.

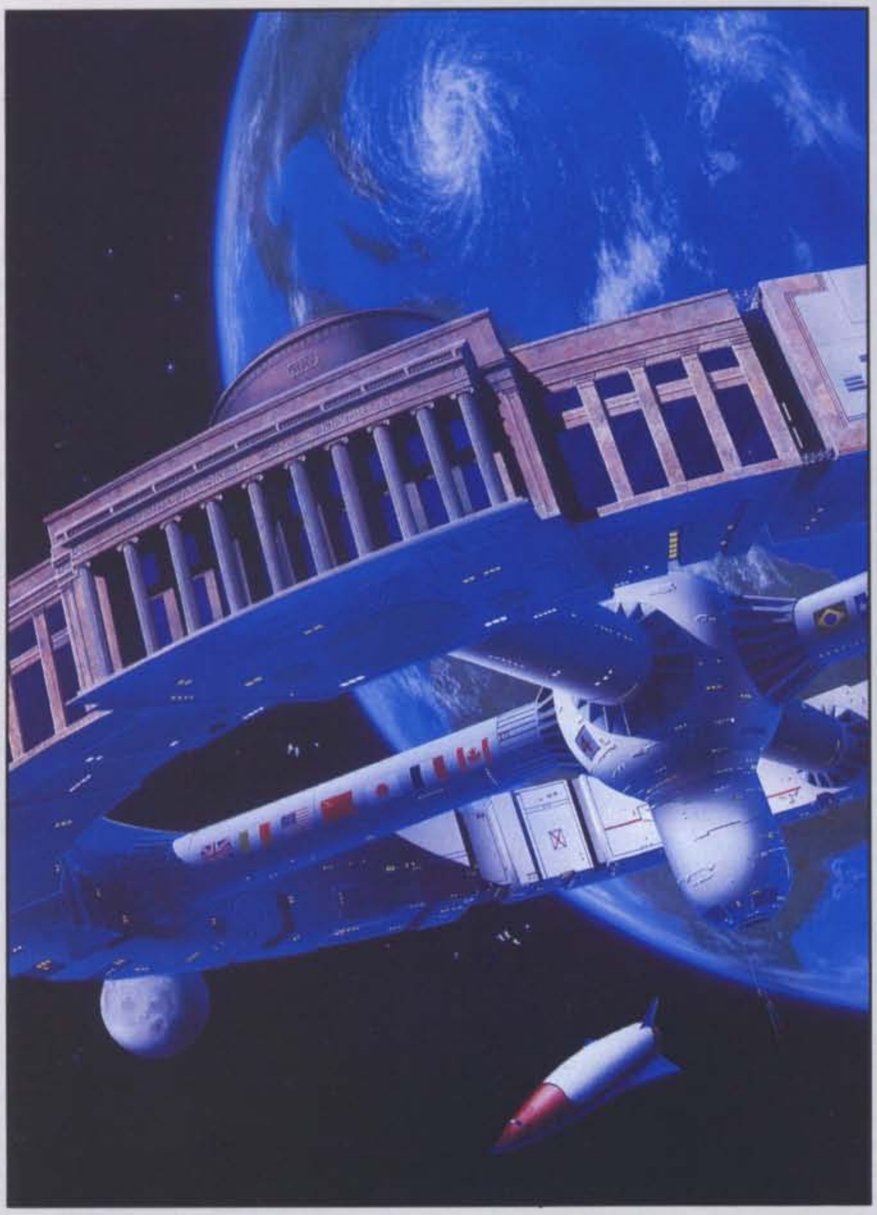
L'intégration des expériences Uosat-E (Transordinateur et perturbations sous l'effet de particules élémentaires, et générateur solaire à l'arséniure de gallium avec deux plaquettes de piles ultrafines) devrait commencer en juin 1989. Le lancement en tandem avec le satellite Spot-2 sur une Ariane-4 est remis à novembre 1989. On choisit actuellement le porteur du générateur à l'arseniure de gallium avec piles de plus grandes dimensions (Phase-2).

Les travaux sur la plate-forme pour expériences technologiques Ariane (ARTEP) se poursuivent. L'appel d'offres pour l'approvisionnement de la plate-forme ARTEP-1 devrait être lancé au cours du second semestre 1989.

Préparation de la prochaine tranche du TDP

Dans le cadre des activités préparatoires de la phase-2 du Programme de démonstration de technologie, la date limite de réception des propositions de l'appel d'offres d'expériences de petite et moyenne importance a été repoussée de la mi-mars à la fin avril. L'exercice d'évaluation a commencé en mai. Plusieurs études préparatoires visant à définir des expériences complexes ont été lancées.

INTERNATIONAL SPACE UNIVERSITY®
HEADING TOWARD ORBIT



The International Space University (ISU) was founded in April 1987 at a conference held at the Massachusetts Institute of Technology (MIT). The ISU co-founders—Peter H. Diamandis, Todd B. Hawley and Robert D. Richards—forwarded a concept in space education which has captured the imagination and support of the world's space community. With the involvement of academia, governments and industry from numerous nations, ISU will expand into a full-year academic program and permanent campus locations following 1992, the International Space Year. "Clearly the ISU plans are quite ambitious, but the concept has won over many of its early doubters," notes Mr. Ian W. Pryke, head of the European Space Agency's Washington Office. "The momentum and success the ISU has built is why I am proud to serve as its Chairman of the Board."

continued on next page

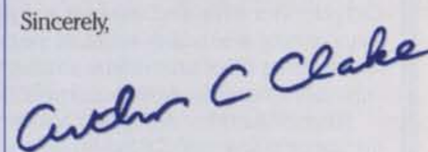
The Birth of a 21st Century Institution

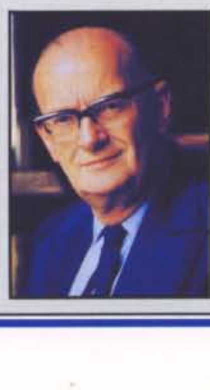
It is my pleasure to write a few words on behalf of an organisation I helped to start and which is close to my heart: the International Space University. ISU is an outstanding new institution dedicated to identifying, unifying and educating the world's best young professionals and outstanding graduate students involved in space-related studies from architecture and engineering to life sciences and business. Through its academic programmes, ISU is cultivating a new generation of leaders dedicated to the peaceful use of outer space.

After the phenomenal success of its inaugural summer session at MIT, ISU is setting its sights on the establishment of a permanent central campus during International Space Year (1992). In the next few years, ISU will expand to include multiple campuses at centres of excellence around the world—linked together via satellite, sharing an electronic library and data bases, offering live lecture transmissions and implementing modern technologies—to enhance cooperative research and development of space. One day soon, perhaps by 2001, ISU will have a campus where it is destined to be: *in orbit!*

ISU is doing more to promote and guarantee the peaceful and permanent development of space than any other institution I know. I have been a sponsor of ISU since its founding, and I hope that you will be able to join with me in supporting this unique educational endeavour.

Sincerely,





Arthur C. Clarke is the author of* 2001: A Space Odyssey. *He serves on the ISU Board of Advisors and is the Chancellor of the University of Moratuwa, Sri Lanka.

ISU Gains Momentum

continued from first page

The inaugural summer session of ISU was held at MIT in 1988, and brought together 104 graduate-level students and young professionals from 21 nations. ISU's first academic program provided an innovative package: a nine-week summer session involving a broad curriculum, state-of-the-art equipment and labs, design projects, and an international faculty and student body. During the program, all students participated in a total of 240 hours of lectures encompassing eight disciplines. The ISU academic program was led by a core faculty of 30, enhanced by more than 70 visiting lecturers representing today's leaders in the international space community.

ISU operates from its Executive Office in Boston, Massachusetts, USA, which is headed by Peter H. Diamandis and Todd B. Hawley

The 1989 summer session will take place at Université Louis Pasteur in Strasbourg, France from 30 June to 31 August. The structure of ISU'89 evolved from the ISU program offered at MIT in 1988: a nine-week session of interdisciplinary lectures and design project activities, and eight academic disciplines: Space Architecture, Space Business and Management, Space Engineering, Space Life Sciences, Space Policy and Law, Space Resources and Manufacturing, Satellite Applications, and Space Physical Sciences.

In conjunction with summer sessions, ISU is pursuing the goal of establishing a permanent campus during International Space Year (1992). Following the 1992 International Space Year, the ISU plan is to open first its Central Campus, later adding Satellite Campuses for advanced research and study in ISU disciplines in existing centers of excellence located around the world. At the permanent campus, worldwide satellite broadcasting of lectures will be routine; computer conferencing and networking, electronic library and database access will be used to link together the varied elements of ISU.

An ISU Founders Association has been launched to help establish ISU's permanent campus and to assure the continuation of this global experience for future generations. Founders Association members will help finance the planning, analyses, needs assessments, design and construction of permanent ISU facilities. Members of the Founders Association are determined to prepare a complete development plan for International Space University, and secure a sound financial base for its implementation.

The process by which humanity develops and explores space has changed in many critical ways over the last 30 years. Space is no longer the realm of the economic superpowers, nor is it a domain limited exclusively to scientists and engineers. Today space development takes place in an international, interdisciplinary arena. ISU seeks to provide a general understanding of technical and non-technical areas important to space development, and to gather together the leaders of tomorrow, allowing them to discuss common goals, motivations and ideas. The International Space University invites visionary men and women of all nations to join and support this critical mission.

ISU Captures the

The International Space University mission is to offer educational programs which are of relevance to today's space industry. From its inception in 1987, ISU has fostered increasing levels of support from a diverse international roster of corporations and agencies whose leaders recognize the value and impact of the programs offered at ISU.

"In this era of expanding civil space programs, there is an ever-growing interest and need in our industry to identify and train young people who can operate successfully in an international commercial environment," notes John McLucas, Chairman of QuesTech, Inc. "The ISU seeks to satisfy the emerging training needs of the aerospace industry."

ISU has pioneered a unique education niche which has proved as relevant to aerospace firms in North America, Japan

The Power of ISU

One hundred and four rare individuals now have friends and professional colleagues in 21 different countries of the world. These are the students of the first graduating class of International Space University. The ISU alumni form a cadre of dedicated space professionals who will provide the leadership to launch humankind into space.

To illustrate the effect the "ISU Experience" has already had, a sampling of alumni perspectives is presented here:

- "This has been the most important educational experience of my life," said Mark Matossian, the first alumnus to obtain graduate course credit for his work at ISU'88, and now a staff scientist at SAIC. "Never have I been asked to push myself as far and as fast as I did at ISU this summer."

- "During ISU I made contact with individuals from many space-related corporations—many of them I have remained in frequent contact with, this will help to create new opportunities for all of us,"

Interest of Space Industry Leaders

Space industry leaders from over 20 nations have endorsed ISU.

Yasuhiro Kuroda
SHIMIZU

Claude Goumy
MATRA SPACE

Dean Burch
INTELSAT

and Europe as it has to telecommunications corporations in Africa and Australia. Proof of this relevance may be noted in Japan's increased participation in ISU in 1989, which will include at least 17 students—an increase from five participants in the 1988 program at MIT.

"We wish to promote the ISU program among Japanese corporations because we believe that space development will require professionals who have an international perspective and who will succeed in the increasingly cooperative world space industry," explains Dr. Yasuhiro Kuroda, Senior Advisor of Shimizu's Space Project Office, Japan's ISU Liaison since 1987.

"In Europe, the multi-national nature of many space activities makes the International Space University program particularly valuable," remarks Claude Goumy, General Manager of MATRA SPACE, which is sponsoring students and curriculum development for the ISU'89 program in Strasbourg, France. "I believe that the international educational experience of the ISU will have very great long-term benefits in our firm, our nation and the world."

At the INTELSAT Organization, 115 nations own and operate an expanding international satellite communications system which is often referred to as one of the best examples of successful multi-national space cooperation. "It has been our pleasure to support [the ISU] enterprise," notes Dean Burch, the INTELSAT Director General and a member of ISU's Board of Advisors. "It is extremely pleasing to see how successful the ISU program has become in such a short period of time."

Networking

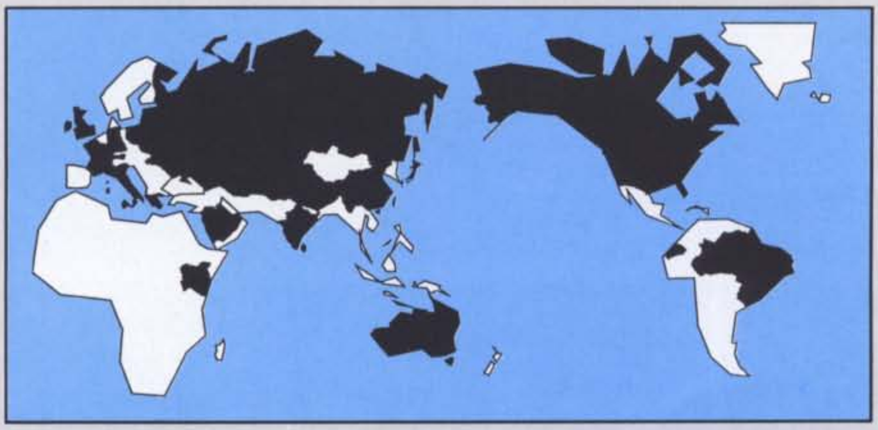
says Akiyoshi Kabe of Mitsubishi Electric Corporation. "I know I am only a fax or a phone call away from hundreds of people—space experts, astronauts and CEOs—who are not only my colleagues but also my friends."

• ISU Alumna Marina Aguiar of Brazil adds: "ISU gave me an excellent understanding of how my work in materials science can be used in the development of space, and the multicultural environment helped to broaden my view of the world."

• Vadim Vlasov, a Soviet alumnus very active in US-USSR relations, noted: "I was impressed with the expertise, diversity and enthusiasm of the ISU faculty. It was extremely interesting for me to hear the perspectives of faculty from 14 nations."

• "Immediately following ISU, I was offered a job by the Canadian Astronaut Program. As one of my first assignments I was sent to the Soviet Union to discuss experimental procedures and logistics for two Canadian experiments to fly on Biocosmos 1989," says Canadian Alumna Kristiina Valter. "My friendship and experience with my 12 Soviet ISU colleagues was invaluable in this trip to the USSR."

ISU'88 graduates Mark Matossian (USA), Akiyoshi Kabe (Japan) and Kristiina Valter (Canada)



The shaded regions on this world map represent those nations which sent their top students to ISU'88

• Russel Hannigan is the youngest member of the British Aerospace Hotol research and development group. He notes, "My experience at ISU and the design project activities allowed me to work with a culturally diverse group of people, and also gave me the opportunity to gain knowledge which is valuable to my work at British Aerospace."

• "When I returned from ISU I received a very important job proposal from Aeritalía, and now I am in Torino (Italy) working on the Human Factors Aspects of the Columbus Space Station," says alumnus Francesco Brunelli. "I really do have to express my warmest gratitude to ISU. I owe it all to ISU."

Between 20 June and 20 August 1988 a group of outstanding students and young professionals came together as strangers and left as friends and colleagues. Coming from 21 different nations, but sharing a common dream and the qualities of perseverance, leadership and brilliance—these students have set out to change the world...together.

Investors in Space Leadership

The 104-member ISU Class of 1988 at MIT

Over 70 corporations and government agencies in more than 20 nations joined to support the ISU program when it began in the summer of 1988. Over US$1 million was raised to finance ISU Executive operations and the innovative ISU'88 program held at the Massachusetts Institute of Technology. In 1989 and beyond, ISU seeks to expand its network of supporters to include individuals and institutions to provide scholarships, curriculum and permanent campus development. Space Biospheres Ventures has already commited a five year scholarship and Life Sciences curriculum support to ISU. "We are delighted with the ISU program, level of excellence and international scope, and are proud to be sponsoring ISU's first textbook this year in the field of Space Life Sciences," says Margret Augustine, CEO and Project Director, Space Biospheres Ventures.

European Space Agency Director General Reimar Lüst has noted that, "[ESA] supports not only the 'principle' of the ISU, but also its day to day activities. To date this has included free advertising in Agency publications, ISU brochure sponsorships and, in conjunction with the 1988 summer session, ESA sponsored scholarships and ESA staff as visiting lecturers." Lockheed Corporation has contributed a senior executive to serve full-time on the ISU summer session faculty for two months each in 1988 and 1989. "ISU is an important force for international space education and awareness. Few programs offer a more inventive and forward thinking approach to this vital frontier," says Lockheed Chairman and CEO Daniel Tellep. "We applaud ISU's efforts and are proud of our company's role in its continuing success."

ISU supporters, Margret Augustine of Space Biospheres Ventures, Reimar Lüst of the European Space Agency and Daniel Tellep of Lockheed Corporation.

ANNOUNCEMENT

An ISU Founders Association has been established to provide a vehicle for visionary men and women to become involved with and to support ISU's transition to a permanent campus in 1992. For more information on the Founders Association, contact:

INTERNATIONAL SPACE UNIVERSITY®

ISU

International Space University
636 Beacon Street
Boston, MA 02215 USA
FAX: (617) 247-1832

ISU extends its thanks to the following for their support of this supplement:

MCDONNELL DOUGLAS

Lockheed

arianespace inc.

MARTIN MARIETTA

GE Astro Space

SHIMIZU CORPORATION SHMZ

FINAL FRONTIER

CENTER FOR INNOVATIVE TECHNOLOGY

Rockwell International

SSI®

AVIATION WEEK & SPACE TECHNOLOGY

Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Availability	Source
Periodicals				
ESA Bulletin	4	ESA's magazine	Free of charge	ESA Publications Division, ESTEC,
ESA Journal	4	ESA's learned journal	,,	2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly (English or French)	4	Remote sensing newspaper	,,	,,
Columbus Logbook	4	Space Station/Columbus newspaper	,,	,,
News & Views	6	ESA Information Retrieval Service's newspaper	,,	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Volumes on specific Conference subjects	Prices below	ESA Publications Division, ESTEC,
Scientific/Technical Monographs	(SP-xxxx)	Specific/detailed information on graduate-level subjects	,,	2200 AG Noordwijk, The Netherlands
ESA Brochures	(BR-xxx)	Summary of less than 50 pages on a specific subject	,,	,,
ESA Folders	(F-xxx)	'Folders' giving short description of a subject for the space-interested layman	Free of charge	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	Prices below	,,
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	,,	,,
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	,,	,,
Other Publications				
Contractor Reports	(CR-xxx)	Study reports from contractors: CR(P) given unlimited distribution CR(X) confined to certain ESA Member States	Prices below ,, ,,	ESA Publications Division, ESTEC 2200 AG Noordwijk, The Netherlands ,,
Technical Translations	(TT-xxx)	Translations of national space-related documents — (Microfiche or photocopy only)	Prices from ESRIN	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy, or ESA/IRS Office, 8-10 Mario Nikis 75738 Paris 15, France
Public-relations material		General literature, posters photographs, films, etc.		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

Charges for printed documents	E0	E1	E2	E3	E4
Number of pages in document:	1—50	51—100	101—200	201—400	401—600
Price (Dutch Guilders)	20	30	40	60	80

1. Cheques to be made payable to: ESA Publications Division
2. Prices subject to change without prior notice
3. Postal charges (non Member States only): Australia Dfl. 25; Canada Dfl. 20; Other Countries Dfl. 15.

Order Form for ESA Publications

RETURN TO: DISTRIBUTION OFFICE ATTN.: F. DE ZWAAN
ESA PUBLICATIONS DIVISION
ESTEC, POSTBUS 299
2200 AG NOORDWIJK
THE NETHERLANDS

No. of copies	ESA Reference	Title	Price per copy, Dfl.	Total Dfl.

Postal charges
(non Member States only: Australia Dfl. 25; Canada Dfl. 20; Other countries Dfl. 15):

Total Amount to be Invoiced: Dfl.

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

MAILING AND INVOICING ADDRESS (Print carefully)

Name ....

Function ....

Organisation ....

Mailing Address ....

....

Town & Postal Code ....

Country ....

Customer's Ref. .... Signature ....

Date ....

ADDITIONAL INFORMATION

1. Publications are available in printed form (as long as stocks last), in microfiche and as photocopies.
2. Publications in the ESA TT series are not available in printed form.

esa
european space agency
agence spatiale européenne

Member States

Austria
Belgium
Denmark
France
Germany
Ireland
Italy
Netherlands
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres

Allemagne
Autriche
Belgique
Danemark
Espagne
France
Irelande
Italie
Norvège
Pays-Bas
Royaume-Uni
Suède
Suisse

TO PREPARE FOR THE 21ST CENTURY
25 YEARS OF EUROPEAN COOPERATION IN SPACE

1964
1989

25 ANS DE COOPERATION SPATIALE EUROPEENNE POUR PREPARER LE 21EME SIECLE

European Space Agency / Agence Spatiale Européenne
8 - 10 rue Mario-Nikis, 75738 Paris Cedex 15, France