esa bulletin

number 54

may 1988

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.

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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. 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;
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(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.

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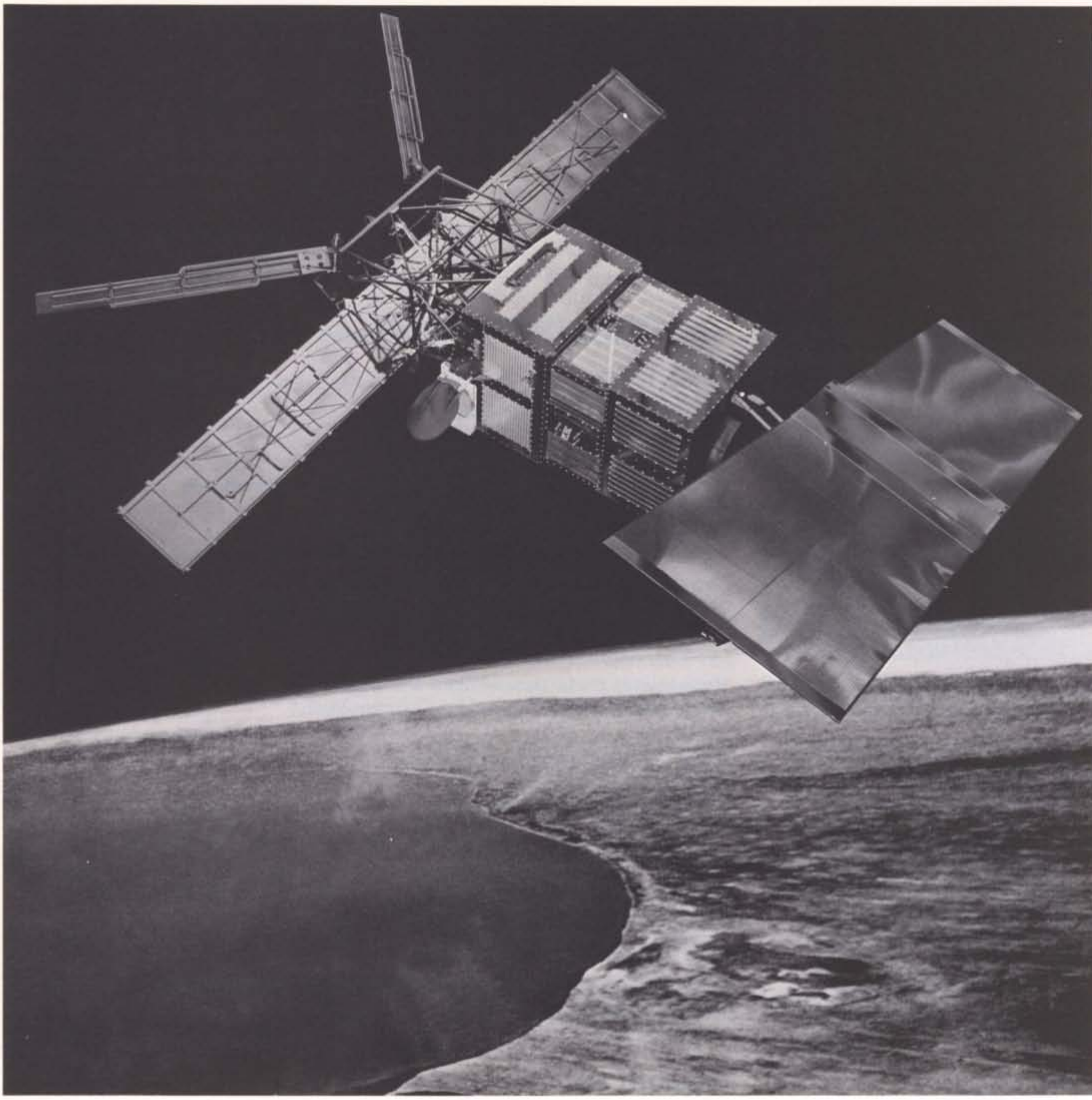

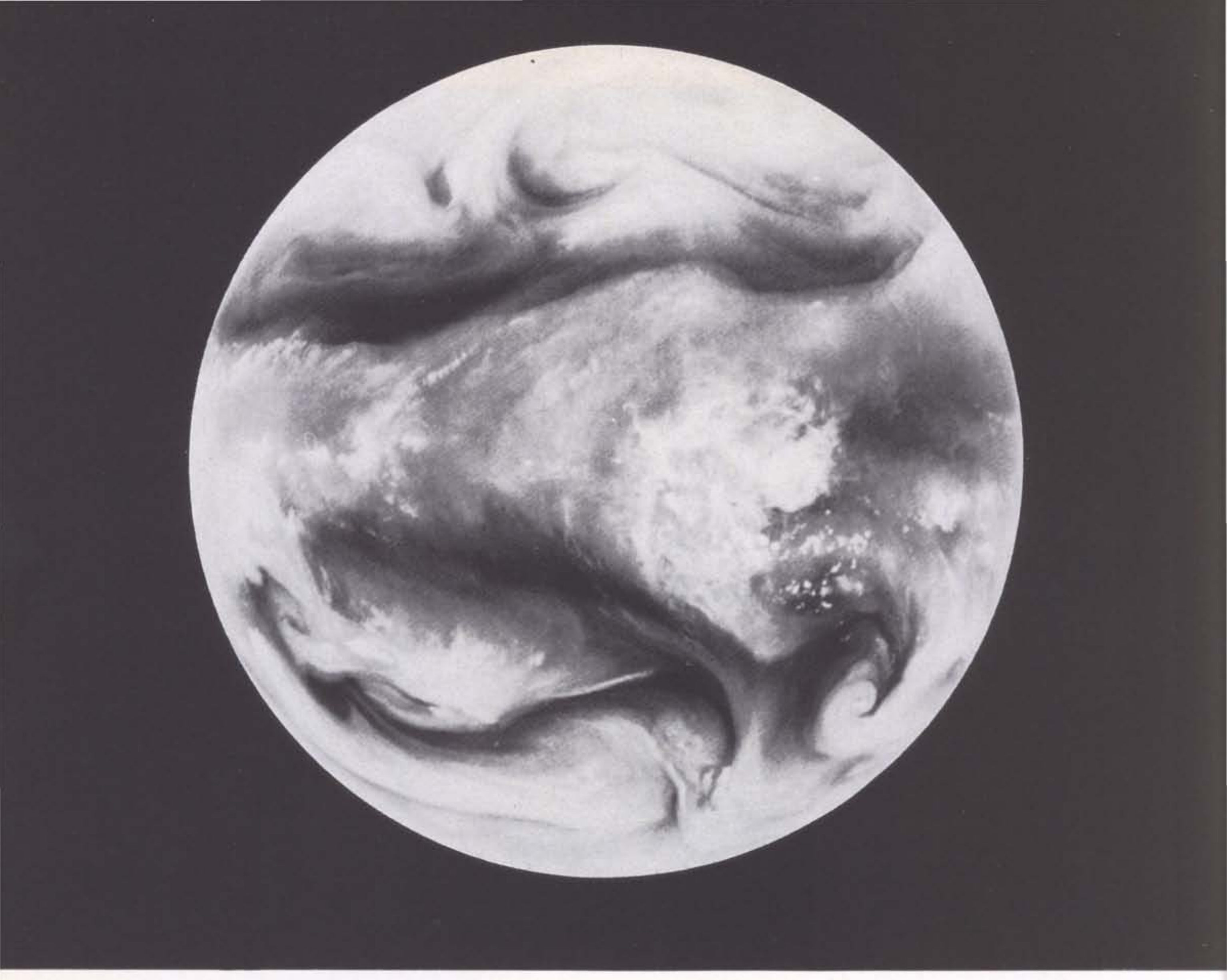

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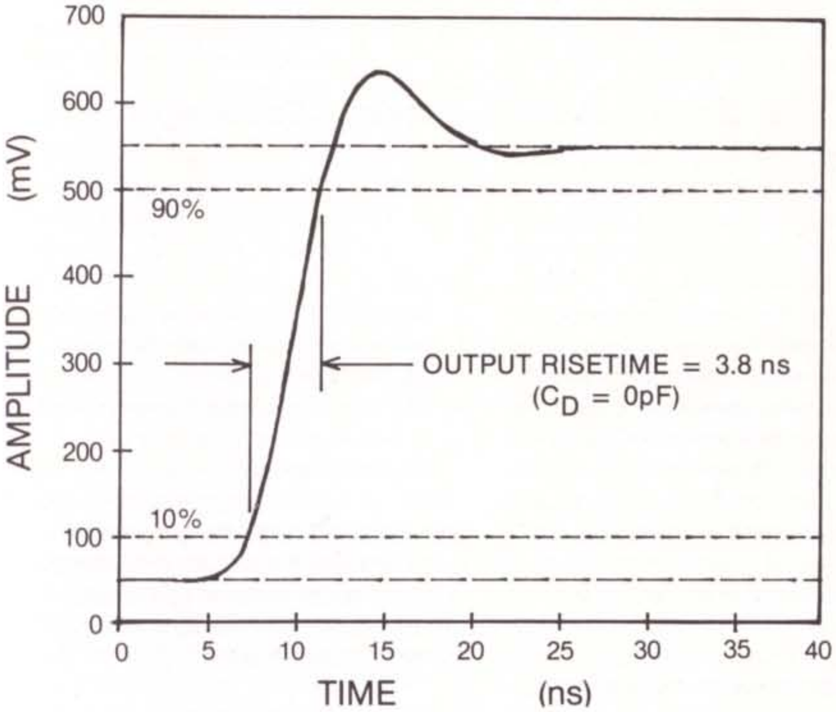

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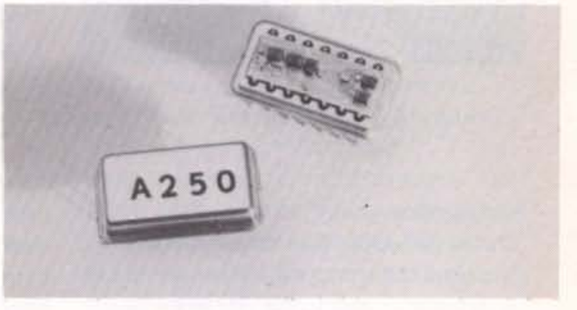

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Europe in Space: The Manned Space System*

Reimar Lüst, Director General, European Space Agency, Paris

Introduction

'Quam Daedalus Quam Nos', or 'as Daedalus did so do we', is as relevant to us today as it was to the Ancient Romans and Greeks. Indeed it is clear from the way our ancestors invested their Gods with the ability to conquer space that this yearning to be free of the Earth's limitations is almost as old as mankind itself. Those early philosophers and writers saw that manned space flight was not just a fantasy; they recognised the need for safety, or if you like, 'Product Assurance'. For while they admired Daedalus for his prudent space travels, they warned of the dangers of foolhardiness by telling the story of his son Icarus, who came to grief because his wings were fastened with wax, which melted when he flew too near the Sun. This 'bonding fault' resulted in Icarus falling into the sea.

The title of this Symposium is both a statement and a pointer to the future. 'Europe in Space' is an accepted reality, and next year we will be celebrating our silver jubilee, marking twenty-five years of joint European ventures in space. The Manned Space System is our next step forward, building on the confidence and experience gained in our first two and a half decades, as well as on Europe's political will to be placed alongside the other two major space powers, with an independent means to carry man into space, and a stake in the International Space Station.

* Based on the Opening Lecture to the International Symposium on Europe in Space, Strasbourg, France, 25 – 29 April 1988.

From time to time miracles do happen, even in Europe. This was the impression conveyed by some of the media when the positive news was announced in The Hague last November that the Ministers of 13 European States had been able to agree, during a two-day meeting, on a Long-Term Space Plan for Europe. This Plan provides the orientation for European activities in space until the year 2000.

To the insider, however, the success of the Ministerial Council in The Hague was not a miracle. Member States were able to recognise just how useful space activities are, given ESA's proven ability to develop and operate 14 scientific and 8 applications satellites successfully, and the record of 17 successful Ariane launches. The individual Member States might have somewhat different motivations for their involvement, but together they recognised the necessity for increased European activities in space, as foreseen in the Long-Term Plan.

I should perhaps stress here that each and every space activity must, of course, fully justify its cost on its own merit.

In addition, there are considerable indirect gains to be made through advancing technology, as well political benefits. Both of these are important arguments in favour of strengthening space activities, but they should not be the deciding factors.

In this presentation, I would like to address three main questions:

1. Why should Europe be in space?
2. Why should Europe have its own manned space system?
3. Why should European Governments as well as private enterprise be involved in space?

Why should Europe be in space?

If one analyses the motives and interests of the European States in space, one can identify six major reasons for the European commitment:

1. Space research, which covers a broad spectrum of scientific disciplines, is a major component of modern basic research. It epitomises the human search for knowledge, cultural advancement, and technical ingenuity.

There is no question that important progress in astrophysics and geophysics is impossible without exploiting the possibilities that modern space techniques offer.

Furthermore, there are areas beyond space science that could benefit from the unique low-gravity conditions found on a spacecraft orbiting the Earth. This special environment is of interest for material sciences, pharmaceutical research, and the life and medical sciences.

It is sometimes forgotten that space exploration and exploitation have brought together many disciplines and techniques that might not otherwise have benefitted from this cross-fertilisation and from the advantages of shared facilities.

2. Although Earth observation by satellite is already widely used, its has still to achieve its full potential. Space-based reconnaissance will certainly lead, with the further development of meteorological satellites and above all in conjunction with the use of larger computers, to greater precision in weather forecasting. This should bring about considerable savings in, for example, agriculture, offshore exploration, fishing and shipping. Special efforts are currently being devoted to Earth observation, and many domains will benefit from this, not least that of environmental protection.

3. Communications satellites are not only important commercially, but have already revolutionised global communications. Their social and political impact will increase further with the advent of direct broadcasting by satellite. It must be admitted, however, that the technology is currently well ahead of the ability of television companies and others to provide new material to exploit the many new opportunities that direct-broadcast satellites will provide. Satellites for marine and aeronautical navigation could have significant advantages in the future for safety and other similar applications. They are as yet only in their infancy.

4. Space opens up new fields of economic activity. Space activities and the use of space have given rise to a new multi-product market for transportation systems, satellites and associated ground facilities.

Microgravity looks likely to provide new potential for economic and industrial ventures, the true possibilities of which remain to be explored.

5. Space technology is relevant not only for space projects, because the latter's stringent requirements influence technological developments in other areas too. Moreover, management systems that were first applied in large space projects have also proved useful for management applications in general.

A group of economists at the University of Strasbourg has made a study of the impact of space projects carried out by European industry beyond specialised space technologies. A similar study has since been carried out for the Federal Republic of Germany, by Kienbaum Unternehmensberatung. Both studies arrived at very similar conclusions, two of which were as follows: first, almost 50% of all contract payments are being spent with smaller or medium-sized firms; secondly, there is a considerable benefit in terms of improved technology, higher quality products, increased sales, better organisation, as well as higher productivity and an improved work factor.

All of this results in overall benefits that can be expressed in terms of a 'return coefficient' of 3.6 for space work. Comparison of these results with those of earlier studies in Strasbourg clearly shows that this coefficient seems to be rising and, according to both studies, there is a remarkable transfer of technology from the space sector to the more general non-space sectors of industry.

6. Finally, one should not forget the political impact — indeed prestige — associated with large-scale space projects, especially when they are manned missions. This should not, of course, provide the main impetus for a European space policy. Nevertheless, as a political symbol and an indicator of political self-confidence, manned space exploration is of particular value.

Why should Europe have its own manned space system?

Let me try to answer this question in two parts; namely,

1. Why is a human being necessary at all in space?
2. Why must Europe be involved? Why not leave it to the Americans and Russians?

Past European missions devoted solely to space science have all been 'automatic' in nature. The same applies to our Earth-observation and telecommunications projects. Having astronauts on-board is an added complication on any spacecraft, given the inherent need for platform stability. Furthermore, safety requirements for astronauts, and the resulting increased costs, will restrict man-tended opportunities for scientific payloads. Most future space-science missions will therefore continue to be automated. However, we always need to ask ourselves what tasks cannot be performed by mechanisms or robots and therefore call for human intervention.

To define these tasks for which humans are indispensable, it is first necessary to evaluate previous experiences, most notably in the United States and the Soviet Union, but also in Europe through our two Spacelab missions. This approach will enable us to formulate sound objectives for the years to come.

The experience of the past has clearly confirmed some of the negative aspects of putting man into space, including higher costs and more stringent requirements. The Challenger disaster and the subsequent three-year 'paralysis' have demonstrated the dire consequences when things go wrong in space. Experience has, however, also highlighted particular circumstances under which man's presence is of great value; the part played by the cosmonauts in the docking of the Soviet astrophysics module, and the earlier spectacular rescue of Skylab with the astronaut-installed 'solar shield' are just two examples.

Neither the Americans nor the Soviets are planning to reduce the importance of the human role, as is clearly evidenced by NASA's promotion of a permanent manned presence in space, and by the manner in which the Soviet Union is assembling its ever-expanding Space Station.

Europe too has already accumulated a some experience with payload specialists/astronauts working in space aboard Spacelab. The significance of this experience ought not to be underestimated, since the man-tended elements of the International Space Station project will be of the Spacelab-type in terms of both hardware and use. The Spacelab missions demonstrated the astronauts' role to be much more important than had hitherto been anticipated, not so much for monitoring experiments or even for playing an active scientific role, but rather for their ability to deal with unforeseeable events, such as hardware failures, and to make adjustments to particular experiments. Astronauts have genuinely 'rescued' many experiments that would never have succeeded in their absence.

There is a growing trend nowadays towards replacing humans with robotic systems wherever the latter can perform tasks more economically or more efficiently, or when the working environment is hazardous. Robots can, in fact, perform quite complex tasks and can even improve on human abilities for highly repetitive jobs.

Clearly, for certain tasks in space robots can replace man. We can also assume that robotics will make dramatic progress in the future, particularly in the area of artificial intelligence. The overall efficiency of future space systems will therefore depend heavily on close 'cooperation' between astronauts and task-oriented robotic systems.

Today's tele-operated systems still have limited capacities in terms of dexterity, versatility and perception. However, by improving the perception systems themselves and the feedback of information to the human operator on the ground, the interaction can be enhanced, so that the ground operator will ultimately have the feeling of being present on the work-site. Development of this so-called 'tele-presence' will lead to 'tele-science' becoming much more realistic.

In the future, tele-robotic operations will support the extension of knowledge and even improve diagnostic systems when remote work stations in space are equipped with a multiplicity of information systems (such as data banks and stereoscopic and graphical displays) to improve information feedback.

Robots will thus enhance man's capabilities, rather than replace him. Robots can only operate in a predefined sequence: they can never match his ability to plan, reason and troubleshoot. Even the most sophisticated robots are not flexible enough to adapt to new tasks and unknown situations. Only humans are capable of integrating new and diverse items of information, and only they have the intelligence and ability to innovate and to solve unexpected problems as and when they arise.

The Agency's Columbus Programme will see the development of a full range of 'automated operations'. Nevertheless, despite the substantial investment in automation planned here, astronauts will still be needed to cope with unforeseeable or highly complex situations, such as:
— the assembly and installation of new experiments, requiring on-site adjustments.
— maintaining equipment and repairing hardware for both experiments and operating systems.

It is therefore not only in the field of microgravity research that astronauts will be necessary; they also have an influential role to play in the future development of space astrophysics. This will become more apparent when the Hubble Space Telescope is finally put into orbit. This telescope's intended operational lifetime of between ten and fifteen years can only be achieved if the facility is maintained regularly and if its sensors can be replaced periodically.

There are, moreover, plans to assemble large radio telescopes in orbit, which will in all likelihood only be possible with astronaut intervention.

Last but not least, new microgravity experiments are being planned. In my opinion, this activity is still in its infancy and a number of scientific experiments of limited interest managed to jump on the bandwagon in the early days. Nevertheless, this should not prevent us from giving this discipline a proper chance and, just as one cannot imagine a totally automated ground-based laboratory being the most efficient solution, I do not think a completely automatic laboratory in space could meet the requirements envisaged.

Nor should we forget the valuable information to be gained from observing the reactions and behaviour of human beings under low-gravity conditions in space, information which can be used profitably by those involved in researching the complexities of the human mind and body.

The true future in space lies in striking the right balance between activities that need to be carried out by humans and those that can be attended to by robots. Mankind already enjoys many of the fruits of technology and automation; life has been made easier as a result, but man is irreplaceable nonetheless. The same will hold true in the future in space.

Without manned space flight, Europe would always have just a fraction of the autonomous capabilities of the large space nations, such as the USA and the USSR. This is why ESA is pressing ahead with the development of both manned and unmanned space systems.

There are four essential elements in ESA's future manned space systems:
- the Columbus project
- the Hermes space plane
- the man-rated Ariane-5 launcher
- the Data-Relay Satellite.

The Columbus project is Europe's contribution to the International Space Station, being developed jointly with the USA, Canada and Japan. Columbus

Figure 1 — Payload Specialist Wubbo Ockels working with the Fluid-Physics Module aboard Spacelab-D1. He was free-floating and, contrary to mission intentions, had to pull out the Module for easier operation. All the paper in view was related to the specific task that he was performing

includes a permanently manned laboratory docked to the Space Station. A further element, to be launched by Ariane-5, will be a free-flying laboratory equipped with a resource module which will be serviced from time to time by astronauts. An additional free-flying platform to be placed in polar orbit, mainly for Earth-observation purposes, is also included.

The Hermes space plane represents a further step towards European autonomy in manned space flight. Launched by Ariane-5, it will be used for servicing both the Space Station and the Man-Tended Free-Flyer.

In addition, ESA is developing a Data-Relay Satellite to establish an independent communications link to the Space Station, the Man-Tended Free-Flyer and the Polar Platform.

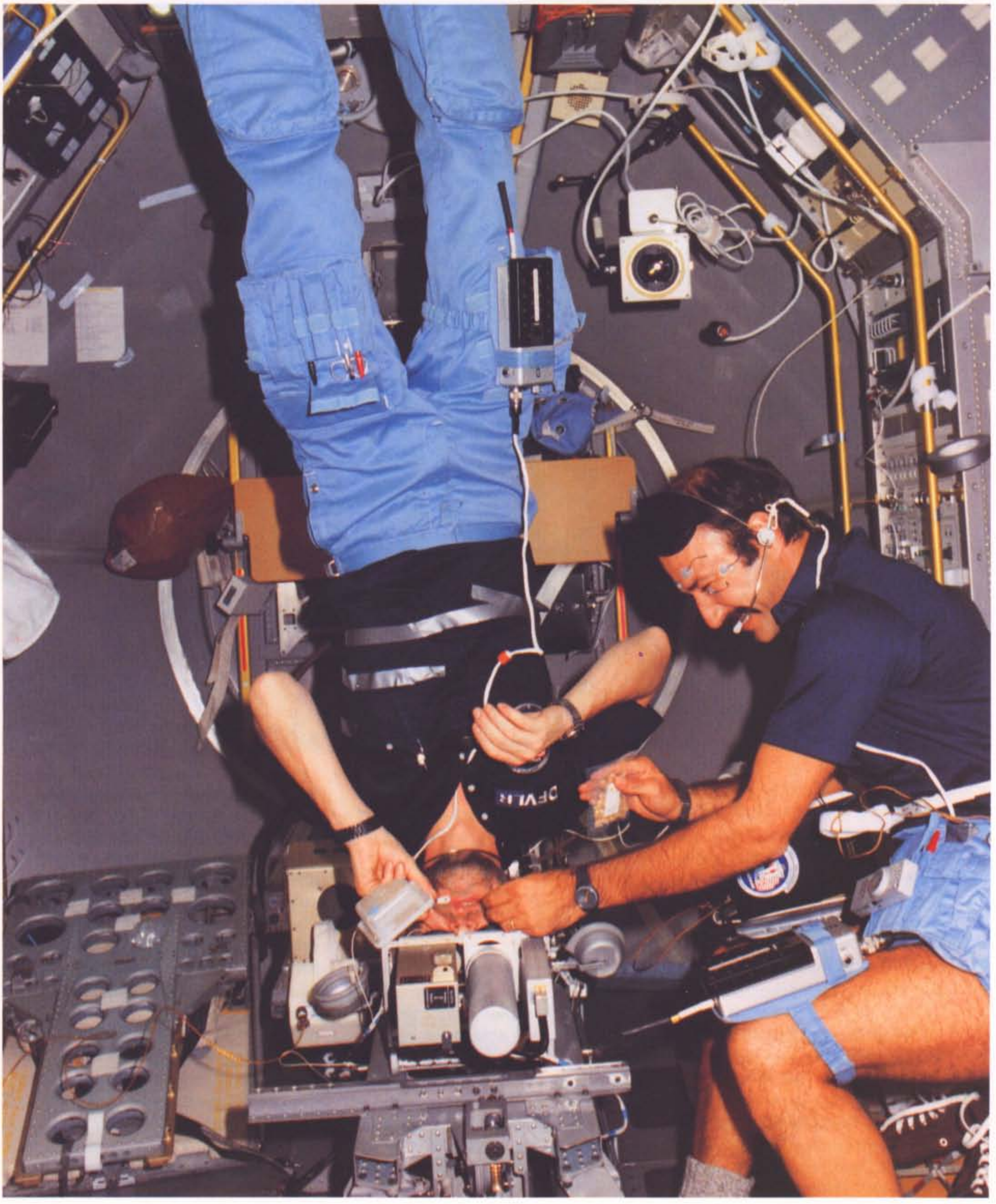
In summary then, it is ESA policy to put human beings into space only when absolutely necessary, using unmanned missions or robots wherever possible.

Why should European Governments as well as private enterprise be involved in space?

During the preparation of the Agency's Long-Term Plan, and in particular at the Ministerial Council Meeting in The Hague last November, the question of whether governmental support in space matters could not be reduced by involving the private sector much more was raised. Although, in principle, the goal of commercialising space activities as much as possible is probably justified, the question of when to hand over to private enterprise remains.

In the United States, there is indeed a strong trend towards commercialisation, privatisation and deregulation. In Europe, however, we are confronted with a somewhat different situation. Unlike the United States, Europe is not a federation and has to cope with a host of different national technical standards and legal and administrative regulations. Despite this, ESA has already succeeded in handing over various space activities to international operators or companies,

Figure 2 — Wubbo Ockels, the ESA scientist-astronaut who acted as one of the Payload Specialists on the Spacelab-D1 flight, seen here assisting Reinhard Furrer of DFVLR during vestibular tests using the Space Sled 'helmet'



thereby ensuring that the results of its space R&D activities can be exploited efficiently to serve the public interest.

In this spirit, the communications satellites being used for television transmission have been transferred to the European Telecommunications Satellite Organisation EUTELSAT, formed by 26 PTTs representing the whole of Europe and not just ESA's Member States. The Agency's two Marecs maritime communications satellites have similarly been leased to the International Maritime Satellite Organisation INMARSAT. On the meteorological side, operational exploitation of the Agency's Meteosat satellites has been taken over by the newly created European Meteorological Satellite Organisation EUMETSAT.

Finally, the Agency's Ariane launcher is now marketed by Arianespace, a private company set up by the Member States that invested in ESA's Ariane development programme. Arianespace has to cover all its costs, other than the launcher's development costs which are borne by the ESA Member States, through income from its customers. Even before the Challenger disaster, Arianespace had captured half of the civilian launcher market. To date Arianespace has managed to chalk up 66 satellite launch contracts: 44 of these satellites are currently waiting for launch, representing a revenue of 14.7 billion French Francs (about 2.5 billion US Dollars).

There are still considerable possibilities for the involvement of the private sector in the space effort which should be explored. Encouragement will be needed, however, to ensure that non-governmental institutions and private firms do indeed make use of the available capacity in space, that they participate in the investment, and that they are ultimately ready to take over the operating responsibilities.

Two sectors of space activity spring to mind in this connection as being of special interest: Earth observation and data-transmission via satellites. Together with potential consumers, we are currently investigating how to involve the private sector from the outset in these domains. There are two important aspects when one is trying to convince future potential customers to invest funds at a very early stage. Firstly, a considerable learning phase is necessary; and secondly the potential customers must have some guarantee that existing opportunities will still be worthwhile in a few years' time.

Even in a field such as meteorology, where the advantage of observing the weather from above seemed so obvious, the learning phase was very long and almost a decade elapsed before the meteorological offices were ready to take over as operators. It is little wonder, then, that in the field of Earth observation there will also be a very long learning phase before these activities can be commercialised, even though Spot Image has already had almost instant success in this domain. Clearly, the user community wants to be guaranteed a continuous flow of data before making heavy investments in the necessary ground infrastructure. This is why a decision to have a follow-up to the Agency's ERS-1 satellite is so urgently needed.

The same logic also applies to the field of data transmission via satellites. Here the future DRS will play a decisive role, and a workshop is being held to discuss the possible involvement of the private sector in this project.

Conclusion

Space offers our society great opportunities for improving living conditions here on Earth, and we as good Europeans must make the most of them.

I hope that this Symposium will give the representatives from all sides of this complex but exhilarating venture a chance to become better acquainted, to exchange views and ideas, to study the opportunities that are now open to us, and to initiate a dialogue that will continue long after we have left Strasbourg. The Symposium will indeed have been a success if we go away with greater confidence in each other, and better equipped for the tasks in hand.

As I said at the beginning 'Quam Daedalus, Quam Nos'. What Daedalus succeeded in achieving in fantasy, may we achieve in reality!

The European Long-Term Space Plan

K-E. Reuter, Coordination and Monitoring Office, ESA, Paris

The Council of the European Space Agency, meeting at Ministerial Level on 9 and 10 November 1987, reviewed the development of Europe's space activities within the framework of a Long-Term Space Plan, formulated during nearly three years of preparatory work, initiated by the previous Ministers' Meeting in January 1985.

The Ministers welcomed the Director General's proposal on this Plan, which will carry ESA Member States' efforts far into the next century, and endorsed it as the strategic framework and basis for the subsequent decisions regarding Europe's space activities and programmes up to the end of this century. They also underlined that all of the elements of this Plan are important for achieving its objectives and considered that the carrying out of the programmes required a reinforcement of ESA's role as a coordinating, strategic and executive authority, especially with regard to safety and coherence.

During their Meeting in The Hague, the Ministers paid particular tribute to the impressive results achieved in Europe in the space field during the last twenty years, and to the impetus given to the Programme in 1973 by the European Ministers at the European Space Conference in Brussels. It was this impetus that led to the realisation, through the Ariane Programme, of an independent and competitive launch capability, and to Europe's access to manned-spaceflight technology through the construction and flight of Spacelab.

They also noted that during the same period the exploration and utilisation of space had contributed to the establishment of an overall European policy in the field of technology and that, by the end of the century, space activities as a whole will constitute an important factor in the political, economic, social and cultural life of all countries.

The Ministers recognised that the scope of the Agency's programmes had to be enlarged and its resources increased substantially to cope with the challenge of the next decade and beyond, whilst of course taking the financial constraints of the Member States into account.

Objectives of Europe's Long-Term Space Plan

The guiding objectives underlying the approved Long-Term Plan are based on the need for Europe to maintain and build on the achievements of the first two decades of European space cooperation, and to expand its autonomous capability and its competitiveness in all sectors of space activity.

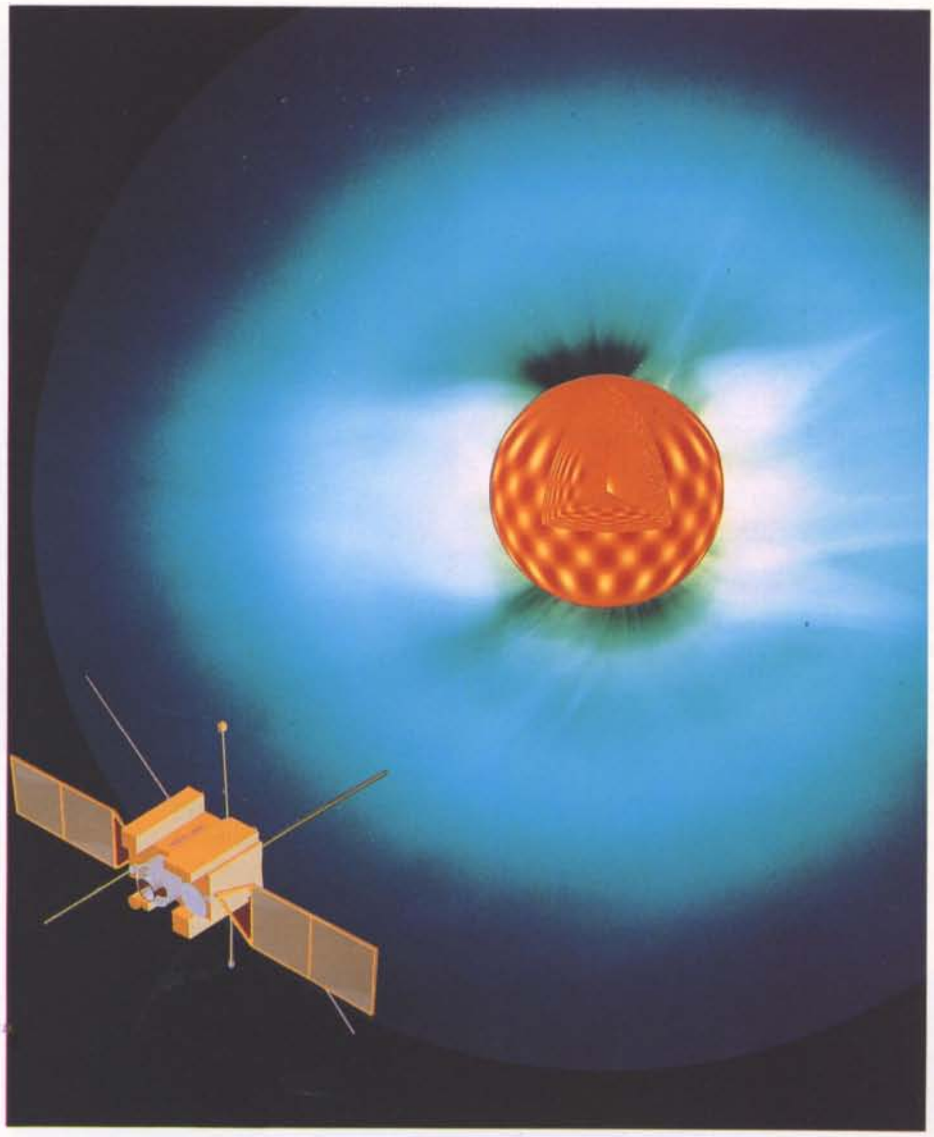
The overriding general guidelines, confirmed by the Ministers in their Resolution adopted on 10 November 1987 in The Hague, are therefore to:

- orient space activities towards achieving a coherent European Programme
- ensure that European spending on space will be balanced between expenditure on enabling tools and infrastructure, and expenditure on primary applications such as space science and space applications
- ensure that the scope of the European Programme allows adequate coverage of all sectors of space activity and that developments in one sector can be to the benefit of all sectors.

The specific objectives of the Plan set by the Ministers are to:

- enable the European scientific community, via an expansion of the ESA Scientific Programme, to remain in the vanguard of space research
- further develop the potential of space in the areas of telecommunications and meteorology
- prepare a substantial contribution from space and ground techniques to Earth-observation sciences and applications and also for the setting up of operational systems and user-oriented organisations to operate them
- improve the competitiveness of European industry in applications

Figure 1 — Artist's impression of the Soho mission element of the Scientific Programme's STSP Cornerstone



areas via advanced development of space systems and technologies
- explore, via a substantial research programme (e.g. in materials and life sciences), the practical applications of microgravity in space
- strengthen Europe's space-transportation capacity, to meet foreseeable future user requirements within and also outside Europe, while remaining competitive with space-transportation systems that already exist or are planned elsewhere
- prepare autonomous European facilities for the support of man in space, for the transport of equipment and crews, and for making use of low Earth orbits
- enhance international cooperation and in particular aim at a partnership with the United States through significant participation in an International Space Station.

The programme proposal

The advent of new space capabilities and Europe's political will to compete with the other space powers, even in the area of manned space activities, have now been given a programmatic framework that will enable Europe to develop and exploit its technical capabilities.

The inclusion of the space infrastructure encompassing Columbus, Ariane-5 and Hermes — supported by the Data-Relay Satellite — gives a new dimension to the Agency's programmes and will form the backbone of these future activities. The impact of the space-infrastructure programmes lies, however, not only in its financial importance; the new elements also impose new parameters for the planning of the Earth-observation, microgravity and space-science user programmes, and require the setting-up of a new ground infrastructure capable of operating all of these elements simultaneously, particularly those to be manned on either an occasional or a permanent basis. A new approach to the operation of this future space infrastructure will therefore have to be devised to comply with all the requirements of the different elements and enable their combined operation.

The Scientific Programme

The general objective in science, via the realisation of the Long-Term Plan 'Space Science:Horizon 2000', is to continue to maintain Europe in the forefront of scientific progress.

The Horizon 2000 Programme was established in 1984 by a Survey Committee, composed of members of the Space-Science Advisory Committee (SSAC) and additional scientists from other international scientific organisations (ESF, CERN, ESO and IAU). It identifies the future major thrusts in space research and those areas where Europe could play a determining role over the next twenty years.

The Programme is founded on four 'Cornerstones':
- The Solar Terrestrial Science Programme (STSP).
- A mission to asteroids or comets, including return to Earth of primitive materials.
- An observatory for spectroscopic studies of X-ray sources.

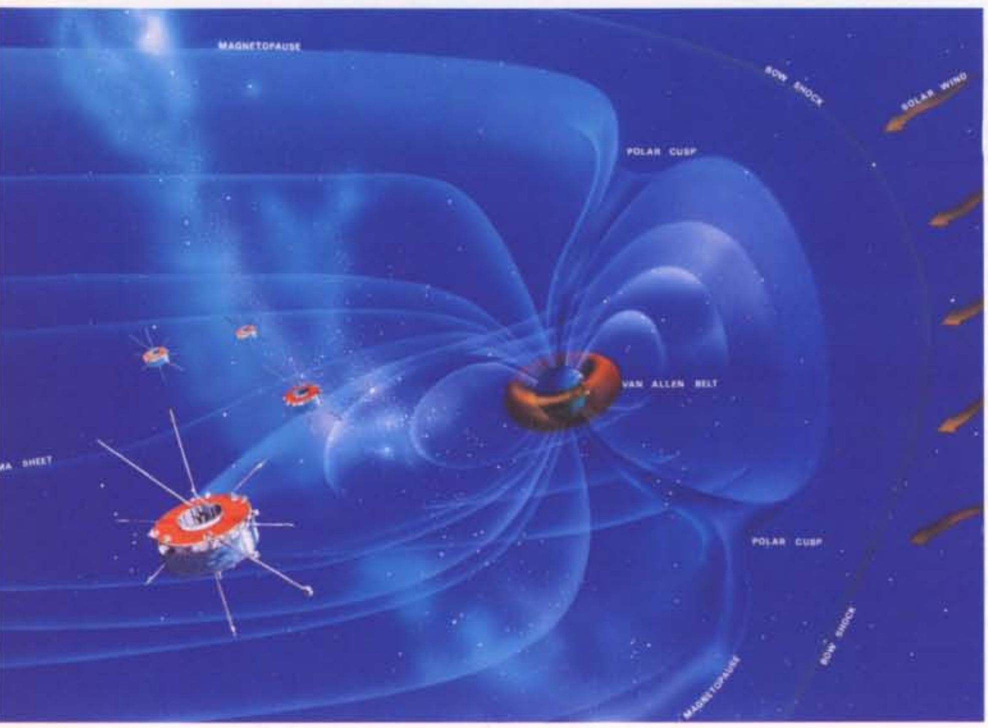


Figure 2 — Artist's impression of the Cluster mission element of the Scientific Programme's STSP Cornerstone

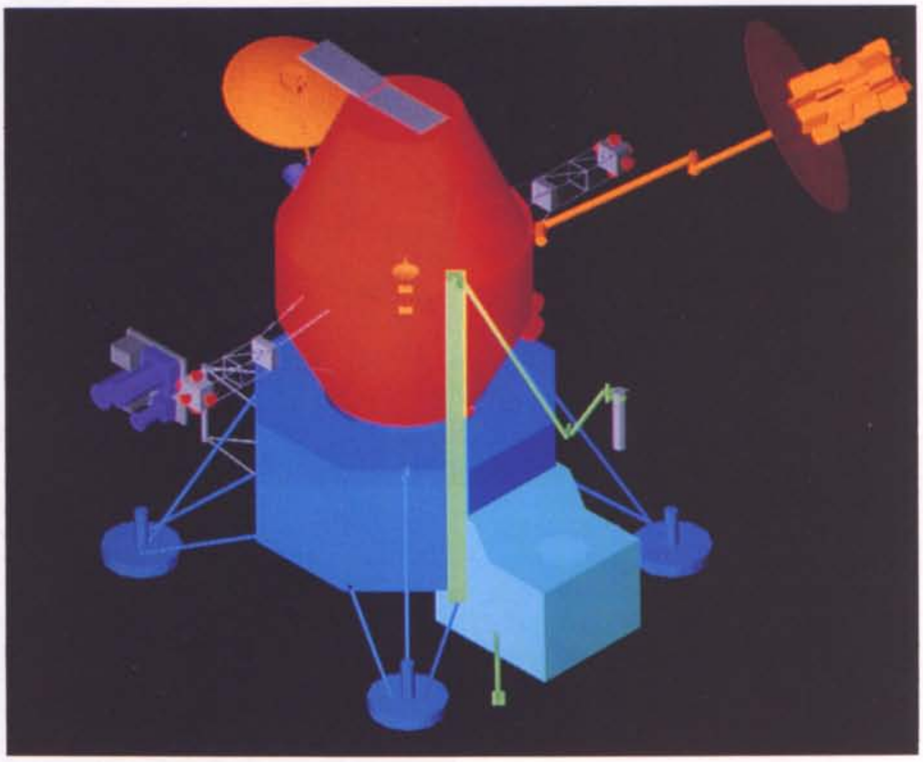


Figure 3 — The Comet-Nucleus Sample Return (CNSR) spacecraft (potential Scientific Programme Cornerstone mission)

- An observatory employing heterodyne techniques at far-infrared/sub-millimetre wavelengths.

In addition to these four Cornerstones, the Horizon 2000 Programme also includes a number of medium- and smaller-sized projects to be selected at appropriate times, via the Agency's present competitive selection procedure, by the bodies responsible for ESA's Scientific Programme.

A number of Eureca and Space-Station-compatible platform flights are also foreseen in order to provide frequent flight opportunities.

The Earth Observation Programme
Taking into account the success of the Agency's work during the last fifteen years in the domain of Earth observation from space, with Meteosat, ERS-1 and Earthnet, the long-term objectives of this Programme are to:
- provide, by the mid-1990s, operational systems in polar orbit tailored to scientific and applications needs in the fields of ocean, ice, coastal processes and meteorology
- develop space techniques from polar orbit for experimental/pre-operational use in remote-sensing land applications, with emphasis on all-weather microwave instrumentation
- continuously improve meteorological services by contributing to the development of a second-generation meteorological satellite
- develop continuous atmospheric monitoring from polar orbit for scientific, operational and climatological purposes
- develop space techniques for a scientific research and application mission in the solid-Earth field
- prepare for potential future missions via advanced system and instrument studies and carry out pre-development work on instruments
- establish and further develop the ground segment, currently based on Earthnet facilities, for payload data handling.

These goals will be achieved via the following main new programme elements:
- An ERS-2 satellite for launch in 1993.
- A multi-disciplinary Earth-Observation Programme based on the use of polar platforms from 1997 onwards.
- An ESA contribution to the development of a second-generation geostationary meteorological satellite

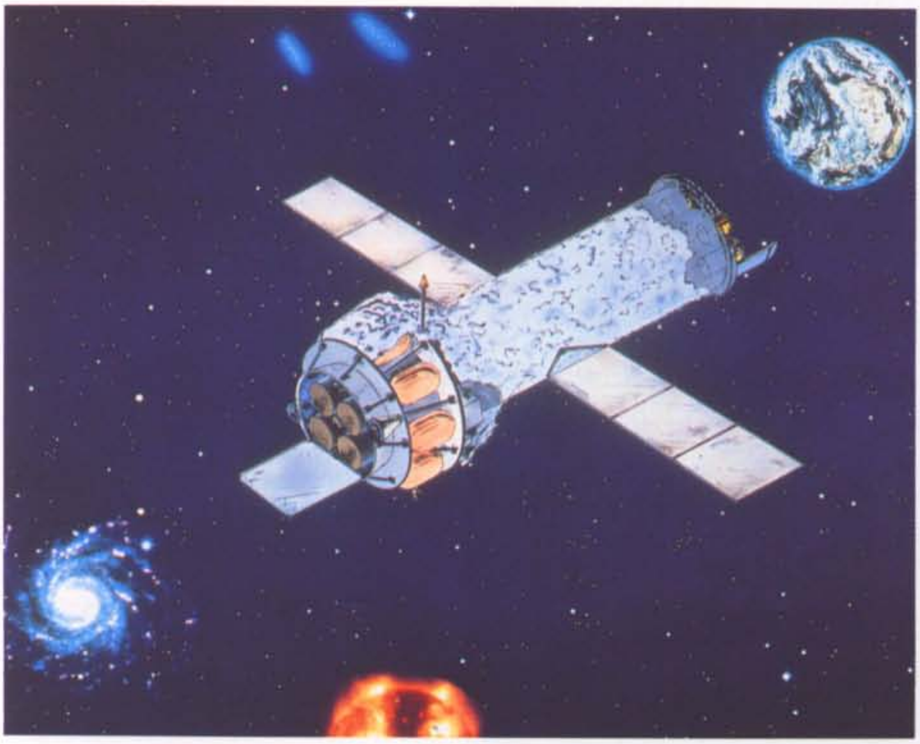


Figure 4 — The X-Ray Spectroscopy Mission (XMM) spacecraft (Scientific Programme Cornerstone mission)

for launch at the beginning of 1995.

- A solid-Earth research and application mission for launch in 1993.
- A climatology and atmospheric-science programme and its proposed extension with studies, measurement campaigns, instrument development and critical technology developments.

The Microgravity Research Programme
The Microgravity Programme is intended to prepare for the future utilisation of microgravity in space and therefore, in a first phase, is promoting fundamental research in the materials- and life-sciences disciplines, such as solidification physics, physical chemistry, fluid sciences, biology, biotechnology, human and animal physiology and medicine. It is also establishing a database upon which future users from research institutes and industry can draw for critical knowledge. Since the materials- and life-sciences communities are likely to be a major user of the future space infrastructure in low Earth orbit, a prime objective of the Programme is to prepare actively, by conducting the maximum number of experiments in space, for utilisation of the Space Station. Life sciences and fluid-physics researchers will be the main users of the manned laboratories, while crystal-growth and metals-processing activities will be mainly performed on the unmanned platforms.

The future phases of the Microgravity Programme are directed towards the preparation and development of payload elements for the Columbus modules, the Attached Pressurised Module (APM) and the Man-Tended Free Flyer (MTFF). The preparatory activities will involve:

- future studies
- reflights of existing facilities or those under development (e.g. Biorack, Autonomous Fluid-Physics Module, Anthrorack, etc.) on the IML-1 and Spacelab-D2 missions
- low-cost/short-duration missions (sounding rockets, parabolic aircraft flights, Shuttle 'Get-Away Specials')
- Eureca flights
- a few new payload elements for Eureca, Spacelab and short-duration missions and Shuttle-independent flight opportunities.

The Telecommunications Programme
A strong, coherent and unified Agency effort in space communications is needed to ensure that European industry can maintain and expand its competitive position in this market, and to enable Europe to operate efficiently and independently in other space fields.

More specifically, the fulfilment of the above broad guidelines requires a well-directed Agency effort in accordance with the following Programme objectives:

- to develop, and ultimately test in orbit, specific advanced space techniques that will contribute to the long-term development of established communications systems
- to demonstrate and promote new space-communication services for the expansion of European activities and the development of a larger European commercial market, as the necessary pre-requisites of any successful export effort
- to support other space missions and applications, such as Space Station and remote sensing, through inter alia the development of a European space-communications infrastructure.

Figure 5 — The Far-Infrared Spectroscopy Mission (First) spacecraft (potential Scientific Programme Cornerstone mission)

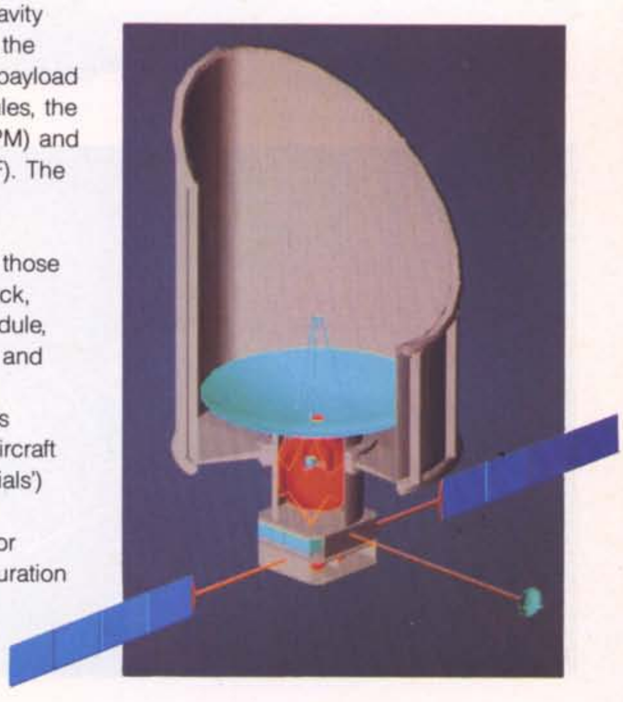
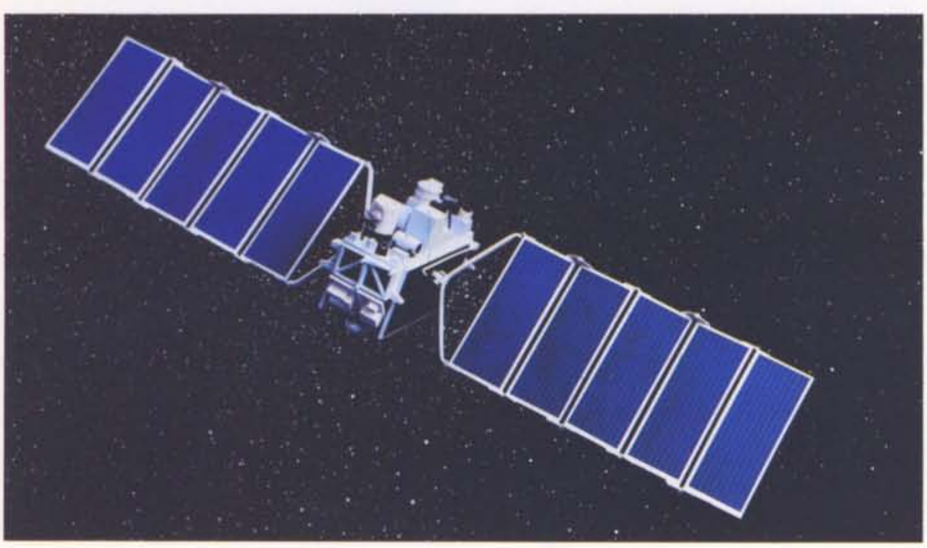


Figure 6 — The first European remote-sensing satellite, ERS-1 (Earth-Observation Programme)

Figure 7 — The Eureca spacecraft (Space Station and Platforms Programme)



The Programme proposal therefore consists of the following elements:

- The Payload and Spacecraft Development and Experimentation (PSDE) Programme, which includes the development and the necessary in-orbit experiments to prepare for the communications-related missions foreseeable in the 1990s.
- The Advanced Systems and Technology Programme (ASTP), which contributes to the technology support needed by the PSDE Programme.
- A first operational European Data-Relay Satellite (EDRS) System, as part of the future space infrastructure.

The space and ground segments of the Data-Relay Satellite System will provide cost-effective data-relay, information-transmission, telemetry, telecommand and ranging services to the future European space programmes, including in particular Columbus, Ariane-5, Hermes and Advanced Earth Observation Satellites.

The EDRS system will be made available in a time frame compatible with the needs of the space infrastructure (i.e. around the mid-1990s). The space segment will consist of two satellites operating in the S- and K-bands, and will also include an optical pre-operational payload.

The Space Station and Platforms Programme

The main aim of the Space-Station Programme is to prepare, as a long-term goal, for an autonomous capability for supporting man in orbit, for docking and robotics operations, for building, servicing and repairing space facilities, and generally for exploiting the low Earth orbit by establishing a manned space infrastructure.

In view of the need to approach this long-term goal progressively, and of the opportunity offered by the Space-Station Programme, the Programme objectives are to:

Figure 8 — The Olympus flight-model satellite under test in Canada (Telecommunications Programme)

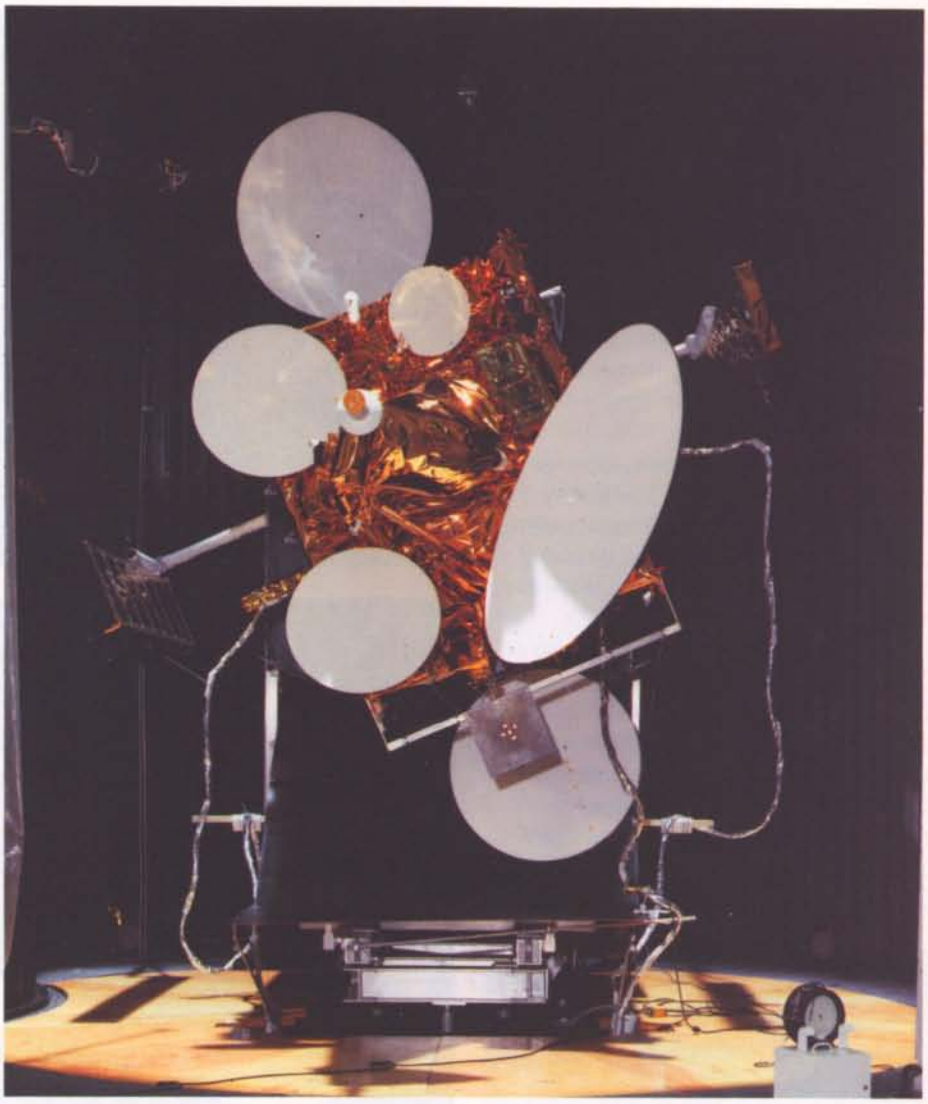
Figure 9 — One concept for the Data-Relay Satellite, DRS (Telecommunications Programme)

- develop and operate elements of the space infrastructure
- provide capacity for users and promote the use of this capacity
- prepare a European autonomous manned space capability.

These objectives will be achieved via the development and exploitation of Columbus.

Columbus development activities
The present plan contains the following elements:
- development of an Attached Pressurised Module (APM) as an integral part of the International Space Station, to be used primarily for materials sciences, fluid physics and life sciences
- development of a Polar Platform (PPF), dedicated primarily to Earth-observation disciplines
- development of a Man-Tended Free Flyer (MTFF), consisting of a pressurised module and a resource module; the MTFF will be used primarily for materials processing, fluid physics and life sciences
- Columbus element launches; the APM will be launched by the Space Shuttle in 1996, while the Polar Platform and the MTFF will be put into orbit by Ariane-5 in 1997 and 1998, respectively
- Utilisation Preparation Activities, which will develop and practise utilisation concepts and methods that will lead to efficient and well-organised exploitation of the space infrastructure, and will elaborate new payload accommodation and operations concepts. The activities foreseen include participation in Spacelab flights, simulating Space-Station conditions from both a hardware and an operations point of view
- ground-infrastructure equipment and preparation activities for the initial operations.

The Columbus Development Programme will be undertaken with a phased approach. Phase-1, which has started at



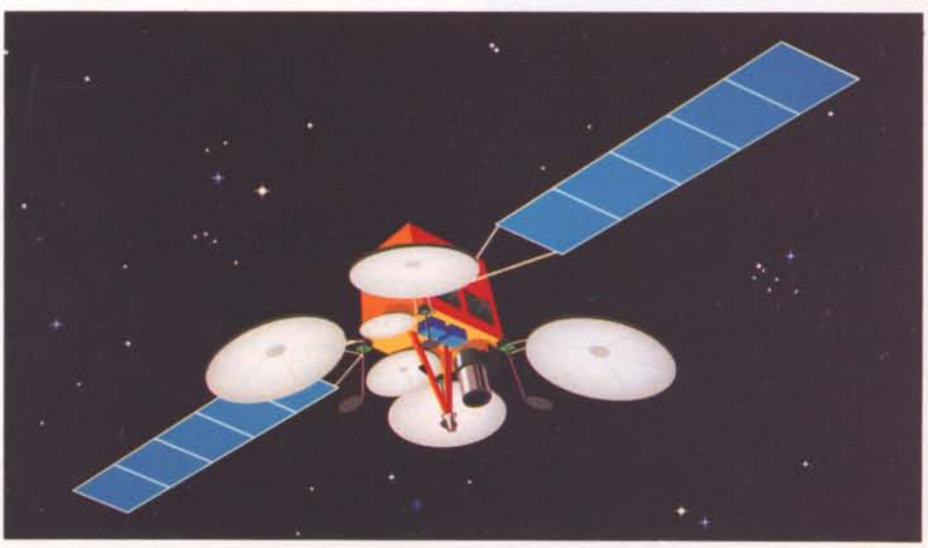
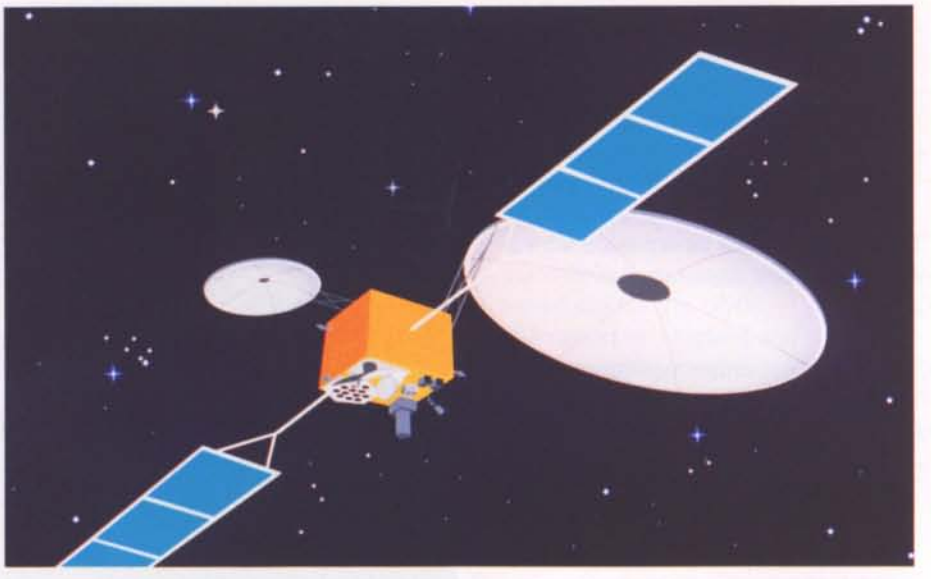
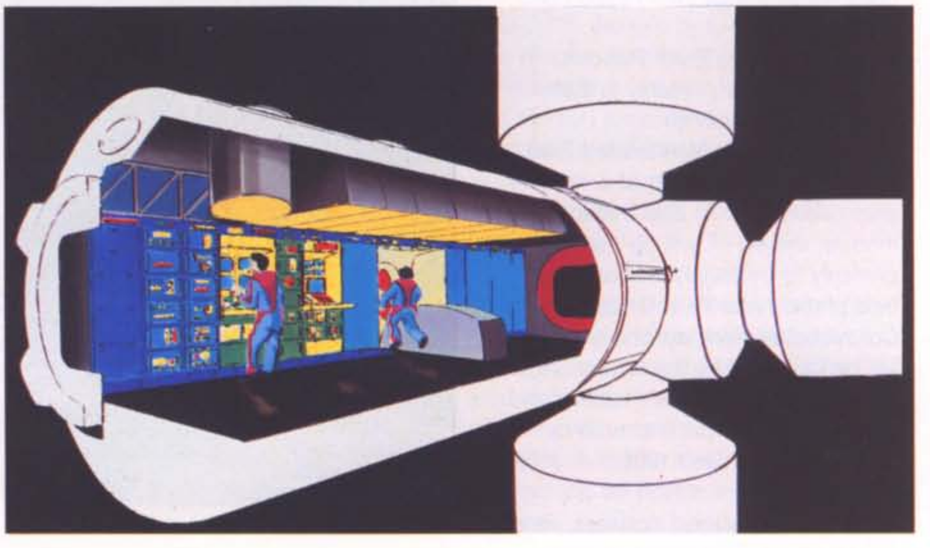


Figure 10 — A concept for a future advanced communications spacecraft (Telecommunications PSDE Programme)

Figure 11 — The Attached Pressurised Module (APM) for the Space-Station/Columbus Programme





the beginning of 1988, will last three years and cover pre-development work on all three Columbus elements.

A self-contained three-year pre-development phase will provide a level of definition for the Columbus elements greater than that normally expected at the beginning of a main development phase (Phase-C/D), and the associated programmatic data will allow a smooth transition to the full implementation phase.

Phase-2 should start — after approval by the Participating States — in January 1991 and will cover the full development, construction and in-orbit deployment of the three Columbus elements: APM, PPF and MTFF.

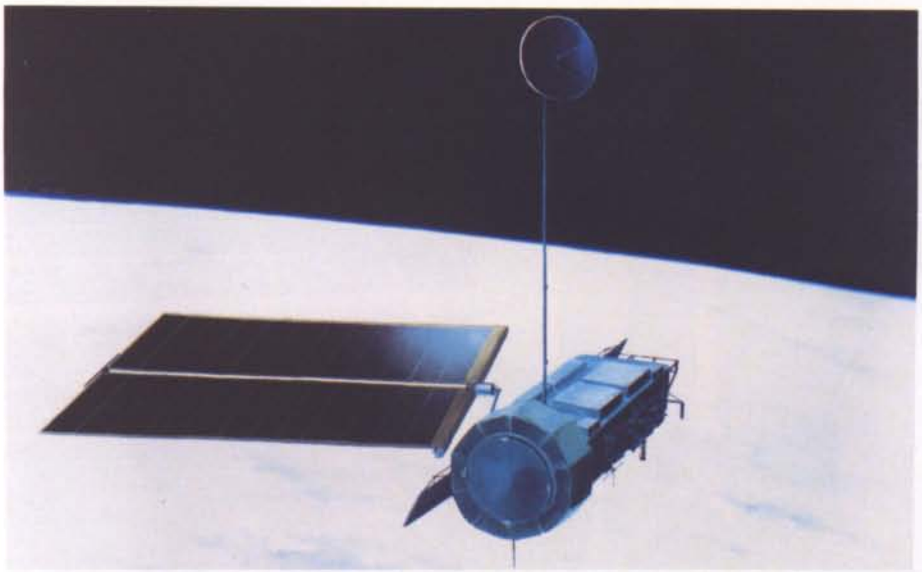
Columbus Exploitation Programme (CEP)
This Programme will cover system operations (e.g. Space-Station services, servicing by Hermes, logistic support) and utilisation support (e.g. payload launch and recovery, user-support-centre operation) during the exploitation of the Columbus in-orbit elements.

The Space-Transportation Programme
The Programme objective here is to maintain an independent capability for Europe that both meets the foreseeable requirements of European and other users, and remains competitive with other space-transportation systems, existing or planned. In addition, a reusable manned transportation capability must be acquired and employed for the supply and servicing of the European space infrastructure.

In line with this objective, the development of a new-generation transportation system is being undertaken which includes:
- The Ariane-5 launcher, including its infrastructure, with improved performance, reliability and cost-effectiveness for launches into geostationary (GTO), low Earth (LEO) and Sun-synchronous (SSO) orbits.
- The reusable space plane Hermes, including its infrastructure, capable of transporting men and payloads, performing servicing and supply missions in-orbit and returning to Earth.

The above goals, plus the need to consolidate the present achievements and to prepare for the future beyond the year 2000, lead to the following main programme elements:
- The Ariane-3/4 Operations Support Programme, aimed at continuous improvement of Ariane-4 until a few years before the end of its operational lifetime (1998).
- The Ariane-5 Development Programme, which will provide Europe with a multipurpose launcher suitable for putting:
  (i) automatic spacecraft with a mass of up to 6800 kg into geostationary transfer orbit;
  (ii) the Hermes space plane, with a mass of 21 000 kg, into low Earth orbit;
  (iii) Columbus elements into various low Earth orbits (the Man-Tended Free Flyer and the Polar Platform).
  The Ariane-5 development phase started at the beginning of 1988 and will be finalised with three test flights:

Figure 12 — The Polar Platform (Space Station and Platforms Programme)



two in 1995 for automatic missions, and one in 1998 for Hermes.
- The Ariane-5 Operations Support Programme (PAPA), which should start in 1996 with the aim of continuously improving the vehicle's operational capabilities.
- The Hermes Development Programme, which will be undertaken in a phased approach. Phase-1 of the Programme, started at the beginning of 1988, will last three years and cover initial development work in order to bring the space plane's design to maturity.

It will validate the technologies needed to reduce the risks in the Development Programme, confirm the Hermes servicing missions, in particular the Hermes/MTFF servicing scenarios, provide the Ariane-5 programme with the data needed for the freezing of the vehicle's conceptual design, and confirm the implementation of the necessary manned safety requirements. Phase-2 of the Hermes Development Programme should start — subject to approval by the Participating States — in January 1991 and cover the full development and construction effort. It will be completed with two qualification flights: one unmanned in 1998, the other manned in 1999.

Preparation of far-term programmes
A space plan covering nearly 15 years of development effort must also look beyond that period, with the aim of achieving full autonomy still to be pursued. Two study and technology programmes are therefore proposed aimed at preparing far-term programmes:

- The European Manned Space Infrastructure (EMSI) Programme, evolving from the present Columbus effort. This study programme will, from 1988/89 onwards, prepare the basis for future manned space capabilities, permitting a start to be made during the late 1990s on the development of an autonomous European Space Station.

- The Future European Space Transportation Investigation Programme (FESTIP), to be initiated in 1988/89, which will prepare Europe for a decision to develop, from the late 1990s onwards, a Space-Transportation System beyond Ariane-5 and Hermes.

The Space Infrastructure Operations
The step-by-step establishment of the European Space Infrastructure will impose a new approach on operations, both in space and on the ground, if the various elements are to work together in a coherent and efficient manner. The overall concept relates to:
- the development and production of space-segment elements
- the production and check-out of transportation systems for both automatic and manned missions
- full operational status of launch sites and rescue facilities
- the readiness of a communications infrastructure
- the availability of ground operations centres, including simulation and back-up facilities
- the continuous construction, improvement and refurbishment of payload and experiment facilities
- the availability of ground training facilities for space-segment crews, etc.

The operations link is therefore present in all programme areas, be it on the infrastructure side, with Ariane-5, Hermes, the Columbus elements and the Data-Relay Satellite (DRS), or on the user side in terms of, for example, scientific, Earth-observation or microgravity projects. An analysis of the various needs has resulted in the proposal to establish

Figure 13 — The Man-Tended Free-Flyer, MTFF (Space Station and Platforms Programme)

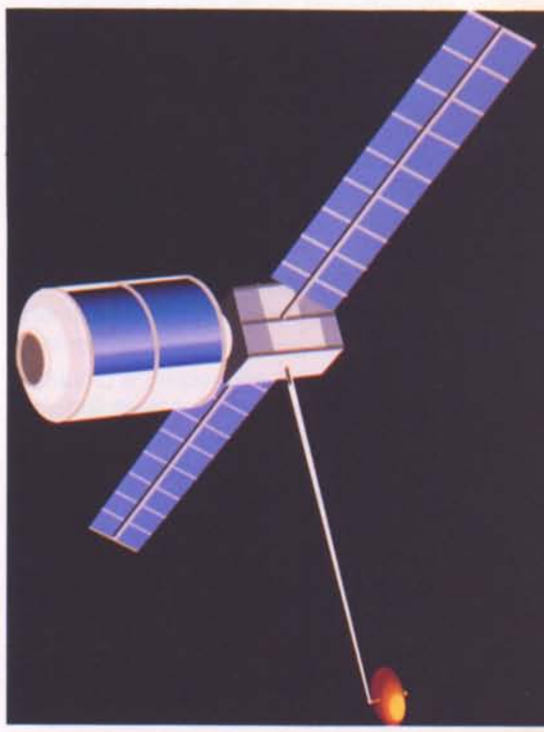
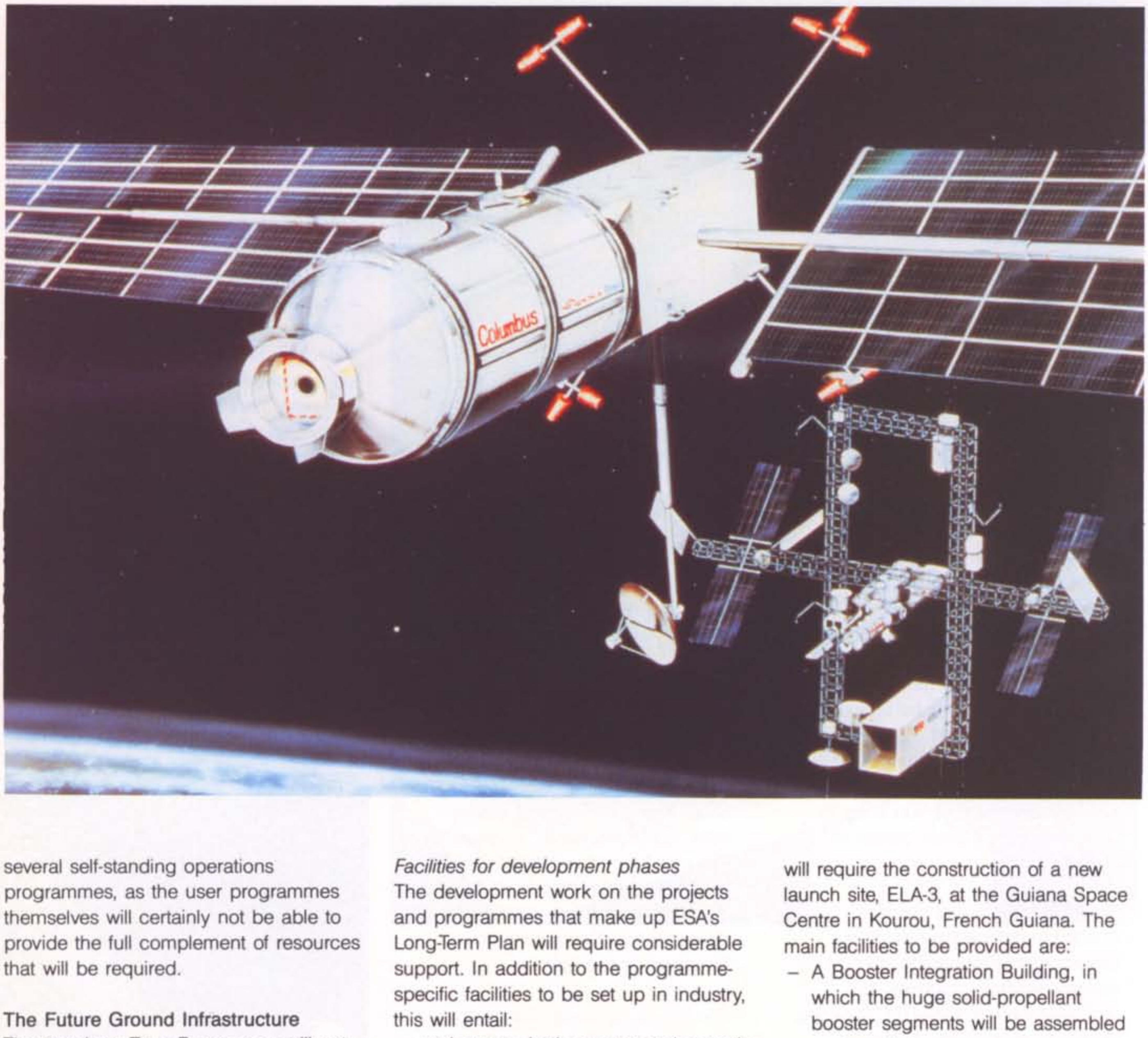


Figure 14 — Artist's impression of Space-Station/Columbus



several self-standing operations programmes, as the user programmes themselves will certainly not be able to provide the full complement of resources that will be required.

The Future Ground Infrastructure

The new Long-Term Programme will not only give the space segment a new dimension, it will also require a ground infrastructure of a different magnitude, as Europe embarks for the first time upon manned space programmes, with their particular safety implications. This new approach also requires a new concept for planning and setting up the ground facilities coherently. In addition, nearly all Agency programmes will be interlinked through the technical capabilities and advantages offered by the space infrastructure's elements.

Facilities for development phases

The development work on the projects and programmes that make up ESA's Long-Term Plan will require considerable support. In addition to the programme-specific facilities to be set up in industry, this will entail:

- an increase in the scope and capacity of general-purpose, multiproject facilities at ESTEC for supporting industry
- the possible building of two additional large environmental test facilities at ESTEC to meet the needs of Ariane-5 and its payloads
- the setting up of an astronaut training complex covering the needs of both Columbus and Hermes.

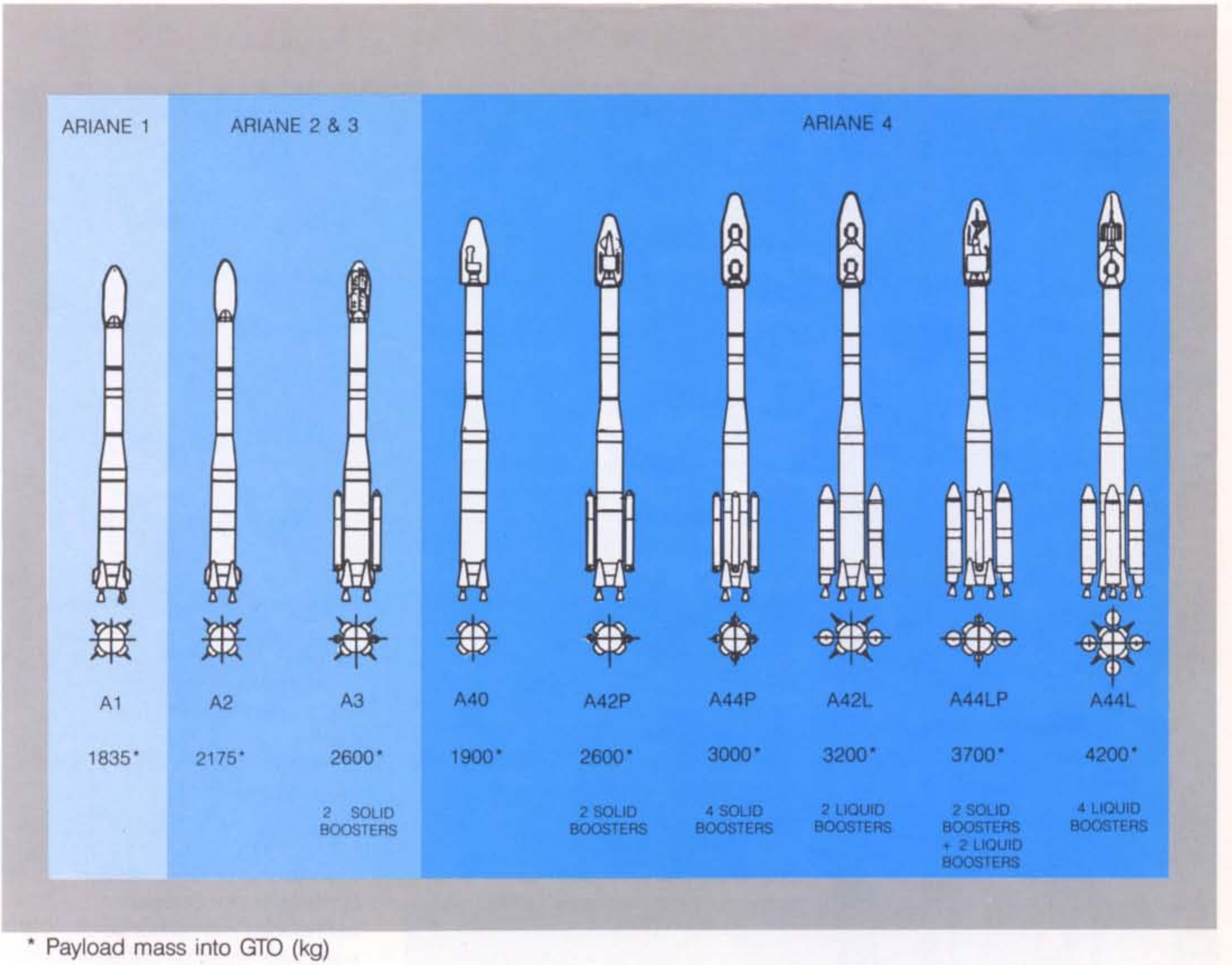
Launch and landing facilities

The preparation and launch of Ariane-5 will require the construction of a new launch site, ELA-3, at the Guiana Space Centre in Kourou, French Guiana. The main facilities to be provided are:

- A Booster Integration Building, in which the huge solid-propellant booster segments will be assembled and erected.
- A Launcher Integration Building.
- A Final-Assembly Building, in which, depending on the launch configuration, the payload composite, the Columbus elements or the Hermes space plane will be mated to the assembled launcher.
- A Launch Zone.
- A Launch Centre, from which the launch team will conduct and monitor launch operations.

The Guiana Space Centre will also be

Figure 15 — The Ariane family of launchers, including today's versatile Ariane-4 series



* Payload mass into GTO (kg)

one of the two prime landing sites for Hermes, the other being at Istres in the South of France. A number of back-up landing sites, at various locations around the World, will also have to be selected.

Ground operations facilities
ESA's existing ground infrastructure will have to be considerably expanded to cope with the planned European space infrastructure. This will entail setting up:

- A Central Mission Control Centre at ESOC, from which all combined and critical operations will be conducted.
- A Hermes Flight Control Centre.
- An Attached-Pressurised-Module Operations Centre.
- A Man-Tended Free-Flyer Control Centre.
- A Polar-Platform Control Centre.
- A Data-Relay Satellite System Operations Control Centre.

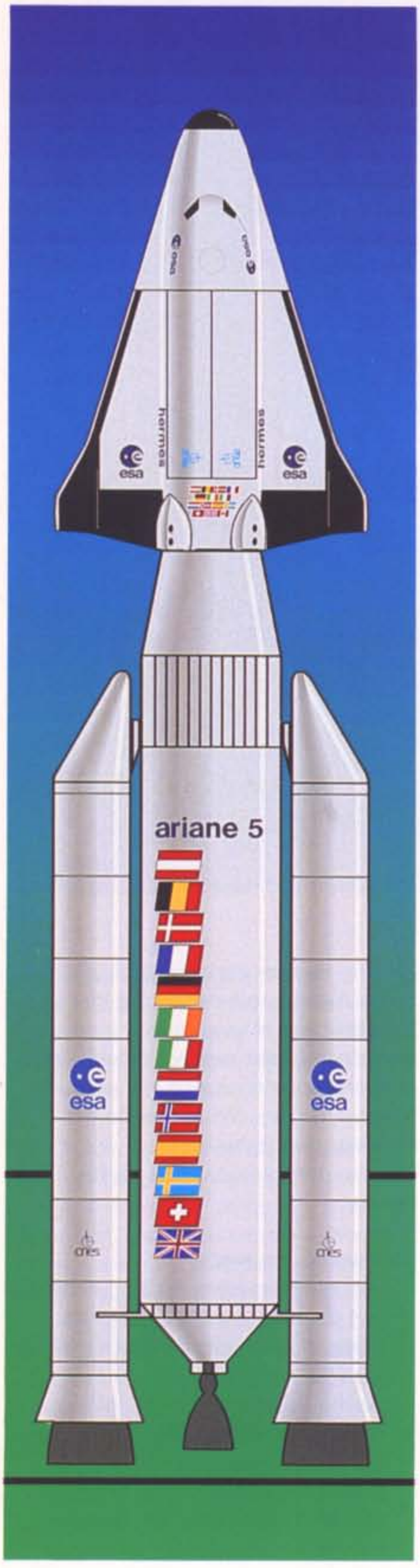
The future ESA ground network, based on existing stations, will consist of three main, overlapping subnetworks:

- The Launch and Early-Orbit Phase Network, consisting of a set of ground terminals located at low latitudes around the World.
- The Mission-Dedicated Network for full-time tracking, telemetry and control, as well as for data-acquisition support for missions not using the Data-Relay Satellite System.
- The Data-Relay Satellite Ground Network.

Data-handling facilities
In order to meet the requirements of a growing number and variety of user communities, present planning foresees the setting up of user centres for different disciplines and/or regions. A centralised coordination and support unit will, however, be required to provide the necessary link between the users and the mission and control centres.

Data will be acquired:
- through the existing tracking network and Earthnet stations for scientific, meteorological and Earth-observation missions
- via the Data-Relay Satellite ground network, at terminals to be set up at ESRIN in Frascati and near the processing and archiving facilities in ESA Member States for Columbus payloads.

Figure 16 — The Ariane-5/Hermes composite



Data will be processed:
- at ESOC in Darmstadt, or at the ground stations, for scientific and meteorological missions
- directly at the receiving stations for Earth-observation missions, with more complete processing being carried out by Earthnet
- at specialised users' centres for microgravity payloads.

Data archiving
The idea is to decentralise archiving as far as possible. However, a central facility will be set up at ESRIN for data-archiving network management and development. Present planning foresees that ESRIN will also be responsible for monitoring a unique data-dissemination network, which will, in addition, be used for near-real-time distribution of data.

The ground investments required by the various programmes of the Long-Term Plan are being scrutinised critically in order to identify possibilities for rationalisation in terms of loading, location and logistics. Utilisation of existing facilities within the Agency or belonging to national organisations, and commonality aspects between programmes, have to be taken into account.

The Technology Programme
The prime goal of the Agency's Technology Programme is to ensure effective technological preparation of Europe's future space projects, while implementing a coherent European industrial policy directed towards improving European competitiveness in World markets. One important contribution towards this objective remains the harmonisation of ESA and national technology activities.

This goal translates into more specific programme objectives, which are to:
- ensure timely availability of the technologies needed to execute all programmes of the Agency
- maintain a high level of competence in space technology in Europe as a basis for the successful competition of European space industry in World markets
- reduce the critical dependence of Europe on US technology and component supply which currently exists in some areas
- provide the means for demonstration and qualification of European technology through ground and flight testing.

To achieve these objectives, the Agency pursues three major programmes:

- The Basic Technology Programme for all the common domains of technology applicable to medium- and far-term missions that advance technology to the point of demonstrated feasibility.
- The Preparatory and Supporting Technology Programme elements for each of the major programme areas, which advance technology to the point of demonstrating flight suitability.
- The In-Orbit Technology Demonstration Programme, which provides in-orbit demonstration opportunities for European technologies that cannot be adequately tested on the ground.

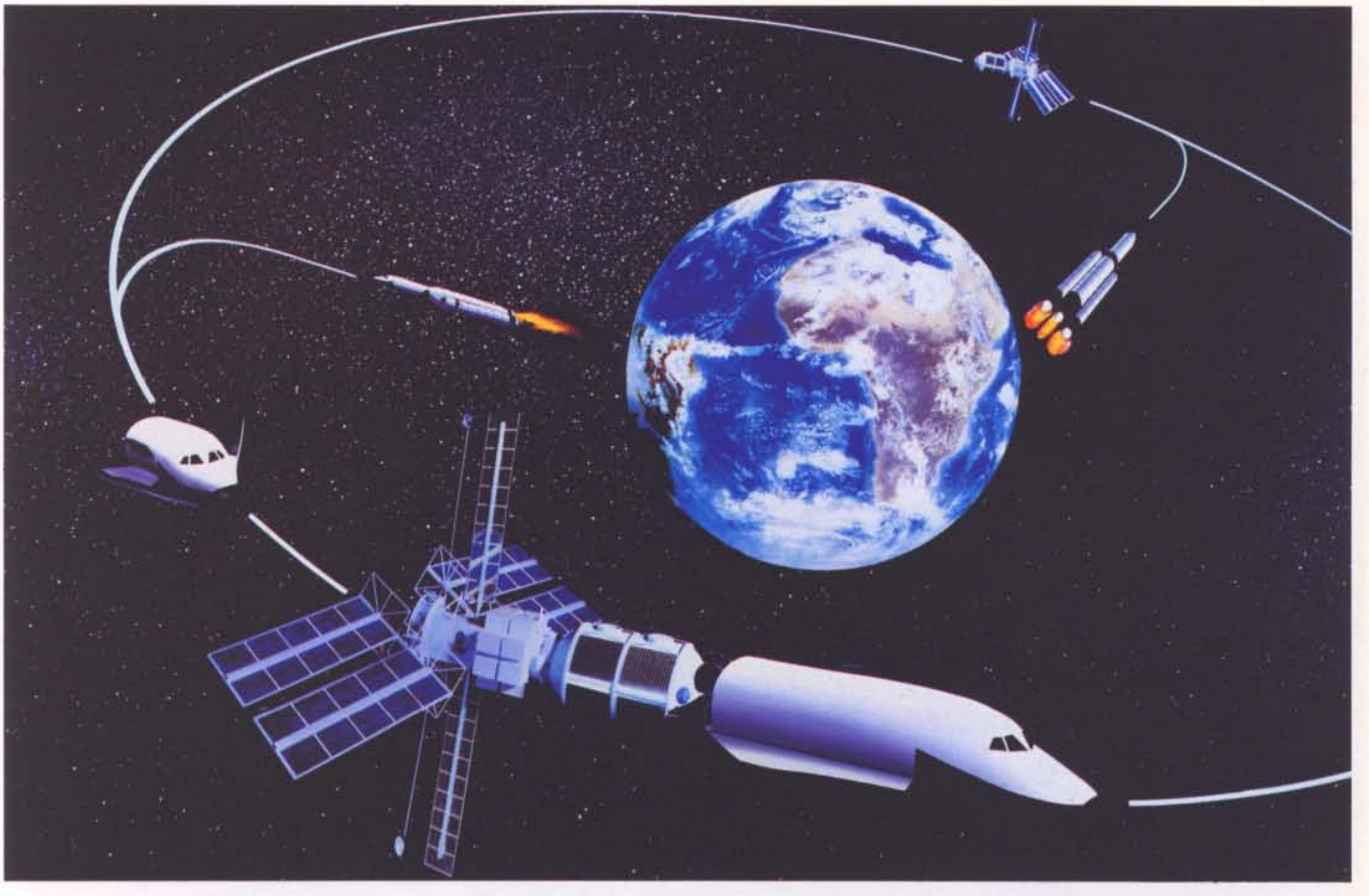
Coherence of the programme
The coherence of this European Long-Term Space Plan can be assessed on the basis of four criteria: funding, performance, schedule and industrial policy.

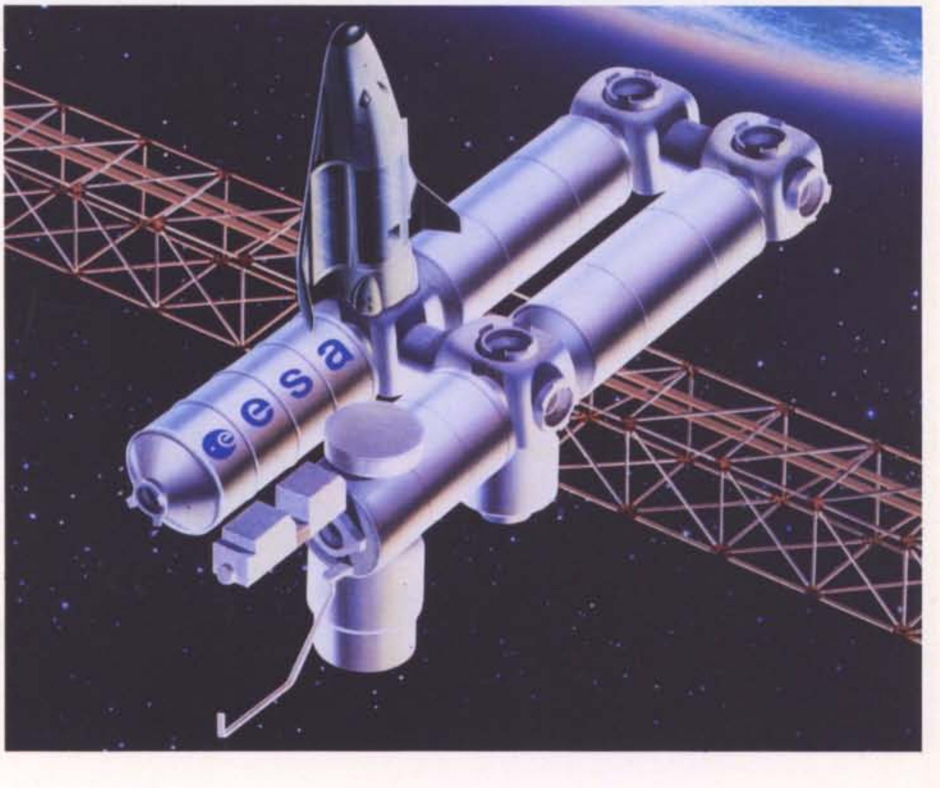
Funding
After a transitional phase that has lasted several years, the three well-established classes of mission, i.e. science, telecommunications and Earth observation, are now running at similar funding levels, while microgravity is increasing gradually to reach the funding level necessary for preparing for utilisation of the Space Station.

The funding foreseen for the Space Infrastructure is already running at the required level. Basic technological

Figure 17 — The Man-Tended Free-Flyer (MTFF) launch and in-orbit-servicing scenario

Figure 18 — The Hermes spaceplane docked with Space-Station/Columbus





research is undergoing a progressive but substantial growth, enhanced by the need for flight demonstration, which reflects the accelerating worldwide evolution.

The relation between mission-oriented user programmes (science, Earth-observation, microgravity and telecommunications) and infrastructure-oriented expenditures (launchers, Hermes, Columbus, DRS, technology) for the period 1987—2000 reflects the need for a continuous infrastructure effort and the fact that ESA is responsible in Europe for launcher and in-orbit infrastructure development that will subsequently be available for national and commercial missions.

The right balance will, however, be achieved when the proposed space infrastructure of the Long-Term Plan is fully operational.

Performance

The Plan will allow Europe to develop the necessary technology and bring it to fruition in the construction of innovative infrastructural elements. In the area of space transportation, a heavy unmanned lift capability and a manned space-transportation capability will be developed. The infrastructure foreseen caters for permanently manned and man-tended pressurised modules, as well as platforms in either polar or equatorial orbits. In addition, provision is made for the installation of the requisite operational infrastructure, of which the two Data-Relay Satellites form a major part.

Schedule

The overall schedule and project implementation is commensurate with the availability initially of Ariane-3 and 4 launchers and occasional use of the Shuttle for Eureca and Spacelab launches. From the mid-nineties onwards, the emphasis will shift, with the availability of Ariane-5 and Europe's participation in the International Space-Station Programme. In the late nineties, the scenario will be influenced by the availability of a European manned transportation capability, which will allow European autonomy to be fully established by the end of the century.

The schedule ensures timely availability of the necessary ground and space-operation infrastructures, in particular through the launches of the DRS satellites in the 1996 time frame.

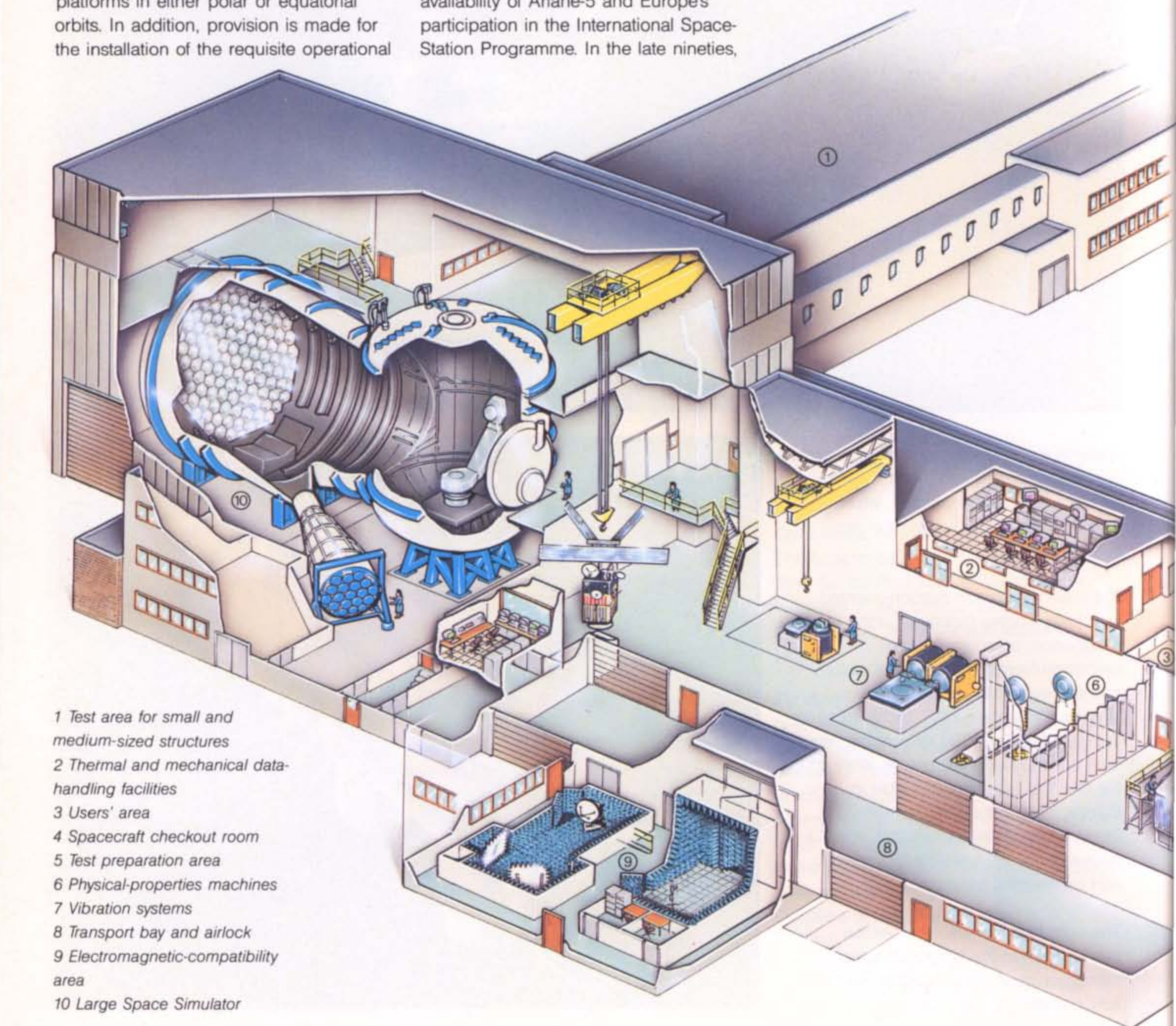


Figure 19 — The ESTEC Test Centre

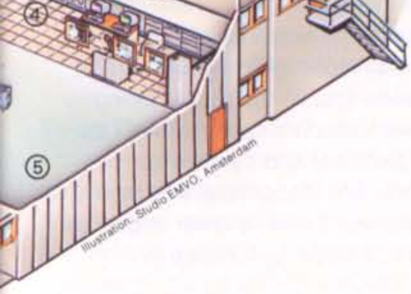
Figure 20 — Two examples of space-technology development
(a) Inflatable rigidised antenna (3 m diameter) being developed by Contraves for future satellites
(b) Docking/berthing latching subsystem being developed by Dornier System

For Columbus payload development, the spending profile is such that experiments and facilities of the necessary quality and performance will be available to meet the established integration, test and launch schedules.

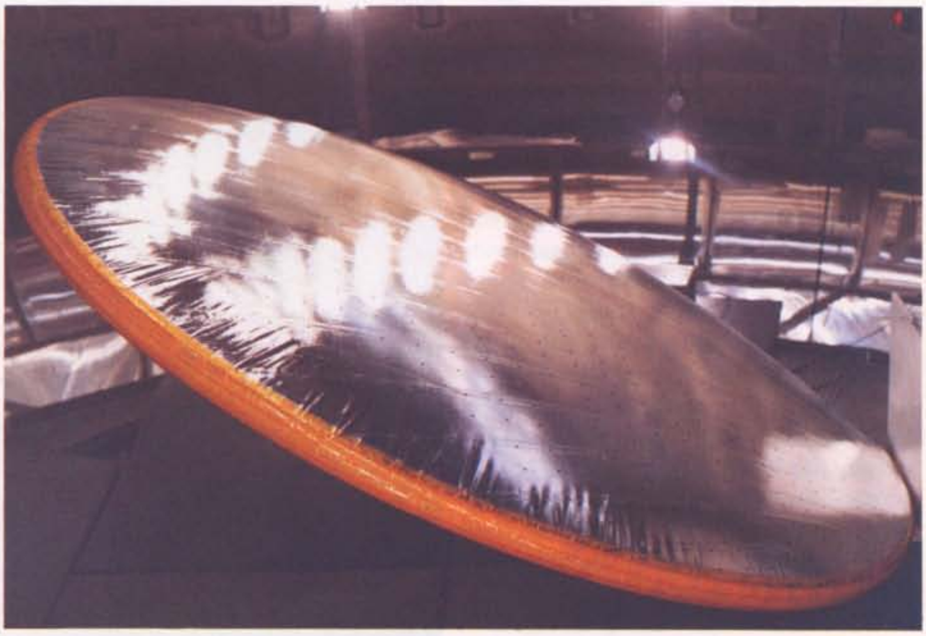
The Columbus Utilisation Preparation Activities will prepare the community for the quantum jump in flight opportunities that availability of the Space Station will bring. The culmination of these activities in the 1992/94 time frame is ideally phased with respect to the launchings of the Columbus elements.

Industrial policy
One of the highest-ranking considerations behind the approval of the Agency's programmes is the aim of implementing an industrial policy that will satisfy Europe's technological aspirations. This goal, expressed in Article VII of the ESA Convention, can be summarised as one of:

a. Meeting the requirements of the European and national programmes in a cost-effective manner.
b. Improving the worldwide competitiveness of European industry through the promotion of space technology and development of an appropriate industrial structure.
c. Ensuring all Member States an equitable participation in the work of technological interest.
d. Exploiting the advantages of free competition, except where incompatible with other objectives.



The competence of European industry in the various technological areas involved in space research has developed progressively, usually drawing upon existing knowhow in associated areas



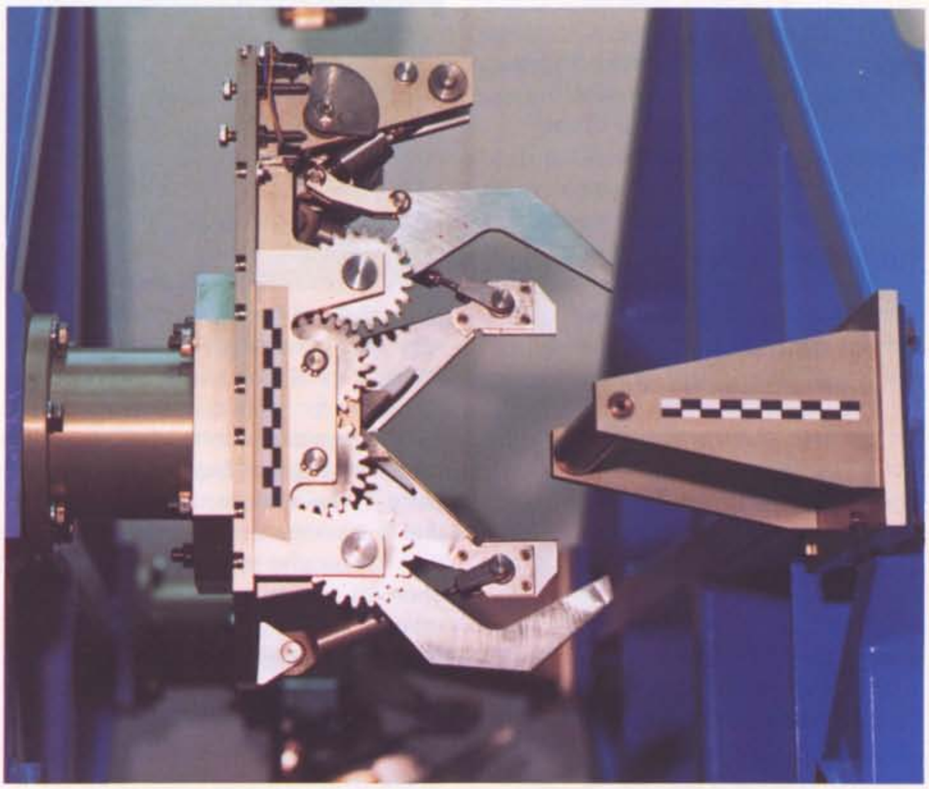
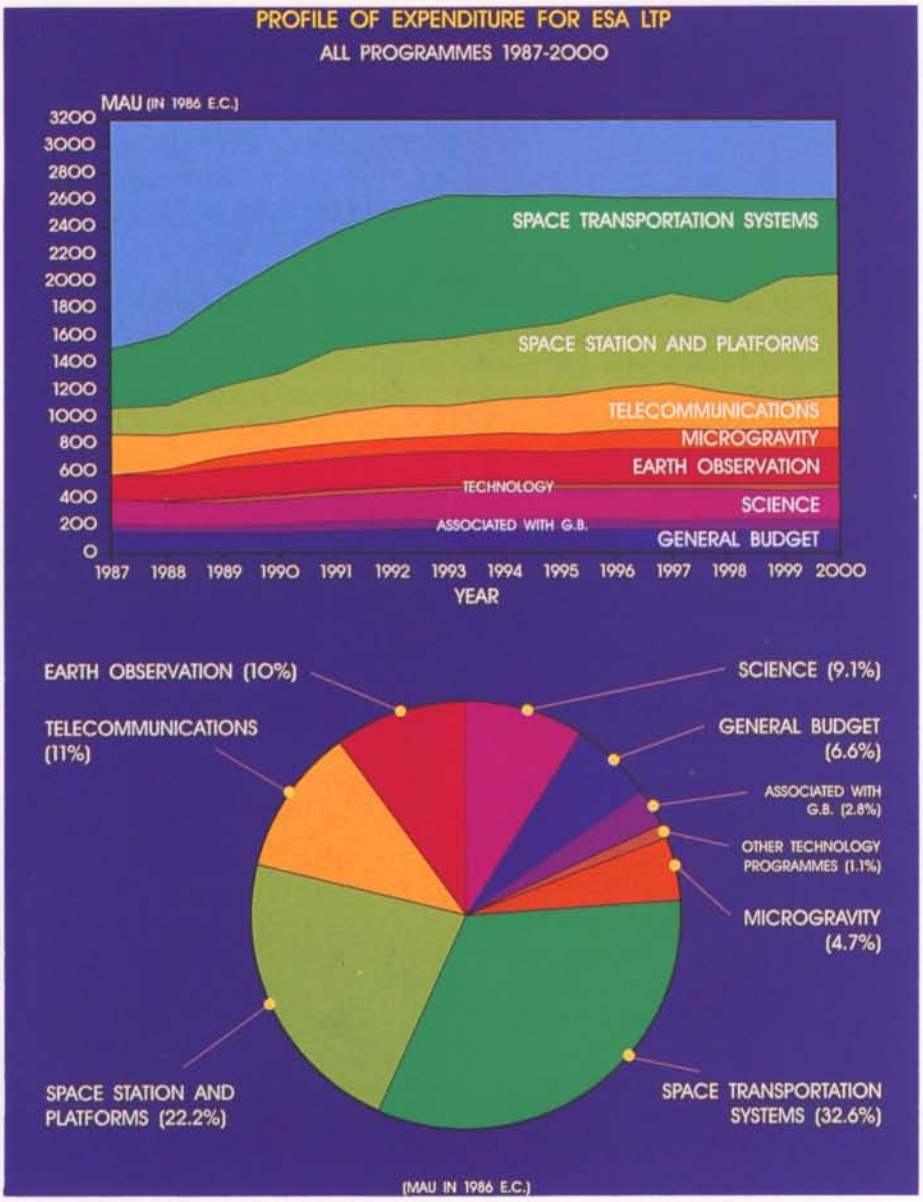


Figure 21 — Funding overview for the Long-Term Programme (per mid-February 1988)



such as aeronautics and terrestrial telecommunications.

ESRO and subsequently ESA have influenced this development in two ways; initially by entrusting the building of satellites to a European industry that had still to master all the necessary technologies, and in a later stage by entrusting technological research projects to a larger number of firms.

The production capacity of the European firms most active in the space segment and the expected trend in this capacity compared with the foreseeable requirements of ESA programmes, national programmes and the commercial market, have been assessed several times. The most recent study on the future workload of European space industry has indicated the need to increase the numbers of skilled personnel in order to be able to meet the requirements of the new programmes now starting, such as Ariane-5, Columbus and Hermes. A major training effort directed at specialised engineers and technicians is therefore essential.

Cooperation with the United States

In a speech on 25 January 1984, President Reagan invited the United States' partners to participate in the design, development and utilisation of an International Space Station. This offer was accepted by the ESA Ministerial Council, meeting in January 1985, while emphasising the need for achieving genuine partnership as proposed by President Reagan.

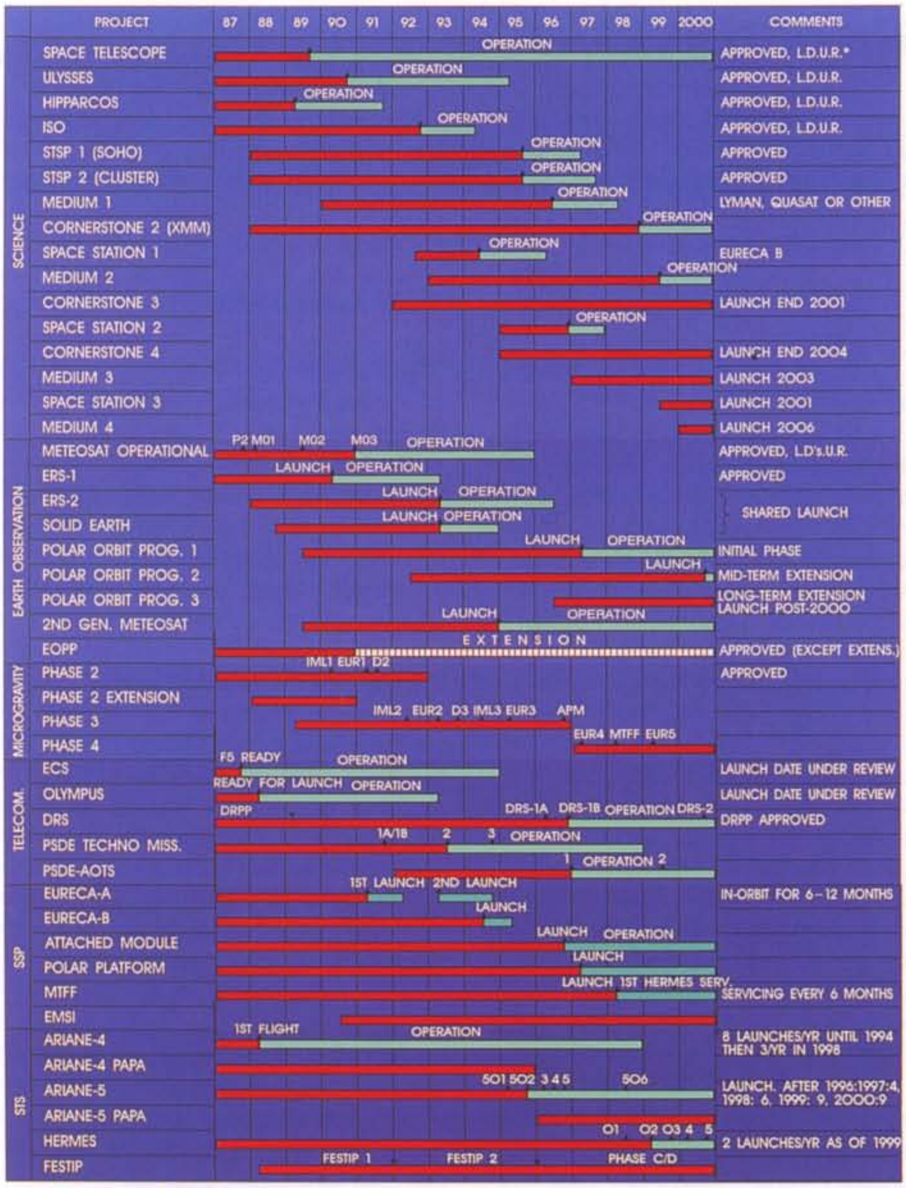
On the basis of the arrangements for the Columbus Preparatory Programme, the Agency negotiated with NASA the Memorandum of Understanding (MOU) on Phase-B studies for a Space Station. This MOU, approved by Council on 25 April 1985, was signed by the ESA Director General and the NASA Administrator on 3 June 1985 in Paris. Its purpose was to define the arrangements and conditions governing the relations between NASA and ESA during their respective endeavours on the detailed definition and preliminary design phase of the Station. Canada and Japan, having also responded favourably to President Reagan's offer, have concluded similar MOUs.

In parallel with the technical definition work during the different steps of Phase-B, initial discussions on the legal framework for future cooperation in the development and operation of the International Space Station have taken place. These discussions concluded that, due to the importance of such a long-term cooperative venture, a two-fold approach had to be adopted; namely to establish on the one hand, an Inter-Governmental Agreement (IGA) between the United States and the ESA Member States as the political basis, and on the other to conclude a Memorandum of Understanding (MOU) between NASA and ESA defining the technical, organisational and financial conditions of the cooperation.

Since 1986, when negotiations on Europe's role in the Space Station began in earnest, the object of these discussions has been to give substance to the genuine partnership offered by President Reagan. ESA's Member States have made it clear from the outset that to them partnership meant a meaningful involvement in a truly international Space Station, with multilateral and bilateral coordination and all partners retaining rights over their contributions, within the limits of technical and operational constraints. The discussions with the US representatives therefore dwelt largely on four items of major importance to Europe:

- jurisdiction and control
- future evolution

Figure 22 — Schedule overview for the Long-Term Programme (per mid-February 1988)



* L.D.U.R. – Launch Date Under Review

- protection of the partners, and
- the civil status and 'peaceful purposes' of the Space Station.

During their Meeting on 9 and 10 November, the Ministers confirmed their interest in participating with the United States in the International Space Station, and established clear instructions for the negotiation rounds still required for finalising the MOU and IGA texts. The ESA Council at Ministerial Level thus prepared the ground for the successful conclusion of the legal documents forming the basis for international cooperation in the Space-Station Programme.

Conclusion

The European Long-Term Space Plan, outlined above and approved by the ESA Council at Ministerial Level last November, represents a major increase over the past level of effort. Indeed, after the progressive buildup over the next few years, it will lead between 1986 and 1994 to a doubling of the resources provided by European Governments for the Agency's programmes. However, this still appears a modest effort not only in absolute terms, seen against the overall programmes of the other space powers, but also on a per-capita basis.

The planned European Programme is characterised by the high degree of integration of its various elements and by the fact that it can, to a large extent, be executed without recourse to non-European products, facilities or services.

The implementation of this Programme will permit a substantial broadening of the scope of European space activities, similar to that which followed the 1971 and 1973 package deals. The latter opened up commercial space exploitation to Europe and enabled European industry to compete with the USA in unmanned space transportation. The new Long-Term Plan will permit a further development of European space-transportation capabilities, including a manned transportation and habitation capability which will eventually lead to full European autonomy in space.

Pursuit of this goal is justified not only by the existing and ever-growing requirements of a wide variety of users, but also by the increase in knowhow and ability it will give to Europe's aerospace industry, not to mention the broadening of economic perspectives and the technological spin-offs it should trigger.

Analyse des facteurs de coûts des expériences embarquées sur vol habité

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Le programme Columbus, qui est entré dans sa phase C/D le 1er janvier 1988, offrira aux utilisateurs des possibilités considérables d'accès à l'espace, qu'il s'agisse de la capacité de ses differents éléments ou de la durée des missions. Cependant, l'extrapolation à Columbus des coûts de développement et de vol des charges utiles de type Spacelab montre qu'il est nécessaire de les réduire si l'on veut rester dans des limites budgétaires compatibles avec le plan à long terme de l'Agence. Afin de déterminer les facteurs de coûts intervenant dans des missions 'habitées', et les moyens de les réduire, une étude a été sous-traitée à Matra, portant sur une expérience mise au point par la firme et menée à la fois dans la station Saliout et le pont intermédiaire de la Navette spatiale. La synthèse des résultats de l'étude est présentée ici, ainsi que les conclusions pouvant en être tirées pour Columbus.

Introduction
Il est nécessaire de pouvoir contrôler et réduire les coûts des missions de Columbus, et donc, en particulier, les coûts de développement, de qualification, d'intégration et d'utilisation des charges utiles, mais aussi de préparation et d'entraînement pour la mission. Dans ce contexte, il a été intéressant de pouvoir bénéficier de l'expérience d'un industriel comme Matra, expérience d'ailleurs unique puisque l'expérience 'Echographie-Doppler' a déjà été embarquée sur Saliout et dans le pont intermédiaire de la Navette spatiale. De plus, l'échographe* va, dans une version améliorée nommée 'As de coeur', voler à bord d'Anthrorack (mission D2), sur la station Mir lors du deuxième vol franco-soviétique (mi-1988) et à nouveau dans la Navette (vol prévu en 1989).

L'étude réalisée a porté sur les deux vols déjà effectués de l'échographe, et a consisté en une comparaison qualitative et quantitative de ces deux vols, en insistant sur leur préparation, l'entraînement des astronautes et la répartition des coûts.

L'article est divisé en deux parties: tout d'abord la présentation des principaux résultats de l'étude, avec la comparaison qualitative des deux missions, l'importance des délais sur les coûts, le rôle des astronautes et leur entraînement, et l'importance de la relation entre scientifiques, industriels et agences; ensuite, les conclusions de l'étude applicables à Columbus, sur la préparation des missions, le problème de la documentation et de la familiarisation de l'utilisateur, l'entraînement des astronautes, la réduction des délais et la coordination des différentes équipes.

Principaux résultats de l'étude
Interface expérience/véhicule
Les deux missions ont eu lieu à trois ans d'intervalle; l'échographe a volé à bord de Saliout en juin 1982 et sur la Navette spatiale en juin 1985. Les deux modèles ayant volé sont en fait identiques quant aux fonctions spécifiques, mais l'échographe a dû être adapté mécaniquement pour prendre place dans le 'middeck locker' (espace de rangement du pont intermédiaire de la Navette). Les contraintes pour l'utilisateur lors de la préparation des deux missions — en termes de documentation à fournir, de revues d'aptitude au vol — étaient à peu près semblables; mais les contraintes mécaniques étaient très différentes, que ce soit pour le transport en orbite ou pour l'installation de l'expérience; ainsi, dans le cas soviétique, le transport de l'expérience se fait dans des conteneurs standards emportés par Progress, et une fois en orbite les interfaces expériences/vaisseaux sont réduites au minimum (les expériences sont accrochées dans Saliout par du Velcro), alors que les interfaces avec l'espace de rangement du pont intermédiaire de la Navette sont un peu plus complexes, à cause des contraintes imposées par la phase de lancement.

* Appareil permettant d'étudier l'evolution de la fonction cardio-vasculaire de l'astronaute en microgravité.

Préparation des missions
En revanche, la préparation de la mission a été très différente: le planning de mise au point de l'échographe pour Saliout a été très serré puisque la sélection des expériences a eu lieu fin 1979, les interfaces des expériences ont été fixées en septembre 1980 et les modèles de qualification testés et livrés fin 1981 (le vol a eu lieu à la mi-1982). Sur une durée de développement de deux ans et demi, à peine plus d'une année a donc été disponible pour la réalisation et la livraison de tous les modèles. En revanche, la mission avec la NASA qui consistait à embarquer de nouveau une expérience, a bénéficié d'environ deux ans pour procéder à l'adaptation de l'échographe. De plus, la préparation de la mission avec la NASA s'est trouvée considérablement améliorée du fait de l'expérience précédente; en particulier, les processus de recette et de qualification de l'échographe ont pu être simplifiés, l'échographe ayant déjà été qualifié en vol et bénéficiant ainsi d'une grande crédibilité. Le premier vol s'est aussi répercuté sur le second au niveau de l'efficacité scientifique: le premier vol ayant permis de déterminer que les modifications physiologiques attendues se produisaient plus tôt que prévu, il a été demandé à la NASA de pouvoir commencer les mesures dès l'arrivée en orbite, et les protocoles expérimentaux au sol, après le retour, ont été également modifiés à la suite du premier vol.

Facteurs de coûts
L'étude des facteurs de coût de ces deux vols a permis d'identifier un élément essentiel de la 'facture' finale: les délais (et surtout les reports). En effet, les coûts sont établis au début du projet sur la base des devis correspondant aux activités nécessaires pour la réalisation des équipements dans le temps imparti. Ceci impose de bien prévoir les enchaînements des tâches successives ainsi que les approvisionnements dont tout retard peut venir bousculer les prévisions. En cas de retard (tests à refaire, date de lancement retardée, etc.), les équipes restent à disposition, ce qui augmente d'autant les coûts. Un essai au moyen du programme PRICE a ainsi montré que l'augmentation relative de coût était égale à la moitié de l'allongement relatif des délais.

L'étude a également permis de mettre en évidence l'importance de l'entraînement des astronautes et leur rôle essentiel dans le succès des deux missions. Il faut remarquer que pour une expérience comme celle de l'échographe, l'astronaute est à la fois opérateur et sujet de l'expérience, et son rôle en est d'autant plus critique. Dans les deux cas, les astronautes ont été incorporés aux équipages et ont subi le même entraînement général que les autres membres des équipes. De plus, Patrick Baudry, qui a volé à bord de la Navette, était le remplaçant de Jean-Loup Chrétien, qui a volé sur Saliout, et vice versa pour la mission NASA, ce qui a permis d'optimiser l'exploitation de l'échographe.

Mais le facteur de succès le plus important a été l'entraînement direct des astronautes par l'équipe scientifique de l'échographe; l'enseignement tiré a été que l'astronaute doit s'entraîner chez l'utilisateur avec l'utilisateur. En effet, à cause de la disponibilité tardive des astronautes et du planning très serré, le contact de ceux-ci avec l'industriel, qui aurait pu les entraîner, a été très restreint. Le problème s'est posé pendant la mission Saliout avec d'autant plus d'acuité que l'entraînement et, de manière plus générale, tous les aspects opérationnels sont très centralisés en URSS; de fait, l'entraînement sur la charge utile était assuré par des 'entraîneurs' officiels, et l'équipe scientifique de l'échographe avait dû entraîner les entraîneurs. Aussi, les contacts directs entre astronautes et utilisateur (l'équipe scientifique), bien que peu nombreux, ont-ils permis un complément d'entraînement très efficace. Le problème était différent aux Etats-Unis, où scientifiques et industriels français pouvaient avoir une relation directe avec les équipes opérationnelles, et bénéficiér d'un entraînement en partie décentralisé.

Enfin, l'étude a montré l' importance fondamentale des bonnes relations entre industriels, agences et scientifiques. Les circonstances particulières du développement de l'échographe, en moins de 18 mois, ont exigé une relation très étroite (allant jusqu'à la sous-traitance) entre le scientifique, auteur du premier prototype, et l'industriel chargé d'en réaliser la version spatiale, le premier étant chargé de definir la performance scientifique de l'appareil, le second assurant les spécifications fonctionnelles et la conception optimale de l'interface homme-appareil. Les coûts ont ainsi pu être réduits par une plus grande responsabilisation de l'industriel vis-à-vis des problèmes de sécurité et de qualité — ce qui a permis d'utiliser des sous-systèmes aux normes militaires, moins chers que des sous-systèmes qui auraient dû être conçus selon des normes les plus extrêmes, i.e. les normes spatiales. Le pourcentage des coûts concernant la qualité et la sécurité s'en est trouvé réduit d'autant et, au total, le coût du projet 'échographe' a été très modéré au regard de projets spatiaux comparables.

Conclusions pour Columbus
Il est tentant d'appliquer directement à Columbus tous les enseignements tirés de l'expérience de l'échographe. Cependant, il faut se rappeler la spécificité de l'échographe, appareil autonome et conçu pour un système (Progress—Saliout) aux interfaces minimales. Aussi cette étude n'a-t-elle pu aborder tous les problèmes qui vont se poser aux utilisateurs de Columbus, utilisant des racks à usages multiples, c'est-à-dire des problèmes de compatibilité, de gestion centralisée des données, d'interfaces complexes. Néamoins, l'une des caractéristiques de l'échographe, son planning très serré de développement, est représentative de Columbus, pour lequel l'un des objectifs majeurs est de réduire les délais. Des conclusions générales peuvent être tirées afin d'améliorer l'efficacité de l'utilisation de Columbus et d'en diminuer les coûts.

Figure 1 — L'échographe prêt à voler à bord de Progress

Figure 2 — L'échographe version rangement dans le pont intermédiaire de la Navette

Figure 3 — L'échographe version Saliout

1

2

3

Familiarisation de l'utilisateur
Le problème de la documentation, et plus généralement du mode d'information de l'utilisateur potential pour parvenir à une connaissance optimale du système et de ses interfaces, influe fortement sur les coûts. Fournir à l'utilisateur une documentation importante, et lui demander en retour un nombre impressionnant de documents techniques sur son expérience est très coûteux en temps et en argent. Il est sans doute plus simple de limiter le plus possible le flot de documents, et d'informer l'utilisateur au moyen de matériel réel ou de bancs d'essai et de simulation, afin de lui permettre d'appréhender directement les spécifications et les interfaces. Afin d'optimiser familiarisation et entraînement, il conviendrait qu'ils puissent se faire le plus près possible de l'utilisateur lui-même, c'est-à-dire de manière décentralisée.

Qualification
Il semble ensuite important de simplifier, sans pour autant relâcher les contraintes de sécurité, les procédures de qualification des charges utiles. A ce sujet, il faut remarquer — et l'étude l'a confirmé — que le nombre d'exemplaires d'un appareil (entraînement, qualification, identification des interfaces, etc) devant être développé pour une mission donnée est un facteur de coût essentiel. Aussi doit-on tenter de minimiser, par une meilleure responsabilisation de l'industriel et une synergie entre les différentes parties concernées, le nombre de procédures et donc de modèles nécessaires.

Entraînement des astronautes
Le rôle de l'astronaute et de son entraînement est considéré comme prépondérant. Améliorer l'efficacité de l'entraînement par des contacts directs avec les responsables scientifiques de l'expérience — c'est-à-dire l'entraînement de l'astronaute par l'utilisateur sur un modèle similaire au modèle de vol — permet également l'amélioration de la performance de l'expérience (ce qui a été constaté à bord de Saliout) en apprenant par exemple à l'astronaute à réparer des défaillances sans gravité de l'expérience en orbite, et réduit le temps de préparation de la mission. De plus, l'expérience de l'astronaute est

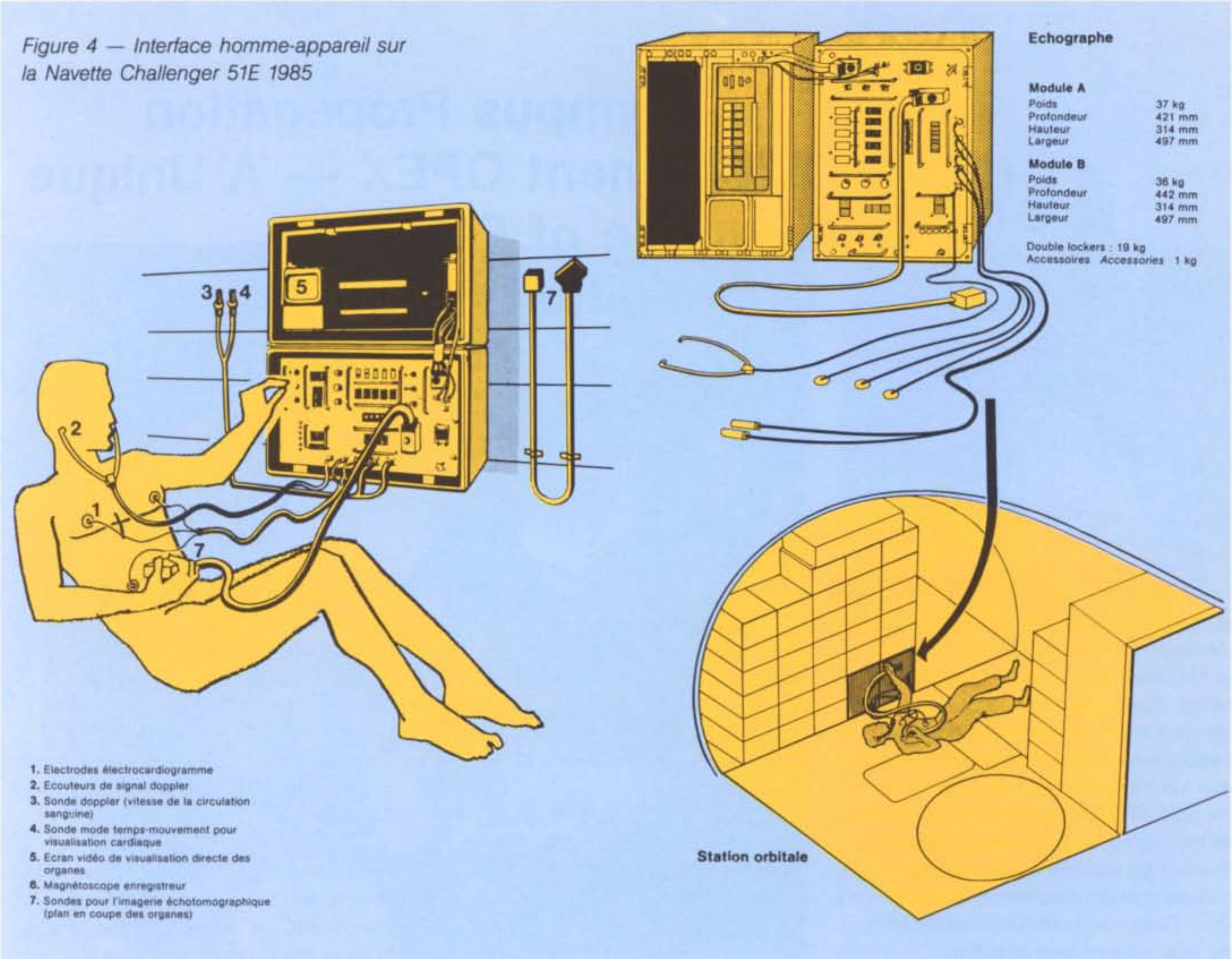


Figure 4 — Interface homme-appareil sur la Navette Challenger 51E 1985

irremplaçable au cas où l'appareil volerait à nouveau, surtout bien sûr avec un appareil de physiologie humaine comme l'échographe.

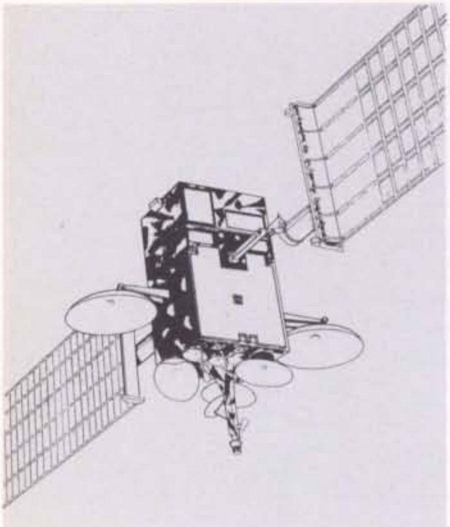
Préparation de la mission

Mais le facteur le plus important reste, comme on l'a vu, les délais entre la conception de l'expérience et son vol. Il faut optimiser ces délais et éviter tout retard; pour cela, il faut réduire les temps de préparation, surtout au niveau intégré, niveau où la préparation est la plus coûteuse, puisqu'elle suppose l'utilisation de maquettes complètes du système et de sa charge utile, à haute fidélité de reproduction. La réduction des délais et la suppression de retards éventuels passe aussi par une organisation efficace du déroulement de la mission, sans doute, certains niveaux (familiarisation, entraînement, premier niveau d'intégration) peuvent-ils être utilement décentralisés, ce qui permet de gagner du temps et facilite le 'parcours du combattant' de l'utilisateur, et le niveau nécessairement centralisé, celui de l'intégration système, doit être minimal.

Coordination des équipes

Enfin, une bonne coordination entre l'Agence, l'industriel et le scientifique permet une répartition optimale des tâches. En particulier, une implication plus grande du scientifique apporte au projet spatial un savoir-faire spécialisé à un coût modéré, contribue à la motivation des équipes et permet plus de souplesse dans la gestion et l'avancement du projet. Cette coordination est due en grande partie, dans le cas de l'échographe, à la relative simplicité de sa conception pour un appareil somme toute assez complexe d'un point de vue électronique, mais qui a pu être fonctionnellement modularisé, et à la nécessité de s'adapter à un calendrier très serré; elle ne sera cependant pas facile à établir dans un projet comme Columbus, dont les charges utiles servent de multiples utilisateurs.

L'expérience acquise au cours des deux vols de l'échographe, et au fur et à mesure du développement de sa version améliorée 'As de Coeur', nous montre donc des voies à explorer pour préparer au mieux l'utilisation de Columbus et pour faire le compromis optimal entre retour scientifique, succès des missions et coûts de développement et d'utilisation. Ces enseignements, tirés des expériences vécues, que nous pourrons appliquer lors des vols de simulation avant Columbus, doivent constituer le point de départ du programme de préparation de l'utilisation de Columbus.



The Olympus Propagation Experiment OPEX — A Unique Example of European Cooperation

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One of the four payloads to be carried by the Agency's Olympus-1 communications spacecraft, due for launch early next year is the so-called 'Propagation Payload'. It will transmit three stable radio-beacon signals covering primarily Europe, but also visible from the East Coast of the USA. These beacon signals will be measured by calibrated ground stations to study the effects of the atmosphere on microwave propagation. This data is indispensable for the planning of new satellite communications systems using frequencies in the 20/30 GHz bands.

A project involving intensive cooperation between the numerous experimenters working with the Propagation Payload has been set up with a view to defining standards for ground-station hardware and data-processing and analysis methods to allow free exchange and pooling of experiment results. This cooperative endeavour is being coordinated by ESTEC under the name 'OPEX'.

OPEX

The Olympus-1 satellite (Fig. 1) will carry four distinct payloads for satellite-communications experimentation and research:

- a Direct-Broadcast Service (DBS) Payload
- a Specialised-Services Payload
- a 20/30 GHz Advanced Communications Payload
- a Propagation Payload.

Experimental utilisation of the first three payloads involves ground transmissions to the satellite and hence sharing of available satellite time among experimenters. This is coordinated through the Olympus Utilisation Programme (see Bulletin No. 50, May 1987). The Propagation Payload will allow ground reception by all participants simultaneously and will be available continuously. Its utilisation, therefore, is not a matter of scheduling. In fact, the high level of interest shown by many research institutes in using this payload has led to a programme of intensive cooperation in preparing for the propagation experiments with Olympus. The background to and content of this unique voluntary cooperative project, coordinated by ESA/ESTEC under the name 'OPEX' (Olympus Propagation EXperiment), are described here.

Characteristics of the Olympus Propagation Payload

This beacon payload consists of three microwave transmitters that will produce three unmodulated continuous-wave signals for transmission via three individual horn antennas (Fig. 2). These signals are designated B0, B1 and B2, respectively. B0 will be transmitted at 12.5 GHz and will deliver 10 dBW of radiated power (EIRP) over the entire visible Earth (Fig. 3). The B1 (20 GHz) and B2 (30 GHz) antennas are designed to cover Western Europe with an EIRP of 24 dBW.

The high effective radiated powers of the beams, and hence high flux densities on the ground, will allow the experimenters to use relatively small earth stations, with antennas ranging from 1 to 6 m in diameter. The beacon frequencies are all derived from a common oscillator, which will allow coherent detection of all three beacons. This feature provides the possibility to conduct special experiments and allows several alternatives for earth-station design.

An interesting feature of the coverage of the 20 and 30 GHz (B1 and B2) beacons is that reception on the east coasts of the USA and Canada is not excluded, albeit with reduced signal power and stability (Fig. 4).

Stability and purity are important design criteria for the beacons. Amplitude stability is required for high-accuracy measurements of attenuation by calibrated earth-station receivers. Phase stability and purity allow the use of very narrow bandwidths, increasing the dynamic range of attenuation measurements. High polarisation purity is required for the measurement of cross-polarisation induced by the atmosphere.

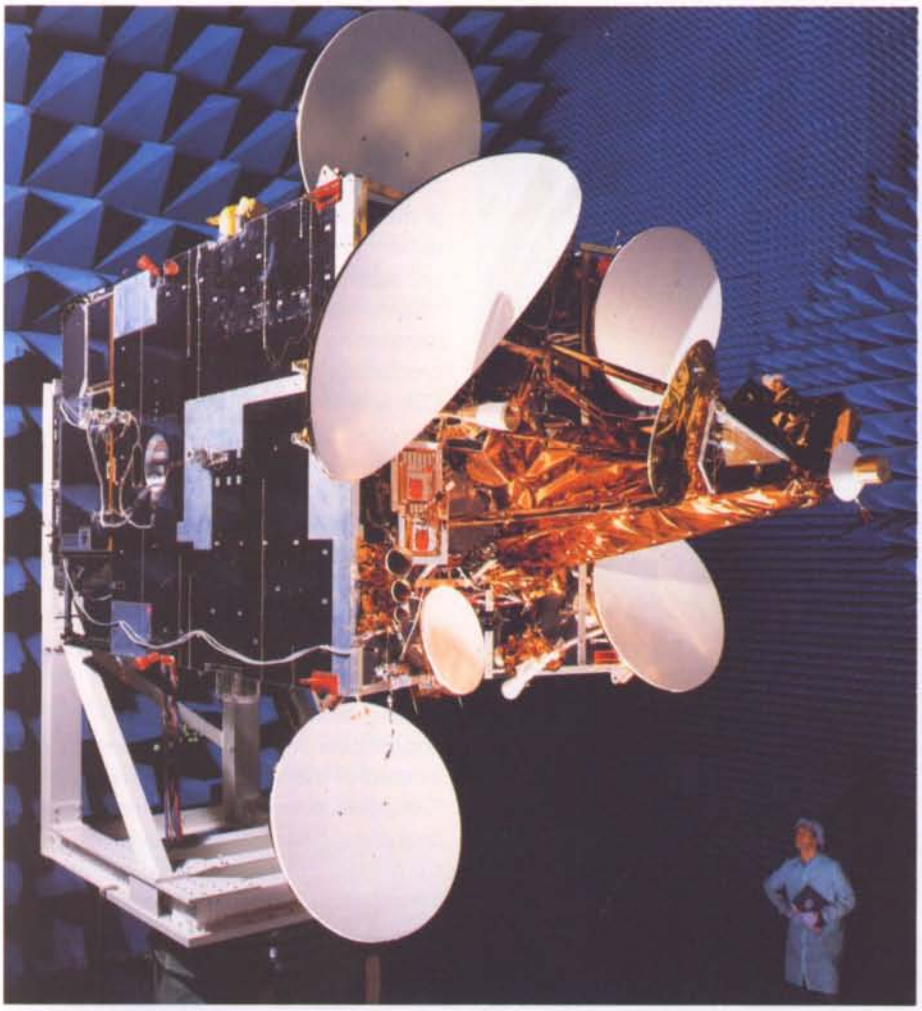


Figure 1 — The Olympus spacecraft

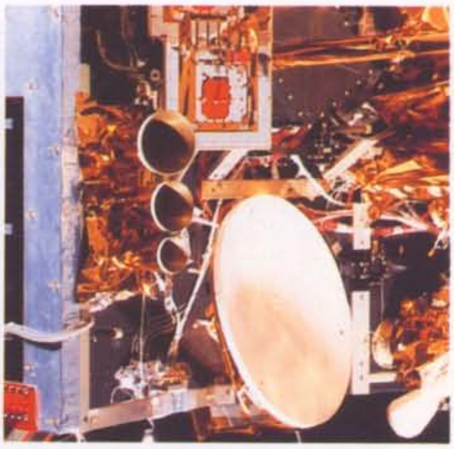


Figure 2 — The Olympus propagation beacon payload (enlargement from Fig. 1)

In its normal operating mode, the B1 beacon will be transmitting with alternating orthogonal polarisations (N—S and E—W). The switching frequency will be 1866 Hz. This arrangement allows measurements of co-polar and cross-polar signal components at both polarisations. This is important as it is the only means of fully characterising the atmosphere's effect on signal propagation. Full measurement of all eight signal components (amplitude and phase, co- and cross-polar, N—S and E—W polarisation) with the requisite accuracy is rather complicated. Similar measurements were made in the early seventies with the Comstar satellites in the USA, but at that time the complications of earth-station receiver design led to rather low participation in the overall experiment.

Background to the propagation mission

The influence of the Earth's lower atmosphere on the propagation of radio waves did not pose severe problems for the design of satellite communications systems operating at 6/4 GHz. At frequencies above 10 GHz, however, this influence can no longer be ignored. Attenuation due to clouds and rain limits the performance of high-reliability systems. Cross-polarisation and scattering due to precipitation and ice may cause interference inside a system or between different systems.

These effects have been studied in recent years with a view to estimating the number and duration of system outages likely to occur under extreme conditions. For today's systems that operate in the 14/11 GHz bands, the employment of 'safety margins' usually means that such outages typically occur for less than 0.1% of the time. The ever-increasing demands for capacity, however, are now necessitating exploitation of still higher frequencies, where the atmospheric effects impose much more severe limitations on system performance. So much so, in fact, that future system design will often be conditioned by propagation considerations.

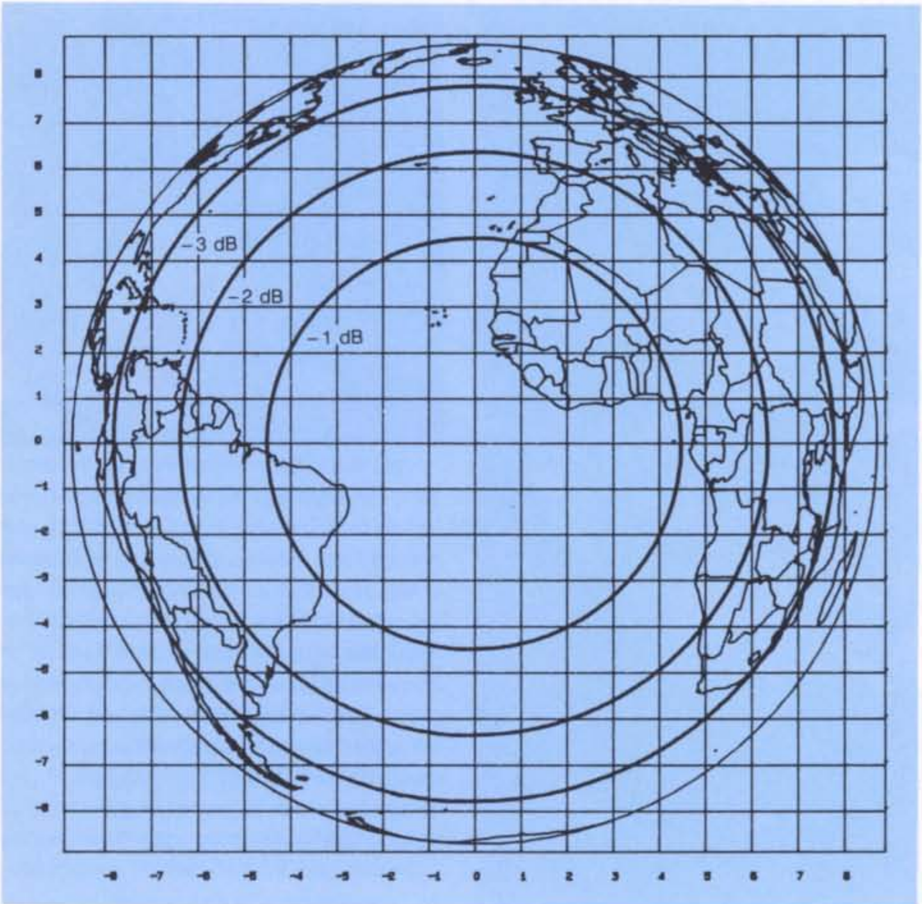
As propagation is a much more critical factor at higher frequencies, with higher outage percentages having to be budgeted for for systems using frequencies above 20 GHz, more detailed models of atmospheric influences are now required for the design of future advanced systems. There is a urgent need for experimental data to supplement theoretical predictions based on physical modelling. The Olympus Propagation Payload will provide Europe with the means to conduct active experiments to provide this information.

History of European cooperation

Between July 1976 and October 1977, NASA's ATS-6 satellite was placed at 35°E longitude and its beacon facilities gave the European scientific community an opportunity to carry out propagation experiments. These included the so-called Millimetre-Wave Experiment with onboard beacons operating at 20 and 30 GHz, and the Comsat experiment

Figure 3 — Coverage of the Olympus B0 beacon from 19°W

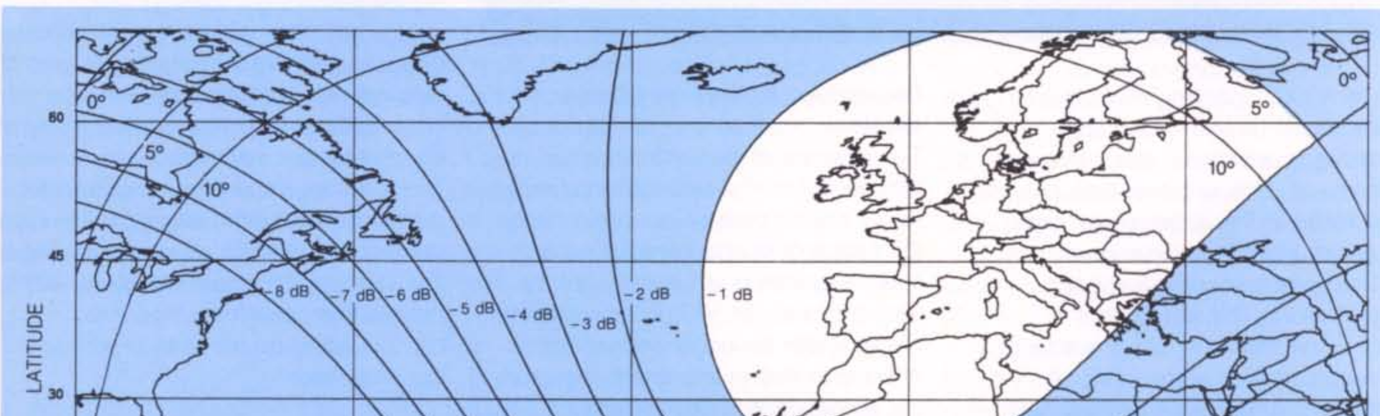
Figure 4 — Coverage of the Olympus B2 beacon from 19°W



using a transponder arrangement allowing 13 and 18 GHz uplink measurements.

Unfortunately, these experiments could only be carried out during certain hours of the day, or rather night. Moreover, rather complicated arrangements were necessary for participation, including dissemination of schedules, loan of transmitting equipment, and centralised processing of the uplink measurements. ESA was therefore asked to coordinate European participation in the experiments and to represent European experimenters vis-a-vis NASA and Comsat. This led to the establishment of a European experimenter group, which met regularly during the project and published its collective results in an ESA Special Publication (ESA SP-131, 1977).

Another example of European cooperation in propagation research was initiated in the framework of the COST (Coopération scientifique et technique) project funded by the European Commission. Between 1972 and 1977, the results of propagation experiments



conducted above 10 GHz in thirteen different countries were collectively analysed to gain a better understanding of the variations of propagation effects with climate. In this project, known as COST 25/4, mainly already-analysed results from many invidual experiments were put together and compared, and some special analyses were carried out by individual experimenters for the project.

It soon became clear, however, that a higher level of collective analysis would have been possible if the statistics obtained from the measurements had been put into a common database and made available for collective analysis. This approach was followed in a subsequent project called COST 205 (1978–1984), in which 11/14/18 GHz propagation data obtained with the ESA satellite OTS and the Italian satellite Sirio were collated and analysed. This required a higher level of cooperation, including agreements on standard formats for presenting the various statistics obtained.

The OTS experiments themselves were coordinated by ESA and Eutelsat together. The habit of convening the coordination meetings of experimenters at the various participating institutes across Europe, initiated for the COST 25/4 project and followed since for many other COST projects, has led to an intensive exchange of information. This approach has proved indispensable in terms of promoting cooperation at the working level.

Collective European results from these satellite propagation experiments have been made available to the International Telecommunications Union (ITU), where they form a major part of the database of CCIR Study Group 5, charged with the development of worldwide models for the prediction of propagation effects on radio communication systems.

Organisation of OPEX

Thus, in the previous 15 years an active European community of researchers in the field of radio propagation had been established and the scene was set for further collaboration. When plans for a large satellite carrying a number of experimental telecommunications payloads were taking shape in the late seventies, this community was called upon to input their requirements for a propagation experiment. ESA's specifications were drawn up in consultation with prospective experimenters. It quickly became clear that there was wide interest in such experiments and a need existed for regular information exchange in the preparatory stages. As early as 1980, meetings were held between the interested parties, both researchers and industry. Since then, these meetings have been taking place on a regular basis.

Based on prior experience with the

Table 1 — Participants in OPEX

Organisation	Location	Organisation	Location
Technical University Graz	Graz, Austria	CSR	Ilkley, UK
Austrian Solar & Space Agency	Vienna, Austria	BTRL	Martlesham, UK
Bell Telephone Manufact. Co.	Antwerp, Belgium	Portsmouth Polytech.	Portsmouth, UK
Newtech	Antwerp, Belgium	BAe	Stevenage, UK
EBU Technical Centre	Brussels, Belgium	Politecnico di Milano	Milan, Italy
UCL/Lab. de Telecomm.	Louvain-la-Neuve, Belgium	CNR/PSN	Rome, Italy
CRC/Radio Prop. Lab.	Ottawa, Canada	Fond. Ugo Bordoni	Rome, Italy
FTZ	Darmstadt, W. Germany	Selenia Spazio	Rome, Italy
Dornier System	Friedrichshafen, W. Germany	Telespazio	Rome, Italy
Inst. für Rundfunktechnik	Munich, W. Germany	CSELT	Turin, Italy
DFVLR	Oberpfaffenhofen, W. Germany	Telecomm. Research Est.	Kjeller, Norway
P&T/Radio Comms. Office	Copenhagen, Denmark	ELAB	Trondheim, Norway
Elektronikcentralen	Copenhagen, Denmark	NIVR	Delft, The Netherlands
TUD/Electromagn. Inst.	Copenhagen, Denmark	Technical Univ. Delft	Delft, The Netherlands
ETSI Telecomunicacion	Barcelona, Spain	Technical Univ. Eindhoven	Eindhoven, The Netherlands
ETSI Telecomunicacion	Madrid, Spain	APT	Huizen, The Netherlands
CNET	Paris, France	Dr. Neher-Lab. PTT	Leidschendam, The Netherlands
IRAM	Grenoble, France		
EUTELSAT	Paris, France	Universidade Aveiro	Aveiro, Portugal
March Microwave	Braintree, UK	Swedish Telecom. Radio	Farsta, Sweden
Univ. of Bradford	Bradford, UK	Helsinki Univ. of Technol.	Espoo, Finland
Signal Processors	Cambridge, UK	Virginia Tech.	Blacksburg, USA
Rutherford Appleton Lab.	Chilton, UK	NASA/JPL	Pasadena, USA
Univ. of Essex	Colchester, UK	NASA HQ	Washington DC, USA

COST projects, the general consensus was that collective development of specifications for earth-station hardware as well as procedures for data acquisition, preprocessing and analysis, would be very beneficial for experimenters and would greatly enhance the results obtained. This work was started in 1984 with the establishment of three working groups:

- Working Group 1
  Earth-Station Requirements
  Chairman: Mr S.K. Barton (UK)

- Working Group 2
  Data Acquisition and Preprocessing
  Chairman: Mr F. Zelders (NL)

- Working Group 3
  Data Analysis
  Chairman: Prof. A. Paraboni (I).

The overall objective of the OPEX project thus established was, and still remains, to arrive at a level of standardisation that allows direct comparison of experiment results without the usual uncertainties regarding equipment quality and compatibility of data-analysis procedures. The work of the three Groups has already resulted in the issuing of three handbooks, specifying quality objectives and defining interfaces for data acquisition, preprocessing and analysis, respectively.

Participation in the OPEX meetings has been very encouraging and a high level of interest is being maintained. Each meeting is attended by some 40 specialists drawn from all of the ESA Member States.

The possibility of carrying out experiments from the North American continent has stimulated interest from a number of US experimenters also, and regular contact with a NASA-sponsored group of researchers has been established. The accompanying table lists the organisations that are now actively involved in the OPEX endeavour.

Results and outlook

The first result of the work of the OPEX group was the issue of three handbooks, as mentioned above. The handbook for receiver design, rather than constraining development by specifying a particular design, gives a clear output specification and quality criteria as well as several ideas for design alternatives and trade-off areas. A wide variety of earth stations can be used, ranging from very small stations for attenuation measurements only, to elaborate stations for a full co-polar and cross-polar experiment. A number of stations have already been built, and others are under development, based on these recommendations.

The second handbook, concerning procedures for data pre-processing, analyses the requirements for data editing, data error-correction, and data reduction to include only interesting 'events'. This is a fundamental cornerstone of the collaboration; only if the preprocessing and calibration of measured data is standardised in detail will it be possible to compare results meaningfully. At the same time this requires a level of cooperation and a willingness to standardise that is unique in this type of voluntary collaboration.

The material of the pre-processing handbook has been condensed into a specification for a 'model software' system, for which a contract study will be placed by the Agency to obtain a detailed software design. This will possibly be followed by actual production of standard software to be made available for use by the experimenters, thereby ensuring the maximum level of compatibility between results.

The same activity has taken place for the topics of data analysis and presentation of results, the material for which has been collected in the third handbook. A design study, again possibly followed by software production, will establish a truly European standard for the production of propagation statistics. Only in this way can the goal of providing a European database for satellite communications systems design be achieved.

Conclusion

Fifteen years of cooperation between research institutes in Europe have resulted in a level of international cooperation and coordination that will ensure that maximum benefit is derived from the planned Olympus propagation experiments. Furthermore, the 20/40/50 GHz beacon payloads planned for the Italian Italsat satellite, which will have similar characteristics, will allow experiments at even higher frequencies to be carried out in the nineties with the same level of cooperation.

The final result should be the collation of a very large database of statistics on atmospheric radio-propagation effects, which will be an indispensable tool for the design of Europe's future advanced satellite communications systems.

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

In Orbit / En orbite

	PROJECT	1988 – 1994	COMMENTS
SCIENT. PROG.	IUE		OPS. FUNDED UNTIL END 1988
APPLICATIONS PROGRAMME	MARECS-1		
APPLICATIONS PROGRAMME	MARECS-2		LIFETIME 5 YEARS
APPLICATIONS PROGRAMME	METEOSAT-2		
APPLICATIONS PROGRAMME	ECS-1		LIFETIME 7 YEARS
APPLICATIONS PROGRAMME	ECS-2		LIFETIME 7 YEARS

Under Development / En cours de réalisation

	PROJECT	1988 – 1994	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
SCIENTIFIC PROGRAMME	ULYSSES		MISSION DURATION 4.5 YEARS
SCIENTIFIC PROGRAMME	SOLAR TERRESTRIAL SCIENCE PROG. (STSP)		LAUNCHES: SOHO MARCH 1995; CLUSTER DEC. 1995
SCIENTIFIC PROGRAMME	HIPPARCOS		LIFETIME 2.5 YEARS
SCIENTIFIC PROGRAMME	ISO		LAUNCH 1992/93
TELECOM. PROGRAMME	ECS	ECS-5	LAUNCH DATE UNDER REVIEW
TELECOM. PROGRAMME	OLYMPUS-1		LIFETIME 5 YEARS
TELECOM. PROGRAMME	DATA-RELAY SATELLITE (DRS)		SYSTEM OPERATIONAL 1996
TELECOM. PROGRAMME	PSDE/SAT-2		READY FOR LAUNCH MID-1993
EARTH OBSERVATION & MICROGRAVITY PROGRAMMES	ERS-1		
EARTH OBSERVATION & MICROGRAVITY PROGRAMMES	EARTH OBS. PREPAR. PROG. (EOPP)		
EARTH OBSERVATION & MICROGRAVITY PROGRAMMES	METEOSAT P2/LASSO		LAUNCH DATE UNDER REVIEW
EARTH OBSERVATION & MICROGRAVITY PROGRAMMES	METEOSAT OPS.PROG.	MO-1; MO-2; MO-3	MO-3 LAUNCH DATE UNDER REVIEW
EARTH OBSERVATION & MICROGRAVITY PROGRAMMES	MICROGRAVITY	IML-1; SPACELAB-D2; IML-2	LAUNCH DATES UNDER REVIEW
SPACE ST. & PLATF. PROG.	EURECA		
SPACE ST. & PLATF. PROG.	COLUMBUS	PHASE 1; PHASE 2	3 YEAR INITIAL DEVELOPMENT PHASE
SPACE TRANSPORTATION PROGRAMME	ARIANE-2/3	V21	LAUNCH DATES UNDER REVIEW
SPACE TRANSPORTATION PROGRAMME	ARIANE-4	V22	OPERATIONAL UNTIL END 1998
SPACE TRANSPORTATION PROGRAMME	ARIANE-5		START MAIN DEVELOPMENT PROG. JANUARY 1988
SPACE TRANSPORTATION PROGRAMME	HERMES	PHASE 1; PHASE 2	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

Télescope spatial

Les deux ailes du générateur solaire de vol qui avaient été livrées aux Etats-Unis il y a deux ans ont été renvoyées en Europe au début de cette année. Une réunion de revue a eu lieu en février pour convenir du programme de réfection de ces ailes. Ce programme comportera le remplacement des nappes du générateur solaire par des nappes plus puissantes résistant à l'oxygène atomique, la protection d'autres éléments du générateur solaire de l'oxygène atomique, et des modifications mécaniques permettant de remplacer facilement les panneaux solaires en orbite.

Une revue de définition de base de référence du second générateur solaire a eu lieu en mars 1988. Ce générateur devrait être disponible d'ici à la fin de 1990.

La chambre à objets faibles (FOC) a été réinstallée dans le télescope spatial le 27 janvier. L'un des détecteurs de rechange de la FOC a subi un étalonnage sous vide de deux semaines à l'IAL.

Hipparcos under test at ESTEC

Hipparcos aux essais à l'ESTEC

Hipparcos

La période concernée par ce rapport a vu la concentration des activités relatives au satellite sur les essais de recette au niveau du système. L'intégration du prototype de vol du satellite (PFM) a été menée à bien chez Aeritalia (Italie) et a été suivie par un essai de système intégré (IST) du satellite complet. Il s'agit d'un essai électrique permettant de vérifier le fonctionnement complet du système de satellite.

L'achèvement réussi de l'IST en décembre a permis le transport du satellite chez Intespace, à Toulouse, pour des essais des propriétés de masse et d'ambiance dynamique. Ces essais, qui comprenaient des essais acoustiques et de vibration aux niveaux de recette, entremêlés de contrôles du bon état électrique du système satellite (contrôle du système intégré), ont été terminés avec succès au début février, quand le satellite a été emballé et expédié à l'ESTEC pour des essais finals de recette dans des conditions de vide-température.

Le satellite est arrivé le 12 février à l'ESTEC où, dans les limites de conditions d'ultra-propreté (classe de propreté 100), il a été préparé pour des essais dans le grand simulateur spatial (LSS). C'était la première fois que cette installation était utilisée pour une série d'essais aussi complexe. Le début des essais de vide-température a été retardé de quelques jours pour des raisons de sécurité du satellite et de l'installation mais, grâce aux efforts et à la détermination de toutes les personnes concernées, les séquences d'essai complètes (à haute température et à basse température) ont été terminées à la date prévue, permettant ainsi de maintenir à la mi-avril la date prévue pour la revue de recette de vol du satellite. A la date où ce rapport est rédigé, une analyse détaillée complète des résultats des essais reste à effectuer, mais un examen rapide et l'observation visuelle des essais de déploiement du générateur solaire indiquent que l'essai de vide-température est très concluant, les quelques incidents qui ont été enregistrés étant tous de nature mineure.

Bien que les principaux efforts aient été consacrés au prototype de vol du satellite, des essais supplémentaires de qualification mécanique ont été exécutés sur le modèle d'identification du satellite, pour démontrer la capacité de survie du satellite aux niveaux de vibration et d'ambiance acoustiques qui ont été récemment annoncés pour Ariane-4. Ces essais se sont terminés de manière satisfaisante et le satellite a été ensuite expédié chez Matra (F) pour servir à des activités de validation de l'entreposage de la charge utile, conçues pour assurer que la charge utile du prototype de vol du satellite ne se dégradera pas pendant le stockage du satellite.

Olympus

Les essais électriques du satellite se sont poursuivis aux laboratoires David Florida (DFL) à Ottawa. L'essai de base de référence de communications (CBT) et l'essai d'intercompatibilité de la charge utile ont été conclus avec succès, et le comité de revue des essais s'est réuni en décembre 1987. L'instrumentation

Space Telescope

The two flight solar-array wings delivered to the USA two years ago were returned to Europe at the beginning of 1988. A review was held in February to agree the rework programme for these wings. It will involve replacing the solar-array blankets with higher power, atomic-oxygen-resistant blankets, protecting other solar-array elements from atomic oxygen, and mechanical modifications to allow the easy exchange of solar arrays in orbit.

A Baseline Design Review for the second solar array was held in March 1988. This array should be available by the end of 1990.

The Faint-Object Camera (FOC) was re-installed in the Space Telescope on 27 January. One of the FOC spare detectors has recently completed a two-week vacuum calibration at IAL.

Hipparcos

This reporting period has seen the concentration of satellite activities on system-level acceptance testing. Integration of the Proto-Flight Satellite (PFM) was completed at Aeritalia (I), followed by a complete satellite Integrated System Test (IST), an electrical test that checks the complete functioning of the satellite system.

Successful completion of the IST in December allowed the satellite to be transported to Intespace, Toulouse, for mass-properties and dynamic environmental testing. These tests, which included acoustic and vibration tests interspersed with electrical satellite-system health checks, were successfully accomplished by early February, when the satellite was packed and shipped to ESTEC for final acceptance testing under thermal-vacuum conditions.

The satellite arrived at ESTEC on 12 February where, within the confines of ultra-clean conditions (cleanliness class 100), it was prepared for testing in the Large Space Simulator (LSS) facility. This was the first time the facility had been used for such a complex series of tests.

The start of thermal-vacuum testing was delayed for some days for satellite/facility safety reasons. Through the hard work and determination of all involved, the full test sequences (hot and cold temperatures) were nevertheless completed by the scheduled date, thereby permitting the satellite Flight Acceptance Review to be maintained in mid-April.

At the time of writing, full detailed analysis of the test results still has to be performed, but quick-look analysis and visual observation of solar-array deployment testing indicate a very successful thermal-vacuum test, with the few recorded incidents all being minor in nature.

Whilst the main effort was devoted to the protoflight satellite, additional mechanical qualification testing was being performed on the engineering-model satellite, to demonstrate the satellite's survival capability at the recently announced Ariane-4 vibration/acoustic levels. These tests were completed satisfactorily and the satellite was then shipped to Matra (F) to be used for payload-storage validation activities, designed to ensure that the PFM payload will not degrade during the satellite storage period.

Olympus

Electrical testing of the spacecraft has continued at the David Florida Laboratories (DFL) in Ottawa. The Communications Baseline Test (CBT) and Payload Intercompatibility Test have been completed successfully and Test Review Boards met in December 1987. Instrumentation for the Electromagnetic Compatibility Test was then installed and this test was conducted successfully whilst the spacecraft was still in the anechoic chamber.

The Special Performance Test is currently being conducted, and the results will be reviewed at a Test-Readiness Review to be held before proceeding with environmental testing.

Radio-frequency compatibility testing of the Operations Control Centre (OCC) at Fucino (Italy) using a spacecraft 'suitcase' simulator will be carried out in April 1988. This will complete the formal acceptance of the OCC for Olympus.

The in-orbit-testing ground stations for the specialised services and TV-broadcast payloads have been handed over to the Agency by the contractors. The specialised-services station will be used in the test campaign for the Agency's forthcoming ECS-5 communications satellite, which will provide useful early operational experience with this station. The transportable stations for the specialised services, 20/30 GHz and TV-broadcast payloads, are all undergoing in-plant testing by the contractors.

More than a hundred potential users have already expressed interest in Olympus and a detailed utilisation plan has been prepared for the first Olympus flight model. This is now being updated on a regular basis.

DRPP

Two parallel Phase-A1 studies of the Data-Relay System (DRS) have been completed. These two studies, conducted by industrial consortia led by Matra (France) and MBB (Germany), have resulted in the definition of a baseline for the complete DRS, including the data-relay satellites, the user space terminals and the associated ground segment.

The DRS will consist of two operational satellites in geosynchronous orbit. The baseline DRS satellite has four antennas, each with a diameter of about 3 m and one optical package to support five user spacecraft simultaneously. The satellite also has two antennas for the links to ground, one providing permanent European coverage and the other steerable spot coverage of any location visible from the satellite. The maximum data capacity of each DRS satellite is about 1.2 Gbit/s and their lift-off mass is estimated to be between 2500 and 3000 kg for the full mission as currently specified.

A Phase-A2 contract will be awarded to an industrial group led by Selenia Spazio, Italy. The basis of this Phase-A2 work will be the baseline defined in Phase-A1, but reduced options reflecting alternative user scenarios will also be addressed.

It is planned to construct a hardware simulation facility to verify system assumptions regarding the maximum *permettant l'essai de compatibilité électromagnétique a ensuite été installée, et cet essai a été réalisé avec succès tandis que le satellite se trouvait encore dans la chambre anéchoïque.*

L'essai de performances spéciales est en cours de réalisation, et les résultats en seront passés en revue lors de la réunion de revue du degré de préparation de l'essai qui doit se tenir avant qu'il soit procédé aux essais d'ambiance.

Les essais de compatibilité de radiofréquence du centre directeur des opérations (OCC) de Fucino (Italie), faisant appel à un simulateur 'mallette' du satellite seront effectués en avril 1988. Ces essais compléteront les essais officiels de recette de l'OCC pour Olympus.

Les stations terriennes d'essai en orbite destinées aux services spécialisés et aux charges utiles de diffusion de programmes de télévision ont été remises à l'Agence par les contractants. La station destinée aux services spécialisés sera utilisée dans la campagne d'essai pour le prochain satellite de communications ECS-5 de l'Agence, lequel fournira une expérience utile de début d'exploitation avec cette station. Les stations transportables destinées aux services spécialisés, charges utiles de 20-30 GHz et de diffusion de programmes de télévision, sont toutes en train de subir des essais en usine chez les contractants.

Un intérêt considérable pour l'emploi d'Olympus a été manifesté par plus d'une centaine d'utilisateurs en puissance, et un plan d'utilisation détaillé a été préparé pour le premier modèle de vol d'Olympus, lequel est maintenant mis à jour régulièrement.

DRPP

Deux études parallèles de Phase A1 du système de relais de données (DRS) ont été menées à bien. Ces deux études, réalisées par des consortiums industriels menés respectivement par Matra (France) et par MBB (Allemagne), ont abouti à la définition d'une base de référence pour le DRS complet, y compris les satellites de relais de données, les terminaux spatiaux des utilisateurs et le secteur terrien correspondant.

Le DRS se composera de deux satellites opérationnels sur orbite géosynchrone. Le satellite du DRS de base de référence a quatre antennes, ayant chacune un diamètre de 3 m environ et un bloc optique prenant en charge cinq satellites utilisateurs simultanément. Le satellite a aussi deux antennes pour les liaisons avec le sol, l'une assurant une couverture européenne permanente et l'autre la couverture par pinceau dirigeable de n'importe quel point visible depuis le satellite. La capacité de données maximale de chaque satellite DRS est de 1,2 Gbit/s environ, et leur masse au décollage est estimée entre 2500 et 3000 kg pour l'ensemble de la mission telle qu'elle est actuellement spécifiée.

Un contrat de Phase A2 sera adjugé à un groupe industriel mené par Selenia Spazio, Italie. La base de ce travail de Phase A2 sera la base de référence définie dans la Phase A1, mais d'autres options réduites, refléctant d'autres scénarios d'utilisateurs possibles, seront également étudiées.

Pour vérifier des hypothèses de système concernant la capacité maximale par canal, il est prévu de construire une installation de simulation du matériel. Un contrat de réalisation du matériel de codage et de décodage destiné à cette installation a été adjugé à Newtec (Belgique), avec SPL (Royaume Uni) comme sous-traitant. Des offres concernant le matériel de modulation et de démodulation sont à l'étude, et un contrat sera adjugé sous peu.

Des contacts sont actuellement maintenus avec la NASA et la NASDA (Japon) pour examiner le degré d'interfonctionnalité souhaitable entre le DRS européen et les systèmes américain et japonais équivalents.

PSDE

Trois missions sont actuellement programmées dans le cadre du programme PSDE:

- *Une charge utile évoluée de communications aéronautiques et maritimes mobiles (Aramis) sur Sat-1.*
- *Un satellite technologique de communications évolué, Sat-2.*
- *Une mission de communication et de navigation pour mobiles terrestres faisant appel à des orbites inclinées (Archimède) sur Sat-3.*

Sat-1 (Aramis)

Aramis est une charge utile évoluée de communication entre mobiles assurant la couverture, par pinceaux multiples, de l'océan Atlantique et des régions côtières depuis une orbite géostationnaire. Un certain nombre d'études de charge utile et de satellite ont été effectuées, et la charge utile est à un stade de définition avancé. La réalisation de la charge utile Aramis se poursuivra selon la tranche No 2 du programme PSDE.

D'après un accord passé entre les participants du PSDE, toutefois, le satellite Sat-1 ne sera réalisé et lancé que si son financement peut être assuré par des tiers. A cette fin, l'ESA a soumis une proposition à Inmarsat, et les discussions sont encore en cours.

Sat-2

Les études de Phase A de toutes les charges utiles pressenties pour cette mission sont maintenant très avancées. De plus, les études de Phase A concernant la mise en place des charges utiles pressenties sur des plates-formes européennes existantes de classe demi-Ariane (Eurostar, Spacebus et Italsat) indiquent qu'il est possible de réaliser une combinaison de charges utiles représentant un véritable défi. Les résultats de ces études ont été présentés à une première réunion des participants potentiels au PSDE en février, et depuis le choix des charges utiles a encore été affiné. Des charges utiles de base de référence pour la mission sont maintenant:

- *Une charge utile de communications optiques offrant des communications à très haut débit de données entre une orbite géostationnaire et une orbite basse.*

- *Une mission combinée bande L-bande S faisant appel à un grand réflecteur non repliable. La mission en bande L assurera des pinceaux multiples à hautes performances au-dessus de l'Europe pour développer le marché des mobiles terrestres. Une charge utile de navigation (Locstar ou Navsat) pourrait en outre être* capacity per channel. A contract for the development of the encoder and decoder equipment for this facility has been awarded to Newtec (Belgium) with SPL (UK) as subcontractor. Proposals for the modulation and demodulation equipment are in hand and a contract will be awarded shortly.

Contacts are being maintained with NASA and NASDA (Japan) to examine the degree of interoperability desirable between the European DRS and the equivalent American and Japanese systems.

PSDE

Three missions are currently planned within the PSDE Programme:
- An advanced aeronautical and maritime mobile communications payload (Aramis) on Sat-1.
- An advanced communications-technology satellite, Sat-2.
- Land-mobile communications and navigation using inclined orbits (Archimedes) on Sat-3.

Sat-1 (Aramis)
Aramis is an enhanced mobile communications payload providing multiple spot-beam coverage of the Atlantic and coastal regions from geostationary orbit. A number of payload and spacecraft studies have been performed and the payload is at an advanced stage of definition. Development of the Aramis payload will continue under the PSDE Programme Slice-2.

Based on an agreement between the PSDE participants, however, the Sat-1 spacecraft will only be developed and launched if funding by third parties can be assured. To this end, ESA has submitted a proposal to Inmarsat, and discussions are still in progress.

Sat-2
Phase-A studies for all candidate payloads for this mission are now largely complete. In addition, Phase-A studies for the accommodation of the candidate payloads on existing European platforms of half-Ariane class (Eurostar, Spacebus and Italsat) indicate that a challenging payload combination can be realised. The results of these studies were presented at a first PSDE potential-participants' meeting in February and payload selection has since been further refined. Baseline payloads for the mission are now:
- An optical communications payload offering very high data rate communications between geostationary and low Earth orbits.
- A combined L-band/S-band mission using a large unfurlable reflector antenna. The L-band mission will provide high-performance, multiple spot beams over Europe to develop the land-mobile market. A navigation payload (Locstar or Navsat) may further be combined with the L-band payload.
- A communications payload operating at 40/50 GHz, providing steerable spots for inter-orbit communication, and also capable of offering fixed services for very-small-aperture terminals.
- A propagation experiment at 45/90/135 GHz to provide propagation data at the higher frequency range.
- An on-board processing payload to prepare for technology offering greater interconnectivity.
- Technology experiments such as ion-propulsion and a nickel-hydrogen battery to improve spacecraft performance.

Phase-B1 spacecraft studies will take place between April and August 1988, leading to final payload selection shortly thereafter. Phase-B2 contracts will be placed at that time, maintaining competition up to the award of a Phase-C/D contract to a single prime contractor during 1989.

Phase-B payload-development and breadboarding activities will continue in parallel, under the management of a single contractor for each payload. Hardware procurement will be competitive, however.

Sat-3 (Archimedes)
This mission is based upon 12 h and 24 h quasi-synchronous orbits with an inclination of 63° (Molniya and Tundra orbits). If sufficient satellites with the correct orbital phasing are in operation, the land-mobile user in Europe and the northern regions will obtain continuous coverage at high elevation angles, resulting in increased system availability. ESA's Navsat navigation system also uses these orbits to provide continuous service over the European Continent and the Atlantic with a minimum number of satellites.

A number of related feasibility studies are in progress.

ERS

Programmatic/technical aspects
The main event during recent months has been completion of the ERS-1 System Critical Design Review (CDR), which was initiated with data-package delivery on 12 October and concluded with the Board Meeting on 11 November. The System CDR had been preceded by 56 CDRs at equipment, subsystem and instrument level.

The Board assessed that these preceding CDRs, the data package with supporting information, and the review presentation had allowed thorough review and assessment of the status of the programme. It concluded that the requisite performances can indeed be met and that the programme has matured sufficiently to allow progressive release of flight-model hardware manufacturing.

Since the Review, work has continued to resolve open action items; in particular, much attention has been paid to system-level evaluation of instrument test results.

Launcher
Launch-operations-facility requirements have been agreed with ERS-1 contractors. These, together with definitions of the launcher interfaces and the launch-operations tasks, have been included in the Agency's 'Demande d'Utilisation Ariane', issued to Arianespace as a basis for detailed discussion and subsequent agreement.

Schedule
Following the delays that have occurred in the delivery of the engineering-model (EM) instruments, integration of the EM payload has been resumed in March, leading to predicted completion of the EM payload tests in November 1988.

Subsequent integration of the EM payload and flight-model (FM) platform will allow the flight- and engineering-model satellite tests (functional, electromagnetic and radio-frequency *combinée à la charge utile en bande L.*

- *Une charge utile de communications fonctionnant à 40-50 GHz, assurant des pinceaux dirigeables pour la communication entre orbites, et également capable d'offrir des services fixes pour des terminaux à ouverture très petite.*
- *Une expérience de propagation à 45-90-115 GHz, fournissant des données de propagation dans la gamme de fréquence supérieure.*
- *Une charge utile de traitement à bord, permettant de préparer la technologie offrant la plus grande possibilité d'interconnexion.*
- *Des expériences technologiques telles que la propulsion ionique et une pile nickel-hydrogène pour améliorer les performances des satellites.*

Les études de la Phase B1 du satellite auront lieu entre avril et août 1988, et aboutiront au choix final de la charge utile peu après. Des contrats de Phase B2 seront adjugés à ce moment-là, pour maintenir la concurrence jusqu'à l'adjudication d'un contrat de Phase C/D à un seul et unique maître d'oeuvre en 1989. Les activités de mise au point et de construction de maquette d'une charge utile de Phase B se poursuivront parallèlement, sous la direction d'un contractant unique pour chaque charge utile. Toutefois, la fourniture du matériel sera ouverte à la concurrence.

Sat-3 (Archimède)

Cette mission est basée sur des orbites quasi-synchrones de 12 heures et de 24 heures, avec une inclinaison de 63 degrés (orbites Molniya et Tundra). Si un nombre suffisant de satellites à phases orbitales correctes est en service, les utilisateurs de mobiles terrestres en Europe et dans les régions septentrionales obtiendront une couverture continue avec de grands angles d'élévation, avec pour résultat une plus grande disponibilité du système. Le système de navigation Navsat de l'ESA utilise lui aussi ces orbites pour assurer un service continu au-dessus du continent européen et de l'Océan Atlantique, avec un nombre minimal de satellite.

Un certain nombre d'études de faisabilité connexes sont en cours.

ERS

Aspect programmatique et technique

Au cours des derniers mois, le principal événement a été l'achèvement de la revue de conception critique (CDR) du système ERS-1, qui avait commencé avec la livraison de l'ensemble de données le 12 octobre et s'est terminée avec la réunion du comité le 11 novembre. La CDR du système avait été précédée par 56 CDR au niveau des matériels, des sous-systèmes et des instruments. Le comité a estimé que les CDR précédents, l'ensemble de données avec les informations à l'appui, et la présentation de la revue permettaient une revue et une évaluation complètes de l'état d'avancement du programme. Il en a conclu que les performances exigées pouvaient en réalité être respectées et que le programme était assez mûr pour permettre le lancement progressif de la fabrication du matériel des modèles de vol. Depuis la revue, le travail de résolution des problèmes en suspens s'est poursuivi; en particulier, une grande attention a été consacrée à l'évaluation, au niveau du système, des résultats des essais des instruments.

Lanceur

Les exigences concernant l'installation nécessaire aux opérations de lancement ont fait l'objet d'un accord avec les contractants d'ERS-1. Celles-ci, ainsi que les définitions des interfaces du lanceur et les tâches opérationnelles de lancement, ont été incluses dans la 'demande d'utilisation Ariane' de l'Agence, présentée à Arianespace pour former la base de discussions détaillée et d'un accord ultérieur.

Calendrier

Suite aux retards qui se sont produits dans la livraison des instruments du modèle d'identificattion (EM), l'intégration de la charge utile de l'EM a pu être reprise en mars 1988, aboutissant à l'achèvement prévu des essais de la charge utile de l'EM en novembre 1988.

L'intégration ultérieure de la charge utile de l'EM et du modèle de vol de la plate-forme permettra l'achèvement, d'ici à la mi-1989, des essais (fonctionnels, de compatibilité électromagnétique et de radiofréquence) du modèle de vol et du modèle d'identification du satellite.

Parallèlement aux essais du modèle de vol et du modèle d'identification du satellite, l'intégration de la charge utile est programmée de façon à battre son plein d'ici à novembre 1988, pour aboutir à la fin des essais du modèle de vol de la charge utile d'ici à la fin juillet 1989. L'intégration et les essais ultérieurs du modèle de vol de satellite sont prévus pour le second semestre de 1989, tout en permettant une revue de recette de vol d'ici à la fin 1989 et la fin des préparatifs de lancement en avril 1990, conformément aux dates fixées dans le contrat de lancement d'ERS-1.

Centre de gestion et de commande de la mission (MMCC)

Une revue détaillée du plan de mise en oeuvre de la mission (MIP) a eu lieu, aboutissant à un accord fondamental sur le contenu et les estimations de prix correspondantes, sous réserve d'une réévaluation de plusieurs facteurs de prix mineurs.

Les détails de l'interface de matériel entre le MMCC et le bureau du programme Earthnet (EPO) ont fait l'objet d'un accord. La fourniture d'un système de mise au point formant le noyau du premier système informatique d'ERS a commencé, la livraison et l'installation étant prévues pour avril 1988.

Des négociations ont eu lieu avec la Swedish Space Corporation (SSC) pour définir le soutien qui doit être apporté par la SSC à la station ERS-1 de Kiruna pour la période allant de mai 1988 à octobre 1989. Le contrat couvrira l'achèvement des bâtiments, les essais d'intégration et de recette de la station, la mise en service, et une période de transition éventuelle jusqu'au début du contrat classique de maintenance et d'exploitation pour la phase opérationnelle.

Earthnet

Landsat

Les performances de Landsat-5 ont été nominales au cours de la période concernée par ce rapport. La station de Fucino a saisi des données tout au long de la période, tandis que la station de Maspalomas a arrêté la saisie le 16 décembre 1987 (fin de la campagne CEE). La station de Kiruna a interrompu la saisie en décembre-janvier à cause de compatibility) to be completed by mid-1989.

In parallel with the flight- and engineering-model satellite tests, integration of the flight-model (FM) payload is scheduled to gain full momentum by November 1988, leading to finalisation of the FM payload tests by the end of July 1989. Subsequent integration and testing of the FM satellite is foreseen during the second half of 1989, still allowing a Flight Acceptance Review by the end of 1989 and readiness for launch in April 1990, in accordance with the dates in the ERS-1 launch contract.

Mission Management and Control Centre (MMCC)
A detailed review of the Mission Implementation Plan (MIP) has taken place, leading to basic agreement on the content and associated cost estimates, subject to re-appraisal of several minor cost elements.

Details of the hardware interface between the MMCC and the Earthnet Programme Office (EPO) have been agreed. Procurement of a development system forming the nucleus of the first ERS computer system has been initiated, with delivery and installation planned in April 1988.

Negotiations have taken place with the Swedish Space Corporation (SSC) to define the support needed for the ERS-1 Kiruna Station from SSC for the period May 1988 to October 1989. This covers building completion, station integration and acceptance testing, commissioning, and a possible bridging period until the start of the classical maintenance-and-operation contract for the operational phase.

Earthnet

Landsat
Landsat-5 has performed nominally during the reporting period. Fucino has acquired data throughout, whilst Maspalomas stopped acquisition on 16 December 1987 (end of the EEC campaign). Kiruna suspended acquisition in December-January due to problems with low Sun elevation. Contracts for 1988 operations at Fucino and Kiruna have been negotiated.

Data processing and distribution has been carried out regularly. Thematic-Mapper data acquired at Maspalomas during 1987 have been shipped to Frascati for transcription, which will allow the generation of Thematic-Mapper data for West Africa in the very near future.

MOS-1
MOS-1 data are being acquired regularly at the four stations of Fucino, Kiruna, Maspalomas and Tromsø.

Development of the product-generation chain is encountering some difficulty with the integration of the mission-specific equipment and the processing hardware. This will have a negative impact on the delivery date of the applications software to the stations, which was originally planned for the second quarter of 1988.

Tiros
The spacecraft and acquisition stations have been performing normally. Development of the basic subsystems has been completed. Product-generation chains to be installed at Maspalomas and Tromsø are being manufactured for delivery in April/May 1988.

ESA-EEC Agreement
Extension of the Agreement for the 1988 Landsat/Spot/Tiros campaign is being negotiated.

ERS-1
The Request for Quotation for Phase-C/D for the ERS-1 Central User and Browse Services (CUS/BS) has been issued. Work is in progress on the detailed definition of the Earthnet ERS-1 Central Facility (EECF) interfaces with the other elements of the ERS-1 ground segment.

ERS-1 precise tracking
The first ERS-1 Tracking Workshop was held at the German Institute for Geodetic Research (DGFI) in Munich on 15—16 December 1987. Laser-station operators have shown interest in supporting ERS-1 tracking operations, but existing medium/long-term commitments are resulting in conflict problems of a substantial nature.

EOPP

Earth-Observation Preparatory Programme (EOPP) activities have continued in three main programme areas: Solid-Earth, Meteosat Second-Generation and Polar-Orbit Earth Observation.

Solid-Earth Programme: 'Aristoteles'
Following successful negotiations, a contract has been placed with a European industrial team headed by Dornier System (D) for the Phase-A study of the Aristoteles mission.

Phase-A1, which was kicked off in January 1988, is devoted to a system trade-off of various technical concepts relating to suspended versus fixed-gradiometer accommodation, two-axis versus three-axis accelerometers, as well as different measurement accuracies, orbital altitudes, mission durations and numbers of measured gravity-gradient tensor elements.

At the end of this first phase, in March 1988, a preferred concept will be selected for more detailed study in terms of technical feasibility and programme cost and schedule during Phase-A2.

The study is planned to be completed in July 1988.

Meteosat Second Generation
Studies have continued on various aspects of the Meteosat Second-Generation Programme. In addition, contacts with Eumetsat have been intensified to pave the way for the Phase-A activities.

The two system-configuration studies by Aerospatiale (F) and BAe (UK) are proceeding according to schedule and mid-term presentations have been held at ESTEC. Both studies are focussing on configuration possibilities and both industrial teams have looked at a number of satellite designs: spinner, dual-spin and three-axis stabilised, with the various instruments in different configurations. Work in the second phase will concentrate on preferred concepts, and final presentations are scheduled during April.

An important aspect has already been highlighted by both contractors, namely that if all payload items (Imager, IR Sounder, Microwave Sounder and Data-Circulation Expt.) are kept as presently foreseen, it will be difficult to keep the mass of the satellite to less than half the capability of an Ariane-4. This has considerable financial implications and the situation is currently under review.

problèmes posés par la faible hauteur du Soleil. Des contrats ont été négociés pour les opérations de Fucino et de Kiruna en 1988.

Le traitement et la distribution des données se sont déroulés régulièrement. Les données du cartographe thématique saisies à Maspalomas en 1987 ont été expédiées à Frascati pour transcription, ce qui permettra la création de données du cartographe thématique pour l'Afrique occidentale dans un très proche avenir.

MOS-1
Les données de MOS-1 sont actuellement saisies régulièrement aux quatre stations de Fucino, Kiruna, Maspalomas et Tromsø.

La réalisation de la chaîne de création de produits rencontre actuellement certaines difficultés dues à l'intégration des équipements spécifiques à la mission et du matériel de traitement. Cela aura des répercussions négatives sur la date de livraison du logiciel d'applications aux stations, laquelle était prévue à l'origine pour le second trimestre de 1988.

Tiros
Le satellite et les stations de saisie de données se sont comportés normalement. La réalisation des sous-systèmes fondamentaux a été terminée. Les chaînes de création de produits qui doivent être installées à Maspalomas et à Tromsø sont en cours de fabrication en vue de leur livraison en avril-mai 1988.

Accord ESA-CEE
L'extension de l'accord pour la campagne Landsat-Spot-Tiros de 1988 est en cours de négociation.

ERS-1
L'appel d'offres pour la Phase C/D des services d'utilisateurs centraux et de Browse (CUSBS) d'ERS-1 a été lancé. Le travail de définition détaillé des interfaces de l'installation centrale d'ERS-1 d'Earthnet (EECF) avec les autres éléments du secteur terrien d'ERS-1 est en cours.

Poursuite précise d'ERS-1
La première réunion de travail pour la poursuite d'ERS-1 a eu lieu à l'Institut Allemand de Recherche Géodésique (DGFI) à Munich les 15 et 16 décembre 1987. Les opérateurs des stations laser ont manifesté de l'intérêt pour la prise en charge des opérations de poursuite d'ERS-1, mais des engagements à moyen terme et à long terme existants entraînent actuellement des problèmes conflictuels de nature substantielle.

EOPP

Généralités
Les activités du programme préparatoire d'observation de la Terre (EOPP) se sont poursuivies dans trois secteurs principaux: le programme solide terrestre, l'observation de la Terre en orbite polaire, et le Météosat de seconde génération.

Programme Solide Terrestre: 'Aristote'
Après des négociations couronnées de succès, un contrat a été adjugé à une équipe industrielle européenne menée par Dornier System (D) pour l'étude de Phase A de la mission Aristote.

La Phase A1, dont le coup d'envoi a été donné en janvier 1988, est consacrée à un compromis des systèmes de divers concepts techniques relatifs à la mise en place d'un gradiomètre suspendu ou fixe, à des accéléromètres à deux axes ou à trois axes, ainsi qu'à différentes précisions de mesure, altitudes orbitales, durées de mission et nombre d'éléments tenseurs de gradient de gravité mesurée.

A la fin de cette première phase, en mars 1988, un concept sera retenu pour une étude plus détaillée, en termes de faisabilité technique, de coût et de calendrier de programme pendant la Phase A2.

L'achèvement de l'étude est programmé pour juillet 1988.

Seconde génération de Météosat
Les études se sont poursuivies sur divers aspects du programme Météosat de seconde génération (MSG). De plus, les contacts avec Eumetsat se sont intensifiés pour ouvrir la voie aux activités de Phase A.

Les deux études de configuration de système confiée à l'Aérospatiale (F) et à BAe (UK) se déroulent selon le calendrier, et des présentations de mi-étude ont eu lieu à l'ESTEC. Les deux études se concentrent sur les possibilités de configuration, et les deux équipes industrielles se sont penchées sur un certain nombre de conceptions de satellite: gyrateur, double gyration et stabilisation sur trois axes, avec les divers instruments dans des configurations différentes. Dans la seconde phase, le travail se concentrera sur les concepts préférés, et les présentations finales sont programmées pour le mois d'avril.

Un aspect important a déjà été mis en lumière par les deux contractants, à savoir que si tous les éléments de la charge utile (imageur, sondeur infrarouge, sondeur à hyperfréquences et appareillage expérimental de circulation des données) sont maintenus dans la configuration actuellement prévue, il sera difficile de maintenir la masse du satellite en deçà de la moitié de la capacité d'une fusée Ariane-4. Cela a de considérables implications financières, et la situation est actuellement passée en revue.

Systèmes à orbite polaire: observation de la Terre
Pendant la période concernée par ce rapport, les activités se sont poursuivies dans les divers secteurs d'étude. Parallèlement, d'intenses activités internes ont eu lieu pour analyser la situation qui prévalait après la conférence ministérielle et pour identifier les diverses lignes de conduite possibles.

De plus, l'Exécutif a établi une base de référence possible pour le secteur terrien d'observation de la Terre et le traitement des données de la charge utile (extrapolée de l'expérience ERS) dans le cadre des activités de l'autorité de conception centrale (CDA), auxquelles il sera mis un point final en mars-avril 1988.

Météosat

Programme pré-opérationnel
La première partie de la campagne de lancement de Météosat P2 a eu lieu de la mi-novembre à la mi-décembre 1987. L'ensemble de la campagne était divisé en deux parties pour laisser une marge au cas où des problèmes auraient surgi pendant la préparation du satellite. Toutefois, aucun problème ne s'est posé et le satellite est maintenant entreposé

Polar-orbiting systems: Earth observation
During the reporting period, activities have continued in the various study areas. In parallel, intense internal activities have been taking place to analyse the Post-Ministerial-Conference situation and identify possible courses of action.

In addition, the Executive has established a possible baseline for the Earth-observation ground segment and payload data handling (extrapolated from ERS experience) in the framework of the Central Design Authority (CDA) activities, which will be finalised in March/April 1988.

Meteosat

Preoperational programme
The first part of the Meteosat P2 launch campaign took place from mid-November to mid-December 1987. The overall campaign was split into two parts to provide a margin in the event of problems arising during preparation of the spacecraft. However, no problems were encountered and the satellite is now being stored in its container in Kourou (CSG). The two apogee-boost motors (prime and spare) have been tested and are also being stored at CSG. The flight battery is being stored under refrigeration at the CSG technical centre; it will be installed in the spacecraft during the second part of the campaign.

The Ground-Segment Readiness Review was held at ESOC in January. The Review Board's report concluded that the ground segment is ready to support the P2 launch, subject to successful completion of a few action items.

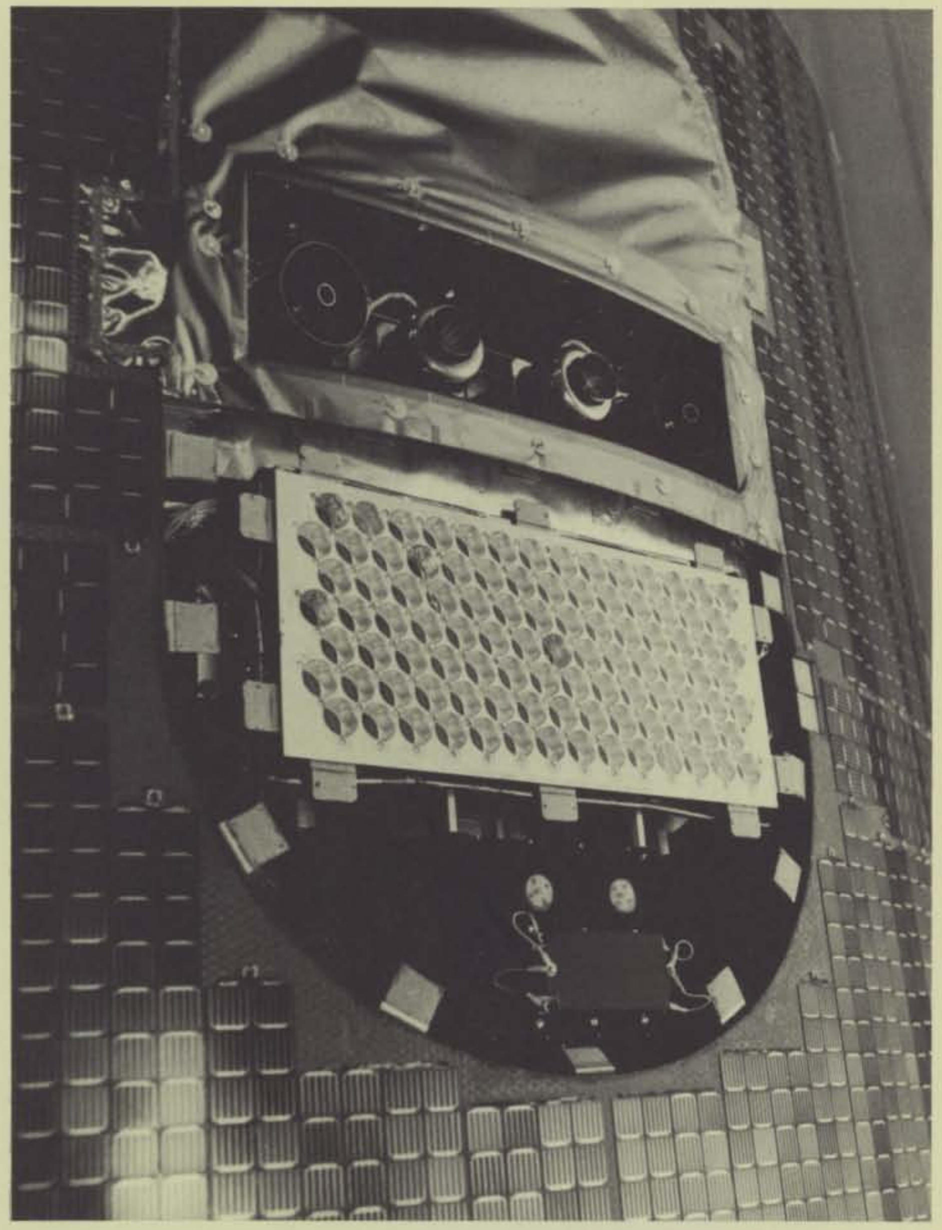
The Flight Acceptance Review, scheduled to be held at the beginning of February, has been postponed until March.

The Ariane 401 launch is now scheduled for the the second half of May 1988. It is therefore planned to resume the Meteosat launch campaign at the beginning of April.

The LASSO experiment was successfully tested during the first part of the P2 launch campaign. The flight retroreflector is being kept in storage and will be installed on the spacecraft just before launch.

In accordance with the LASSO Control Centre contract, the Telespazio team has been put on standby and will be called into service two months prior to launch.

Operational programme
Flight-hardware manufacture and system testing for the three MOP spacecraft are progressing satisfactorily at Aerospatiale. System testing was temporarily suspended on the MOP-1 satellite as the prime task of the project team was preparation of the P2 spacecraft for launch, scheduled for the second quarter of 1988. MOP-1 activities have been resumed early in 1988, but will again be interrupted when the second part of the P2 launch campaign starts at the beginning of April.



Le panneau rétroréflecteur de l'expérience LASSO embarquée sur Météosat P2 (vue rapprochée).

Close-up of the LASSO retro-reflector array on Meteosat P2.

Ground segment and operations
Extension of the ground-segment capabilities to full MOP satellite standards has been successfully completed. Further work, such as refurbishment of the ranging system as well as the extension of the Data-Collection Platform (DCP) receiving chain (up to 72 channels), is on schedule, with completion expected towards mid-1988.

The GOES-IV satellite, supporting the DCP operations, has no fuel left to *dans son conteneur au centre spatial guyanais (CSG) de Kourou. Les deux moteurs d'apogée (principal et de rechange) ont subi des essais et sont également entreposés au CSG. La batterie de vol est actuellement entreposée à basse température au centre technique du CSG; elle sera installée dans le satellite pendant la seconde partie de la campagne.*

La revue du degré de préparation du secteur terrien s'est tenue à l'ESOC en janvier. Le rapport du comité de revue a conclu que le secteur terrien était prêt à prendre en charge le lancement de P2, sous réserve que quelques actions ponctuelles soient menées à bien.

La revue de recette de vol, programmée pour le début de février, a été repoussée au mois de mars.

Le lancement d'Ariane 401 est maintenant programmé pour la seconde moitié de mai 1988. Il est donc prévu de reprendre la campagne de lancement de Météosat au début d'avril.

Pendant la première partie de la campagne de lancement de Météosat P2, l'expérience LASSO a subi des essais couronnés de succès. Le rétroréflecteur de vol est maintenu à l'entreposage et sera monté sur le satellite juste avant le lancement.

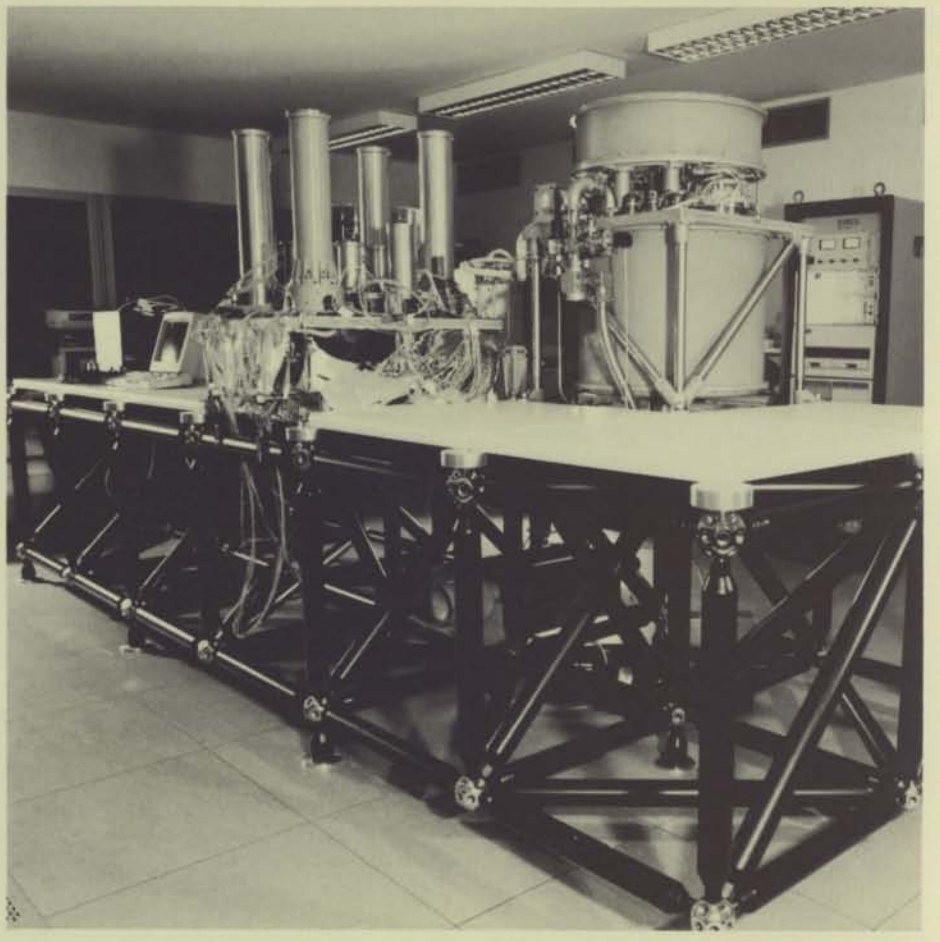
Conformément au contrat passé avec le centre directeur de LASSO, l'équipe de Telespazio a été mise en attente, et on fera de nouveau appel à ses services deux mois avant le lancement.

Programme opérationnel
La fabrication du matériel de vol et les essais du système pour les trois satellites MOP se déroulent de manière satisfaisante à l'Aérospatiale. Les essais au niveau du système du satellite MOP 1 ont été temporairement suspendus, car la tâche première de l'équipe chargée du projet était la préparation du satellite P2 pour le lancement, programmé pour le second trimestre de 1988. Les activités de MOP 1 ont été reprises au début de 1988, mais seront de nouveau interrompues quand la seconde partie de la campagne de lancement de P2 commencera au début d'avril.

Secteur terrien et opérations
L'extension des capacités du secteur terrien aux normes complètes du satellite MOP a été complétée avec succès. D'autres travaux, tels que la remise en état du système d'écartométrie, ainsi que l'extension de la chaîne de réception de la plate-forme de collecte de données (DCP) (jusqu'à 72 canaux) se déroulent conformément au calendrier, en attendant leur achèvement vers la mi-1988.

Le satellite GOES IV, qui prend en charge les opérations de la DCP, n'a plus assez de carburant pour abaisser la forte inclinaison et la ramener dans la bande opérationnelle normale. Par ailleurs, des problèmes se sont posés avec la chaîne d'émetteurs, ce qui a pour effet une détérioration de 20% environ des performances de la mission.

Le satellite Météosat P2, actuellement utilisé pour prendre en charge les missions de saisie et de diffusion d'images, a lui aussi atteint le point (après 6,5 années d'exploitation fructueuse) auquel il n'est plus possible de maîtriser son inclinaison. Toutefois, les deux missions peuvent, pour le moment, continuer à être exploitées avec un chiffre de performances nettement supérieur à celui qui avait été spécifié.



Eureca mock-up structure at DFVLR, Porz-Wahn.

Structure de support d'expérience pour Eureca chez DFVLR à Porz-Wahn.

Microgravité

Fusées-sondes
Une charge utile comportant une contribution de 90% du programme de microgravité de l'ESA a été lancée avec succès dans le programme suédois de fusées-sondes (Maser). Le lancement a eu lieu à Esrange, installation de la Swedish Space Corporation à Kiruna, le 29 février 1988.

La charge utile, pour laquelle l'ESA a fourni sept des huit expériences emportées, a été soumise à des conditions de microgravité pendant 7 minutes et 18 secondes exactement. La recherche fondamentale couvrait des secteurs tels que les alliages non miscibles, la métallurgie, la croissance des semiconducteurs, ainsi que les propriétés de transmission de chaleur et de tension superficielle de liquides.

reduce its high inclination to within the normal operational band. Furthermore, problems with the transmitter chain have occurred, the combined effect being that mission performance has dropped by about 20%.

The Meteosat-F2 satellite, currently being used to support the image-acquisition and dissemination missions, has also reached the point (after 6.5 years of successful operations) at which its inclination can no longer be controlled. However, both missions can, for the time being, continue to be operated at a performance figure well above the specified minimum.

Microgravity

Sounding rockets
A payload with a 90% contribution from the ESA Microgravity Programme has been successfully launched in the Swedish Maser sounding-rocket programme. The launch took place from Esrange, the Swedish Space Corporation's facility in Kiruna, on 29 February 1988.

The payload, for which ESA provided seven of the eight experiments carried, was under microgravity conditions for 7 min 18 sec. The basic research covered such areas as immiscible alloys, metallurgy, growth of semi-conductors, as well as the heat-transfer and surface-tension properties of liquids.

These experiments from ESA Member States (Germany, The Netherlands, Sweden and France) are aimed at significantly improving our understanding of materials processing and also have considerable potential for future applications.

Preparations for the Texus-17 and 18 launches are proceeding well. ESA participation is approximately 59% on Texus 17, and 25% on Texus 18.

Sled
An 'Announcement of Opportunity' offering flight possibilities on the ESA Sled to research institutions interested in neurophysiological investigations has been released. Five proposals (two from France, two from Germany and one from The Netherlands) have been received from the scientific community and are being submitted to a Scientific Peer Group for evaluation.

Biorack
The scientific samples from Biorack-type experiments (using mainly Biorack containers) flown on the Russian Biokosmos 1887 satellite in September 1987 are in the process of being analysed by the investigators in West Germany and the USSR. A joint review of the results is scheduled at ESTEC at the end of April. According to advance information, the results are conclusive, interesting and in line with the results from the Biorack's flight on the Spacelab D-1 mission.

Multi-user facilities on the Spacelab D-2 mission
The multi-user facilities to be flown on the Spacelab D-2 mission consist of the Advanced Fluid-Physics Module (AFPM), the Critical-Point Facility (CPF), and Anthrorack (AR).

Development work is proceeding on these facilities and detailed negotiations on their accommodation are taking place with the Spacelab D-2 Management.

Bubble, Drop and Particle Unit (BDPU)
The Concept Acceptance Review (CAR), the first milestone in the Phase-C/D development contract, was held recently. Its purpose was to define the overall layout of this facility in detail, and the operational concept.

Parabolic aircraft flights
An Announcement of Opportunity for such flights was released in November 1987. As a result, fifteen proposals in the area of fluid-physics/materials-science and twenty-two in the area of life sciences were received. The next flight campaign is scheduled to take place in August this year.

Eureca

The second NASA Safety Review for the Eureca system and thirteen of the fifteen Eureca payload instruments has been completed successfully.

One item still requiring further analysis by NASA and ESA is the interface gap between the Shuttle umbilical and the Eureca hydrazine thrusters, in the event of uncontrolled movements by the Shuttle's Remote Manipulator (RMS). Another is the ability of the Shuttle to fly in special attitudes to protect Eureca from overheating or overcooling (in case of a Eureca heater-system failure) while either inside the Shuttle's cargo bay or held by the Remote Manipulator.

NASA has also given safety clearance for Eureca's high-pressure gas and hydrazine tanks, and work can now proceed on their integration into the structure. The supplier has succeeded in improving the welding technique for the hydrazine lines, removing previous problems in this area.

Preparations for Eureca thermal-model testing in the ESTEC facilities are in progress and these tests are now scheduled for end-April.

Final installation of the OCOE checkout software is proceeding well, with only three problems left to be resolved before the end of April. The bypass design for the liquid-coolant loop has been finalised and procurement of the necessary hardware is proceeding. The planning for part one of the Equipment Qualification Review was finalised, and review activities started at the end of March. They will be completed by the first week in May.

The five core-payload facilities have somewhat diverged in their development status, but all planning dates still comply with Eureca integration-and-test need dates.

Electromagnetic testing of the non-core-payload instruments has continued successfully and will be completed in May 1988. No significant problems are currently expected.

The changed NASA Shuttle Flight Manifest of October 1987 foresees a Eureca launch in January 1991 on Flight 46 and its retrieval in June 1991 on Flight 51.

The current contractually binding planning for Eureca is still for a launch as early as May 1990. The final decision as to how to adjust the final schedule to cope with this and possible further changes in the NASA Manifest has to be taken in early 1989.

Ces expériences provenant d'Etats membres de l'ESA (Allemagne, Pays-Bas, Suède et France) visent à améliorer de manière notable notre compréhension du traitement des matériaux, et représentent également un potentiel considérable pour des applications futures.

Les préparatifs de lancement de Texus-17 et de Texus-18 se déroulent correctement. La participation de l'ESA est de 59% environ pour Texus-17, et de 25% pour Texus-18.

Sled (Traîneau spatial)
Une offre de participation concernant des possibilités de vol sur le 'Sled' de l'ESA a été diffusée aux instituts de recherche intéressés par les investigations neurophysiologiques. Cinq propositions (deux de la France, deux de l'Allemagne et une des Pays-Bas) ont été reçues des milieux scientifiques, et sont actuellement soumises à un groupe de spécialistes pour évaluation.

Biorack
Les échantillons scientifiques provenant d'expériences du type Biorack (utilisant principalement des conteneurs Biorack) embarquées sur le satellite Biokosmos 1987 en septembre 1987 sont en cours d'analyse par les chercheurs d'Allemagne Fédérale et d'Union Soviétique. Une revue conjointe des résultats est programmée à l'ESTEC pour la fin avril. Selon des informations préliminaires, les résultats sont concluants, intéressants et en accord avec les résultats obtenus par le vol de Biorack sur la mission Spacelab D1.

Installations multi-utilisateurs sur la mission Spacelab D2
Les installations multi-utilisateurs à embarquer sur la mission Spacelab D-2 se composent du module évolué de physique des fluides (AFPM), de l'installation point critique (CPF), et d'Anthrorack (AR).

Le travail de réalisation de ces installations est en cours, et des négociations détaillées concernant leur mise en place ont actuellement lieu avec la direction de la mission Spacelab D2.

Unité Bulles, Gouttes et Particules (BDPU)
La revue de recette de concept (CAR), première étape majeure du contrat de réalisation de la Phase C/D, a eu lieu récemment. Son objet était de définir en détail la topographie globale de cette installation, ainsi que le concept opérationnel.

Vols paraboliques d'aéronefs
Une offre de participation à des vols de ce genre a été lancée en novembre 1987. Il en a résulté quinze propositions dans le secteur de la physique des fluides, de la science des matériaux, et vingt-deux dans le secteur des sciences de la vie. La prochaine campagne de vols est programmée pour le mois d'août de cette année.

Eureca

La seconde revue de sécurité de la NASA pour le système Eureca et treize des quinze instruments de la charge utile d'Eureca a été conclue avec succès.

Les éléments qui nécessitent encore une analyse complémentaire de la NASA et de l'ESA sont le jeu d'interface entre l'ombilical de la Navette et les propulseurs à hydrazine d'Eureca, en cas de déplacements incontrôlés par le bras télémanipulateur (RMS) de la Navette, et l'aptitude de la Navette à voler dans des attitudes spéciales pour protéger Eureca d'un échauffement ou d'un refroidissement excessif (en cas de panne du système de chauffage d'Eureca) pendant qu'Eureca se trouve à l'intérieur de la soute de la Navette ou qu'il est maintenu par le bras télémanipulateur.

La NASA a également accepté pour les réservoirs de gaz à haute pression et d'hydrazine d'Eureca du point de vue de la sécurité et le travail d'intégration de ces réservoirs dans la structure peut maintenant se dérouler. Le fournisseur a réussi à améliorer sa technique de soudage pour les conduites d'hydrazine, en résolvant les problèmes antérieurs dans ce secteur.

Les préparatifs d'essais du modèle thermique d'Eureca dans les installations de l'ESTEC sont en cours, et trois de ces essais sont maintenant programmés pour la fin avril.

L'installation définitive du logiciel de contrôle d'OCOE se déroule bien, seuls trois problèmes restant à résoudre avant la fin avril. La conception définitive de la boucle de dérivation du liquide frigorigène a été établie et la fourniture du matériel nécessaire est en cours. Le calendrier prévisionnel de la partie No 1 de la revue de qualification du matériel a été établi définitivement, le passage en revue a commencé fin mars et sera terminé d'ici à la première semaine de mai.

La mise au point des cinq ensembles principaux de la charge utile a évolué quelque peu différemment selon les parties, mais toutes les dates prévisionnelles sont encore compatibles avec les dates fixées pour l'intégration et les essais d'Eureca.

Les essais électromagnétiques des instruments ne faisant pas partie du noyau de la charge utile se sont poursuivis avec succès et seront terminés en mai 1988. Actuellement, on ne s'attend pas à rencontrer de problèmes importants.

Le calendrier de vol de la Navette de la NASA, modifié en octobre 1987, prévoit un lancement d'Eureca en janvier 1991 sur le vol No 46 et sa récupération en juin 1991 sur le vol No 51.

Le calendrier prévisionnel actuel, requis par le contrat du projet Eureca prévoit encore un lancement dès le mois de mai 1990. La décision finale quant à l'ajustement du dernier calendrier de façon à faire face à cette obligation et à de nouveaux changements éventuels du calendrier de la NASA doit être prise par les responsables du projet au début de 1989.

Station spatiale/Columbus

Au cours du dernier trimestre, les principales activités ont été la Revue finale de la Phase B2XX, et l'achèvement des études de compromis de la plate-forme méridienne.

L'ensemble des données fournies par l'industrie a été livré, avec un certain retard, à l'ESA pour évaluation avant la revue conjointe avec les contractants ('Revue finale') qui a eu lieu du 22 au 30 mars 1988 à Brême. Il a été nécessaire d'organiser des revues mineures supplémentaires pendant le mois d'avril pour compléter le cycle de revue total. Cela a eu certaines répercussions sur le début de la phase suivante.

Space Station/Columbus

The main activities during the last quarter have been the Phase-B2XX Final Review, and completion of the Polar-Platform trade-off studies.

The industrial data package was delivered, with some delay, for evaluation by ESA prior to the joint review with the contractors ('Final Review'), which took place during the period 22—30 March 1988 in Bremen. It was necessary to plan further minor reviews during the month of April to complete the total review cycle. This has had some impact on the start of the next phase.

The Final-Review data package included the contractor's assessment of the Coherence Task Force's Step-2 recommendations, and these will now be evaluated jointly with the Hermes project to determine the feasibility, or otherwise, of their incorporation into the respective programme baselines. This evaluation will be conducted in conjunction with the Hermes Phase-B3 Final Review, scheduled for the period mid-April to mid-May 1988.

Assessment of Polar-Platform options continued throughout March. Additional inputs from CNES and BAe were assessed — together with earlier inputs received from Matra, Dornier and MBB/ERNO — against the revised set of requirements. The latter, together with possible Polar-Platform configuration concepts, have now been reviewed within the Agency and with NASA.

Following an internal assessment of the current status of definition of the major Columbus external interfaces with the Space Station and Hermes, and recognising the time needed to completely update and incorporate the Polar-Platform requirements set into the baseline, the Phase-C/D Request for Quotation (RFQ) planning has been adjusted to reflect the following key dates:
- Formal release date of 1 June 1988 for the Phase-C/D RFQ is maintained.
- Submittal date for the Phase-C/D proposal has been shifted to 15 December 1988.
- Phase-C/D Authority-to-Proceed (ATP) is planned for 1 May 1989.

The Agency is currently working with the contractor to establish guidelines for initiating the CØ phase in line with the revised schedule, and taking into account the need during the first five months of the phase to place special emphasis on external interfaces, Polar-Platform definition tasks and possible further Man-Tended Free-Flyer (MTFF) configuration updating, resulting from the revised Polar-Platform baseline.

An ESA/NASA Level-2 Technical Coordination Meeting took place in Washington (Reston) from 22 to 26 February 1988. Screening of the major Space-Station Level-2 Requirements Documents for applicability to the Columbus Programme, particularly the Attached Pressurised Module (APM), was completed and a draft ESA/NASA Programme Description and Requirements Document (JPDRD) was established.

The screening process resulted in the identification of several major interface issues by the Executive as priority-1 issues to be resolved prior to Columbus Phase-C/D RFQ final release. The criterion used by the Executive for identification of priority-1 issues was: any issue, the eventual resolution of which could potentially lead to a basic change in the APM architecture or to a basic architectural change in any of its subsystems. All priority-1 issues were assigned a latest date for resolution of 1 June 1988.

The next key event in the Space-Station Preliminary Requirements Review process is the Level-2 Space-Station Control Board (SSCB) meeting scheduled for 26 April 1988. The prime objective of this meeting is to release an updated NASA Level-2 Requirements Baseline, which will then be used as the basis of the Level-3 Preliminary Requirements Review to be conducted by the Level-3 Work Package Centres during the summer. Once the updated Level-2 Requirements Baseline set has been approved by the SSCB in April, it will be necessary to re-review the recently established draft ESA/NASA JPDRD for possible updating.

The Executive is continuing to prepare and implement the necessary actions to allow the Space Segment to transit from Phase-B to Phase-C/D with the minimum of disturbance to industrial continuity. This transition planning accommodates the additional effort needed to define adequately the system-requirements external-interfaces baseline, and is consistent with the currently known schedules of the interfacing programmes.

Hermes

The Phase-B2 activities that form part of the Hermes Preparatory Programme are nearly complete. The first slice of the Phase-B2 contract placed with the spaceplane consortium headed by Aerospatiale started in June 1987. The second slice covers the first three months of this year.

The results of this phase, and particularly the detailed definition of the spaceplane configuration, will be reviewed by ESA and CNES in April and May 1988. It is expected that this review, which will concentrate on the already-identified critical areas — particularly the aerodynamics and the overall mass budget — will lead to the recommendation of some improvements in the Hermes design.

Following approval of the Hermes Development Programme in November, its declaration was opened to subscription. The latter exceeded the programme-start threshold of 80% on 11 February. The level of subscription is currently 99.05%, and the decision of the twelfth participating state, Canada, is expected shortly.

The contents of the first programme phase, Phase-1, which will cover the years 1988, 1989, and 1990, have been defined in further detail. The objectives of this phase are fourfold: to advance the definition of the spaceplane and other Hermes elements; to develop the most critical technologies needed; to define the interfaces with other programmes, principally Ariane and Columbus; and finally to prepare for the next phase with the negotiation of a detailed industrial offer.

The main contract to be placed during Phase-1 of the development programme covers the definition of the spaceplane. Subject to the approval of the Industrial Policy Committee, this tender will be issued in early April. Steps have been taken to ensure continuity of the industrial effort whilst awaiting final approval of the contract.

L'ensemble de données de la Revue finale comprenait l'évaluation par le contractant des recommandations formulées pour l'étape No 2 par l'équipe spéciale de cohérence, et celles-ci vont maintenant être évaluées conjointement avec le projet Hermès pour déterminer leur faisabilité, ou, sinon, pour les incorporer aux bases de référence de programme respectives. Cette évaluation sera menée conjointement à la Revue finale de la Phase B3 d'Hermès, programmée entre la mi-avril et la mi-mai 1988.

L'évaluation des options de la plate-forme méridienne s'est poursuivie au cours du mois de mars. Les nouveaux apports du CNES et de BAe ont été évalués ainsi que ceux reçus précédemment de Matra, Dornier et MBB/ERNO — en fonction des exigences révisées. Ces dernières, ainsi que les concepts possibles de configuration de la plate-forme méridienne, ont maintenant été revues au sein de l'Agence et avec la NASA.

Suite à une évaluation interne de l'état actuel de la définition des interfaces externes principales de Columbus avec la Station spatiale et Hermès, et compte tenu du temps nécessaire à la mise à jour complète et à l'incorporation des exigences de la plate-forme méridienne dans la solution de référence, le calendrier prévisionnel de l'appel d'offres (RFQ) pour la Phase C/D a été ajusté de façon à prendre en compte les dates suivantes:
- *La date de lancement officielle du 1er juin 1988 pour le RFQ de la Phase C/D est maintenue.*
- *La date de soumission de l'offre pour la Phase C/D a été repoussée au 15 décembre 1988.*
- *L'autorisation de procéder (ATP) pour la Phase C/D est programmée pour le 1er mai 1989.*

L'Agence détermine actuellement avec le contractant des lignes directrices pour engager la Phase C/D en accord avec le calendrier révisé qui prennent en compte la nécessité, pendant les cinq premiers mois de cette phase, de mettre un accent tout particulier sur les interfaces externes, les tâches de définition de la plate-forme méridienne et une nouvelle mise à jour éventuelle de la configuration du module autonome visitable (MTFF), résultant de la révision de la base de référence de la plate-forme méridienne.

Une réunion de coordination technique de niveau 2 a eu lieu entre l'ESA et la NASA à Washington (Reston) du 22 au 26 février 1988. La sélection des principaux documents d'exigences de niveau 2 pour la Station spatiale, concernant l'applicabilité au programme Columbus, notamment le module pressurisé fixé à la Station (APM), a été achevée et un projet de document d'exigences et de description de programme conjoint ESA—NASA (JPDRD) a été établi.

Le processus de sélection a abouti à l'identification de plusieurs questions d'interface essentielles, que l'Exécutif souhaite traiter en priorité avant le lancement final du RFQ pour la Phase C/D de Columbus. Le critère utilisé par l'Exécutif pour déterminer les questions absolument prioritaires était le suivant toute question, dont la résolution éventuelle serait susceptible de conduire à une modification fondamentale de l'architecture de l'APM ou de l'un de ses sous-systèmes. La date limite pour résoudre toutes les questions prioritaires a été fixée au 1er juin 1988.

Le prochain événement majeur du processus de revue des exigences préliminaires de la Station spatiale est la réunion du comité directeur de la Station spatiale (SSCB) de niveau 2, qui est prévue pour le 26 avril 1988. L'objectif premier de cette réunion est la diffusion d'une base de référence mise à jour des exigences de niveau 2 de la NASA, qui sera ensuite utilisé comme base pour la revue des exigences préliminaires de niveau 3, laquelle doit être menée par les centres responsables des lots de tâches de niveau 3 au cours de l'été.

Une fois que l'exigence de base de référence de niveau 2 mis à jour aura été approuvé par le SSCB en avril, il sera nécessaire de passer à nouveau en revue le projet JPDRD en vue d'une mise à jour éventuelle.

L'Exécutif continue à préparer et à mettre en oeuvre les mesures, nécessaires pour permettre aux éléments spatiaux de passer de la Phase B à la Phase C/D sans que la continuité des travaux effectués dans l'industrie en soit affectée. Ce planning de transition prend en compte le travail supplémentaire nécessaire pour définir de manière adéquate la base de référence des interfaces externes des exigences du système; il suit les calendriers actuels des programmes de liaison.

Hermès

Les activités de Phase B2, qui font partie du programme préparatoire d'Hermès, sont presque terminées. La première tranche du contrat de Phase B2, adjugée à un consortium d'avion spatial mené par l'Aérospatiale, a débuté en juin 1987. La seconde tranche couvre les trois premiers mois de cette année. Les résultats de cette phase, et notamment la définition détaillée de la configuration de l'avion spatial, seront passés en revue par l'ESA et le CNES en avril et mai 1988. On s'attend à ce que cette revue, qui se concentrera sur les secteurs critiques déjà identifiés — notamment l'aérodynamique et le bilan masse global — aboutisse à la recommandation de certaines améliorations de la conception d'Hermès.

Suite à l'approbation du programme de réalisation d'Hermès, en novembre, sa déclaration a été ouverte à souscription. Cette dernière a dépassé le 11 février le seuil de 80% exigé pour le démarrage du programme. Le niveau de souscription est actuellement de 99.05%, et la décision du douzième Etat participant, le Canada, est attendue prochainement.

Le contenu de la première phase du programme, la Phase 1, qui couvrira les années 1988, 1989 et 1990, a été défini de façon plus détaillée. L'objectif de cette phase est quadruple: faire progresser la définition de l'avion spatial et des autres éléments d'Hermès; mettre au point les technologies les plus critiques nécessaires; définir les interfaces avec d'autres programmes, principalement Ariane et Columbus; et enfin préparer la phase suivante, en négociant une offre industrielle détaillée.

Le principal contrat à adjuger pendant la Phase 1 du programme de réalisation couvre la définition de l'avion spatial. Sous réserve d'approbation par le comité de politique industrielle, cet appel d'offres sera lancé début avril. Des mesures ont été prises pour assurer la continuité de l'effort industriel dans l'attente de l'approbation finale du contrat.

TDP

The In-Orbit Technology Demonstration Programme has progressed in all areas, in particular:

Common Support Subsystems
Hitchhiker-G Simulator
The breadboard has successfully passed the acceptance test. Production of the units is about to start; four units are to be manufactured.

Payload Control Unit
Phase-1 of the contract will be completed in May 1988. In this phase the recurring price of the unit will be fixed, together with the detailed design.

Experiments
Gallium-Arsenide (GaAs) Solar Array
The production of the solar cells has started. Solar-cell-module prototypes have been tested under thermal cycling in ESTEC. An early flight opportunity to test in-orbit solar-cell strings has been secured.

Altitude-Sensor Package
Work is progressing on this package to upgrade the existing sensors —including Earth sensor, modular star sensor and yaw Earth sensor — to flight status.

Solid-State Micro-accelerometer
The contract for experiment adaptation and integration was awarded in March and work started in April 1988.

Collapsible-Tube Mast and Heat-Pipe Radiator
Industry is preparing its proposals.

Inflatable Space-Rigidised Antennas
The Invitation to Tender (ITT) is currently being prepared.

Transputer and Single-Event Upset
This is a new experiment which has recently been added to the existing experiment list. The ITT is in preparation.

Dynamic Cooler
This item has been deleted, in agreement with the Swiss Delegation.

In-Space Aluminium Coating
The study to define the experiment has been completed and the ITT is in preparation.

Liquid Gauging Technology
A study to define the experiment is in progress and will be completed by mid-1988. A breadboard has been manufactured and tested. The ITT for experiment adaptation will then be issued.

Flight opportunities
The Preliminary Safety Review for the Shuttle Get-Away Special (GAS) experiment (G-21) has been successfully completed for the Solid-State Micro-accelerometer.

The Payload Accommodation Request has been completed for the Liquid Gauging Technology (G-22) and In-Space Aluminium Coating (G-485) Experiments.

For the experiments using Hitchhiker-G carriers — Altitude Sensor Package, Collapsible-Tube Mast and Heat-Pipe Radiator — manifesting is expected in April 1988. NASA's pricing policy for Hitchhiker secondary payloads is still not finalised.

The technical feasibility of flying the Inflatable Space-Rigidised Antenna on the USSR's MIR Space Station has been established. The mechanical/electrical interfaces are currently being defined.

The Transputer and Single-Event Upset Experiment will be carried on board a UOSAT-type spacecraft to be launched shortly. The selection of a small free-flyer satellite to carry the GaAs solar array is still in progress and is expected to be finalised this year.

International cooperation with NASA's Office of Aeronautics and Space Technology has been agreed for the Phase-B of two new experiments proposed by ESA (In-Flight Contamination and Solar-Array-Module Plasma Interaction); both should be carried as passengers with the Collapsible-Tube Mast.

In the context of looking, together with the Ariane Department, for further flight opportunities, negotiations are underway with Arianespace for the launch of a 'Pathfinder Platform' carrying technology experiments.

Preparations for the next phase of the In-Orbit Technology Demonstration Programme have started.

Ariane

The American satellite Spacenet 3R and the French satellite Telecom 1C were launched at 23.28 h, precisely at the opening of the launch window, on 11 March 1988.

The launch campaign, which began on 25 January, the count-down, which began on 10 March, and the final synchronised sequence, which began six min before launch, proceeded smoothly and without incident.

All the launcher systems functioned correctly, the vibration level was low and the spacecraft separated from the launcher according to plan.

Both satellites were injected with a high level of precision into geostationary transfer orbit as can be seen from the table below (injection parameters acquired just before separation).

	Planned	Reached
Spacenet		
Apogee (km)	36 041.8	35 983
Perigee (km)	200.0	200.3
Inclination (°)	6.99	6.99
Telecom 1C		
Apogee (km)	35 985.6	35 956
Perigee (km)	200.4	200.3
Inclination (°)	6.99	6.99

TDP

Le programme de démonstration technologique (TDP) en orbite a progressé dans tous les secteurs, en particulier:

Sous-systèmes de prise en charge commune

Simulateur Hitchhiker-G

La maquette a subi avec succès l'essai de recette. La production des exemplaires est prête à commencer; la fabrication de quatre exemplaires est programmée.

Unité de commande de charge utile

La Phase 1 du contrat sera terminée en mai 1988. Dans cette phase, le prix récurrent de l'unité sera fixé, ainsi que la conception détaillée.

Expériences

Générateur solaire à l'arséniure de gallium (GaAs)

La production des piles solaires a commencé. Des prototypes de module de pile solaire ont été essayés dans des conditions d'itération thermique à l'ESTEC. Une prochaine occasion de vol permettant d'essayer en orbite des chaînes de piles solaires a été assurée.

Bloc capteur d'altitude

Les travaux progressent sur ce bloc — y compris capteur terrestre, capteur stellaire modulaire — pour qualifier pour le vol les capteurs existants.

Micro-accéléromètre à semi-conducteurs

Le contrat d'adaptation et d'intégration de l'expérience a été adjugé en mars, et le travail a commencé en avril 1988.

Mât à tube repliable et radiateur à coloduc

L'industrie prépare ses propositions.

Antennes gonflables à armature rigide

L'appel d'offres (ITT) est en cours de préparation.

'Transputer' et dérangement par les particules élémentaires

Il s'agit d'une nouvelle expérience qui a récemment été ajoutée à la liste d'expériences existante. L'appel d'offres (ITT) est en cours de préparation.

Refroidisseur dynamique

Cet élément a été supprimé, en accord avec la délégation suisse.

Aluminiage dans l'espace

L'étude de définition de cette expérience a été terminée, et l'appel d'offres (ITT) est en cours de préparation.

Technologie de mesure du niveau des liquides

Une étude de définition de l'expérience est en cours et sera terminée d'ici à la mi-1988. Une maquette a été fabriquée et essayée. L'appel d'offres d'adaptation de l'expérience sera ensuite lancé.

Occasions de vol

Pour l'expérience de petites charges utiles en conteneur (GAS) de la Navette, (G-21): la revue de sécurité préliminaire du micro-accéléromètre à semi-conducteurs a été effectuée avec succès; (G-22): la demande de mise en place de la charge utile pour la technologie de mesure du niveau des liquides et (G-485) les expériences d'aluminage dans l'espace, ont été complétées.

Pour les expériences faisant appel à des porteurs Hitchhiker-G — bloc capteur d'altidude, mât à tube repliable et radiateur à caloduc — l'établissement du programme est prévu pour avril 1988. La politique de tarification de la NASA pour les charges utiles secondaires (Hitchhiker) n'est pas encore fixée définitivement. La faisabilité technique du vol de l'antenne gonflable à armature rigide sur la station spatiale MIR de l'URSS a été établie. La définition des interfaces mécaniques et électriques est en cours.

L'expérience 'Transputer' sera menée à bord d'un satellite du type UOSAT, qui doit être lancé prochainement. La sélection d'un petit satellite autonome porteur des générateurs solaires à l'arséniure de gallium se poursuit, et devrait être terminée cette année.

La coopération avec le Bureau de technologie aéronautique et spatiale de la NASA a fait l'objet d'un accord pour la Phase B de deux nouvelles expériences proposées par l'ESA (contamination en vol et interaction entre le module de générateur solaire et le plasma); les deux devraient être emportés comme passagers avec le mât à tube repliable.

Dans le contexte de la recherche, avec le département Ariane, de nouvelles occasions de vol, des négociations sont en cours avec Arianespace pour le lancement d'une 'plate-forme éclaireur' emportant des expériences technologiques.

Les préparatifs de la phase suivante du programme de démonstration technologique en orbite ont commencé.

Ariane

Le lancement du satellite américain Spacenet 3R et du satellite français Télécom 1C a eu lieu le 11 mars 1988 à 23 h 28 mn TU, exactement à l'ouverture de la fenêtre de lancement.

La campagne de lancement qui a débuté le 25 janvier, la chronologie entamée le 10 mars et le décompte final amorcé le 11 mars six minutes avant le lancement, se sont déroulés sans aucun incident.

Tous les systèmes du lanceur ont fonctionné normalement; l'ambiance vibratoire de vol a été calme et les conditions de séparation des satellites ont été nominales.

L'orbite de transfert géostationnaire a été atteinte, pour chaque satellite, avec une très bonne précision selon les caractéristiques suivantes (paramètres d'injection juste avant séparation).

Spacenet	*Prévision*	*Obtenu*
Apogée (km)	*36 041,8*	*35 983*
Périgée (km)	*200,0*	*200,3*
Inclinaison (°)	*6,99*	*6,99*
Télécom 1C		
Apogée (km)	*35 985,6*	*35 956*
Périgée (km)	*200,4*	*200,3*
Inclinaison (°)	*6,99*	*6,99*

Redu – Twenty Years On

J.B. Mac Laughlan, ESA Ground Station, Redu, Belgium

On 1 January 1988, the ESA station at Redu celebrated twenty years of operations. Originally conceived as part of the ESTRACK network supporting ESRO's near-Earth scientific satellites, Redu has evolved to play a major role in the launch and early-orbit operations of ESA's geostationary satellites, and to host a dedicated ECS Control Centre and in-orbit-test facilities for the ECS and Olympus missions. Although these missions will be operational for some years to come, consideration is already being given to the role that Redu can play in future Agency programmes such as PSDE, DRS and AOTS.

Background

ESA's Redu station is situated outside the village of Redu, approximately half way between the cities of Brussels and Luxembourg. It lies in a natural valley and covers an area of some 19 hectares at an average altitude of some 330 m.

The station was declared operational on 1 January 1968 and commenced operations with the ESRO-II satellite which was launched in May of that year. During these early days, the station was equipped with a high- and a low-gain VHF telemetry antenna and a VHF telecommand antenna, together with an interferometer for localisation purposes. An additional VHF telecommand antenna was installed in the mid-1970s for the Geos mission.

The main transformation of Redu into its present form began with the decision in 1979 to install not only the telemetry, telecommand and ranging facilities for the European Communications Satellite (ECS) missions, but also a dedicated Control Centre and a Communications Payload Test and Monitoring Terminal. Subsequent additions have been made to the ECS facilities to permit the control of four ECS satellites in orbit. Three new terminals have also been installed for the in-orbit testing of the Olympus satellite's communications payload.

Early missions

During the first ten years of operations at Redu, the satellites were all scientific and most were in near-Earth orbit, which meant that they were 'visible' to the station for approximately ten minutes during each pass. Such satellites have included: the Agency's ESRO-IA, ESRO-IB, ESRO-II, ESRO-IV and TD-1A and the Dutch ANS spacecraft. Those with highly eccentric orbits have included Heos-A1, Heos-A2 and Cos-B.

The geostationary-orbit era started for ESA in 1977 with Meteosat-1, soon to be followed by OTS-2 and Geos-2 (because of the Thor-Delta launcher failures, Geos-1 was unable to attain geostationary orbit and OTS-1 did not even reach transfer orbit). Redu provided support for all of these missions, and subsequently for Meteosat-2 and the Marecs and ECS satellite series.

Current and planned mission support

Redu currently provides 24 h-per-day support for the ECS satellites (ECS-1, ECS-2 and ECS-4) and OTS-2, and on a regular basis also for the NASA satellite IMP-8. In the course of 1988, Redu will be involved in the Launch and Early-Orbit Phase (LEOP) operations of both Meteosat-P2 and ECS-5.

With the exception of the LEOP, which is controlled from ESOC, and periodic ECS ranging measurements from Villafranca, Redu has full autonomy for all the operations required for the ECS missions. The ECS satellites are operated on behalf of EUTELSAT, who become the satellite owners following in-orbit acceptance and who lease the communications transponders to the various European PTTs.

In addition to the tracking and control of satellites, comprehensive in-orbit-test

Figure 1 — The Main Equipment Room

Figure 2 — The ECS Control Room

Figure 3 — The Test and Monitoring Room

facilities have been installed for the ECS satellites and Olympus. These facilities will also be used for the Scandanavian satellite Tele-X.

The current operational activities at Redu may be conveniently grouped into three categories:
- tracking-station support
- control-station activities for the ECS missions
- in-orbit testing of communications satellites.

For the future, although details are not yet finalised, it is expected that Redu will play an important role in the Agency's Payload and Spacecraft Development and Experimentation (PSDE), Data-Relay System (DRS) and Advanced OTS (AOTS) Programmes.

Site facilities

The main building houses the operational rooms, namely:
- The Station Control Room (SCR), which is the network interface with the Operations Control Centre (OCC) at ESOC in Darmstadt, Germany. The station's general-purpose facilities are monitored and controlled from this room.
- The Main Equipment Room (MER), which houses the telemetry, telecommand and ranging baseband racks, the station computers, timing and communications units, and the other necessary facilities (Fig. 1).
- The ECS Control Room (Fig. 2) and Computer Room (ECC), from which all ECS satellite operations are conducted.
- The Test and Monitoring Room (TMR), from which all the in-orbit testing is carried out (Fig. 3).

In addition, the main building houses the maintenance laboratory and staff offices.

The store of spare parts, consumables and other items is kept in the auxiliary building, which is situated opposite the main building and is currently being extended to house a larger canteen and

Figure 4 — Overall view of the Redu Station

a conference room. The power generation and distribution building is also located close to the main building. Electricity is supplied to the site by two 15 kV lines, configured such that if one should fail the other is immediately switched on-line. Further security is provided by two 400 kVA diesel generators, which start automatically should there be a power loss. A 300 kVA no-break generator is used to supply all computers, electronic equipment, receivers and transmitters. A second no-break generator will be installed during 1988.

The VHF facilities consist of two telecommand terminals (TC1, TC2), two telemetry terminals (TM4, TM5) and a VHF calibration tower.

The SHF facilities include:
- four fixed in-orbit-test terminals (TMS1, TMS4, TMS5, TMS6)
- four transportable in-orbit-test terminals (TMS3A, TMS3B, TMS3C and TMS7)
- four fixed telemetry terminals (TM1, TM2, TM3, TM6)
- one ranging terminal (RG1)
- one satellite multi-services terminal
- one radiometer.

An overall view of the station is shown in Figure 4.

Tracking-station support

LEOP

Redu has played a major role in the launch and early-orbit phases of all ESA geostationary satellites, primarily during the phase when the satellite is drifting towards its final orbital location. Thereafter, control usually passes to a station dedicated specifically to the mission in question. For example, during Meteosat-P2's drift-orbit phase, the satellite will be controlled from the OCC in ESOC via Redu; when it is on-station and working at S-band frequencies, operations will be performed via the Odenwald station in Germany, which has been allocated to Meteosat-P2 for routine-phase support. In the case of ECS-5, operations will be handed over from the OCC at ESOC to the dedicated ECS Control Centre (ECC) at Redu, from where the satellite will be controlled along with the three other ECS satellites already in orbit.

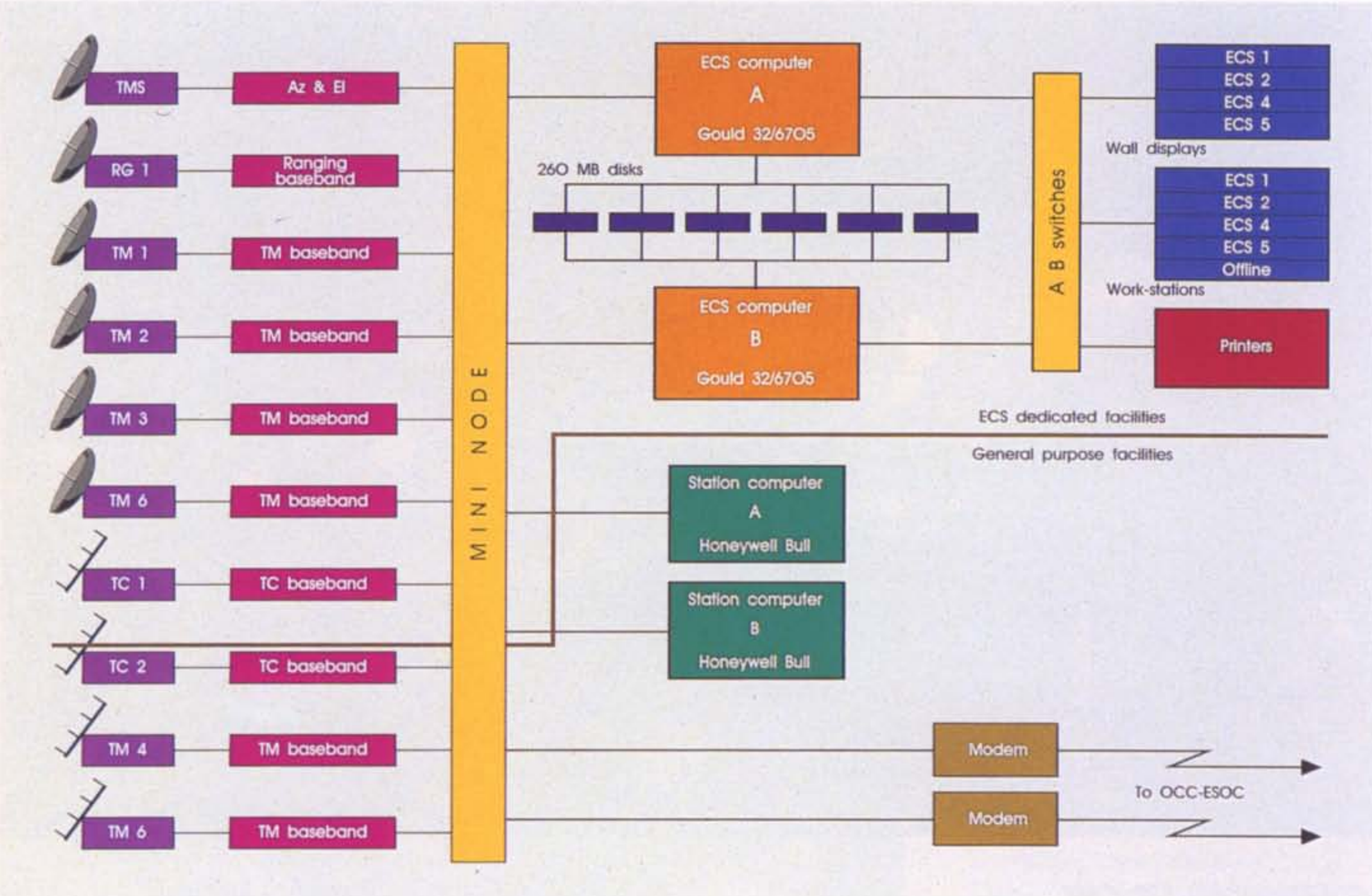
Back-up functions

Redu also provides a VHF back-up service should there be a satellite or station problem. If, for example, Marecs-B2 were to lose 'Earth-lock', leading to loss of the routine-phase narrow-beamwidth telemetry signal by the Villafranca station in Spain, the operations to restore Earth-pointing would be carried out from the OCC at ESOC via Redu, using the latter's broadbeam VHF facilities. Such support can also be provided to the ECS Control Centre should the need ever arise.

Routine support

OTS-2, which celebrates its tenth

Figure 5 — Block diagram of the general-purpose and ECS-dedicated facilities at Redu



anniversary in May 1988, is controlled from the OCC at ESOC via the Redu station. The satellite is regularly used with the Redu in-orbit-test facilities to verify new communications tests and for calibration purposes. Neither of these tasks can be carried out on a satellite carrying operational traffic.

Telemetry data is received on a regular basis from NASA's IMP-8 scientific satellite, recorded on magnetic tape, and forwarded to Goddard Space Flight Center in the USA for analysis.

Control-station support for the ECS mission

Background

The Agency's ECS-1, ECS-2 and ECS-4 satellites already controlled from the dedicated ECS Control Centre at Redu, will be joined by ECS-5 during the second half of 1988. The initial mission baseline was to have two ECS satellites in orbit; one to carry TDMA telephony and telex traffic plus Eurovision television distribution, and the other to act as an in-orbit spare. However, the upsurge in the distribution of television programmes throughout Europe subsequently resulted in ECS-1 being fully utilised for this type of service. Consequently, EUTELSAT requested ESA to operate three satellites in orbit, and shortly thereafter asked for a fourth satellite. The need to control three satellites led to an extension of the Redu ground facilities and the computer system. To cope with the subsequent increase to four satellites, the ECS computer system has been replaced by a more powerful system of the same type as that installed in the OCC at ESOC.

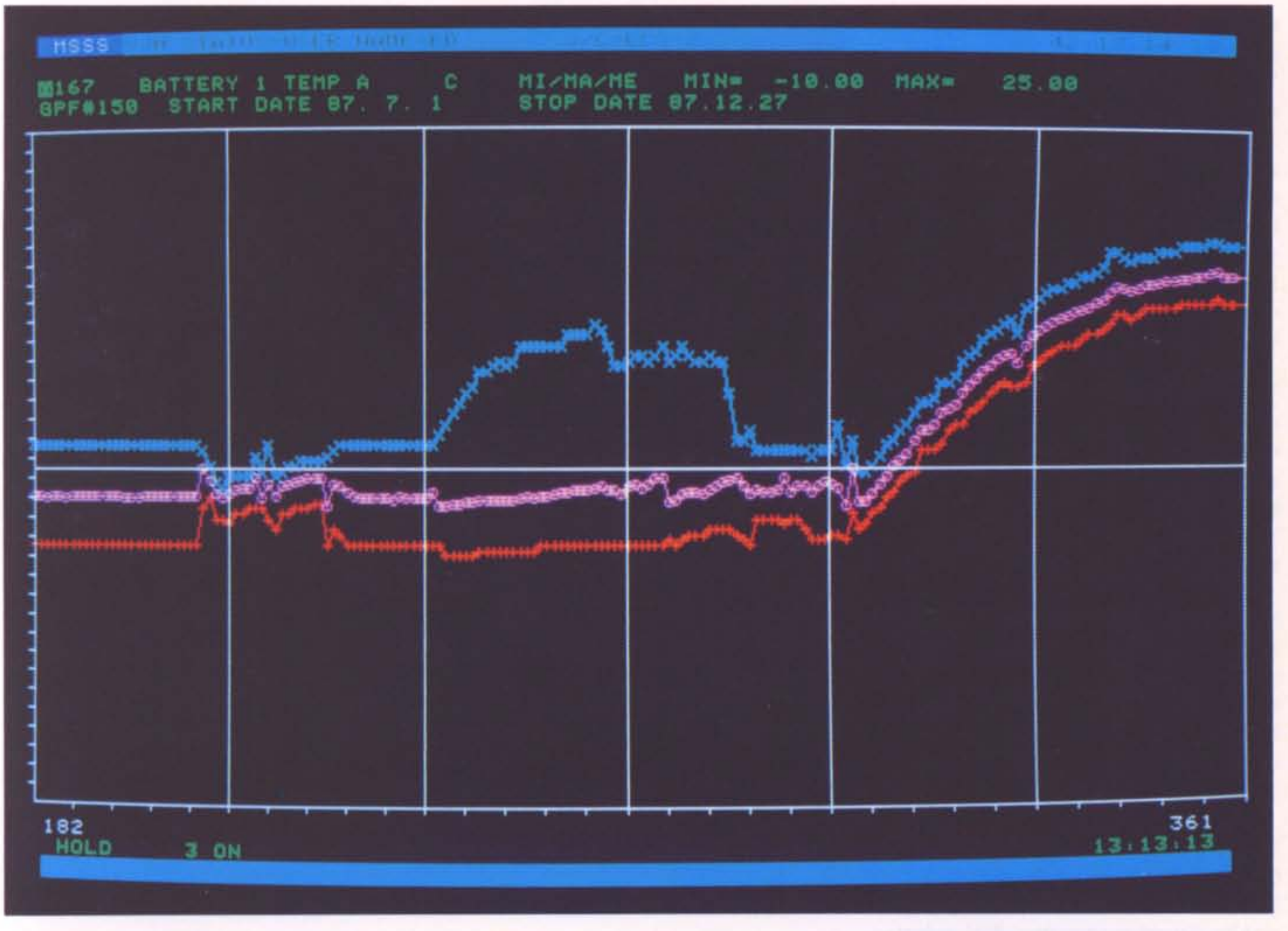
Facilities

The facilities dedicated to the ECS mission are illustrated in Figure 5. Telemetry data is received at SHF frequencies by the four terminals TM1, TM2, TM3 and TM6, which are allocated to ECS- 1, ECS-2, ECS-4 and ECS-5, respectively.

The signals are downconverted and passed via the telemetry pre-processors to the Redu X-25 mini-node, and thence to the ECS computer system. The computer system itself is fully redundant and uses two Gould 32/67 processors with 6 Mbyte memories and six Winchester disks each of 260 Mbyte capacity. It is also possible to route the telemetry data direct from the mini-node to the OCC at ESOC.

Unlike telemetry reception, where each satellite has an individual antenna, only one antenna is used for the tele-commanding of all satellites. This is possible because the frequency used for telecommanding is in the VHF band and the TC1 antenna has a field of view that encompasses the on-station positions of

Figure 6 — Example of an ECS Control-Room graphical display



all four satellites. The command message generated by the computer system contains all the information needed to set up the polarisation, uplink frequency, address and synchronisation word, and the on-board routing automatically. Commands can thus be uplinked to any ECS satellite without the need to reconfigure from one satellite to the next.

Orbit determination is based on ranging and angular tracking data. The RG1 ranging terminal is pointed at each satellite in turn on a routine basis, and a series of ranging measurements are taken automatically. Similarly, the TMS1 in-orbit test terminal, which has a 13.5 m dish, is locked onto the telemetry beacon and an azimuth and elevation reading is recorded. This information is sufficient to allow the orbit of each satellite to be calculated. To ensure that there is no long-term drift in TMS1 pointing, a ranging campaign is conducted from Villafranca approximately once every six months.

Operations

During the drift-orbit phase after launch, when the satellite is drifting slowly to its final in-orbit position, and which usually lasts about three weeks, platform commissioning tests are conducted. The prime objectives are to check the performance of the satellite, perform certain calibrations and measurements, and ensure that all redundant units are functioning correctly. When the ECS satellite is on-station, its communications payload is switched on and, after a short functional commissioning test on the payload, formal acceptance testing begins.

Once the satellites have been accepted and ownership formally transferred to EUTELSAT, they enter 'operational service' and all the operations necessary to keep them functioning correctly are conducted from the ECS Control Centre at Redu.

The ECS Control Room contains both alphanumeric and graphical displays, which enable the controllers to monitor the onboard performances of all of the satellites. Figure 6 shows a typical graphical display.

Figure 7 — A TMS1 in-orbit-test terminal (three TMS3 transportable stations and the radiometer can also be seen)

In-orbit testing of communication satellites

The design specifications for the ECS satellites are based primarily on the communications-payload performance levels that must be achieved once the satellites are in orbit. Demonstration that these levels are indeed within the pre-specified limits enables ESA to accept the satellites from the manufacturer, and in turn to demonstrate to EUTELSAT that they are ready for operational use.

Test and monitoring facilities are therefore required to carry out this in-orbit testing, and this is why the TMS1 terminal (Fig. 7) was constructed at Redu, together with the other test equipment necessary. Three transportable TMS3 stations were also built for use within Europe.

Further in-orbit test facilities — TMS4, TMS5 and TMS6 — have since been installed for Olympus, which also uses the test equipment provided for TMS1. An additional transportable station, TMS7, will be maintained at Redu when it is not needed elsewhere.

Together, these facilities cover all of the frequency bands currently used in Europe for fixed communications services and for direct broadcasting. It is, in fact, possible for other organisations that wish to conduct communications tests to make arrangements with ESA for full or partial use of these facilities. EUTELSAT and the Swedish Space Corporation are two such customers.

Figure 8 is a block diagram of the Redu in-orbit-test facilities. From this it can be seen that the system has been designed such that any of the TMS1, TMS4, TMS5 or TMS6 terminals may be connected to the comprehensive test equipment installed in the Test and Monitoring Room. The principal functions of each terminal are shown in Table 1.

Table 1 — Principal functions of the in-orbit-test terminals

Identifier	Frequency	Principal functions
Fixed Stations		
TMS1	14—11 GHz	Central measurement earth station with fully integrated instrumentation-control and data-handling facilities working in the fixed-services frequency band used for the ECS baseline payload and applicable to other similar satellites.
TMS4	14—12 GHz	Antenna and associated equipment designed to extend the payload test capabilities into the specialised-services frequency band.
TMS5	18—12 GHz	Antenna and associated equipment designed to test satellite performance in the direct-broadcast frequency band.
TMS6	30—20 GHz	Antenna and associated equipment designed to test the higher frequencies of new-generation satellites.
Transportable Stations		
TMS3	14/12—11 GHz	Air-transportable station which can be located anywhere within the satellite coverage and linked to the central measurement facilities at Redu.
TMS7	30—20 GHz	A transportable station similar to TMS3, designed to provide measurements at remote locations in the 30—20 GHz band.

Operations

The in-orbit performance testing of the payload must be carried out accurately and quickly to allow the satellite to be

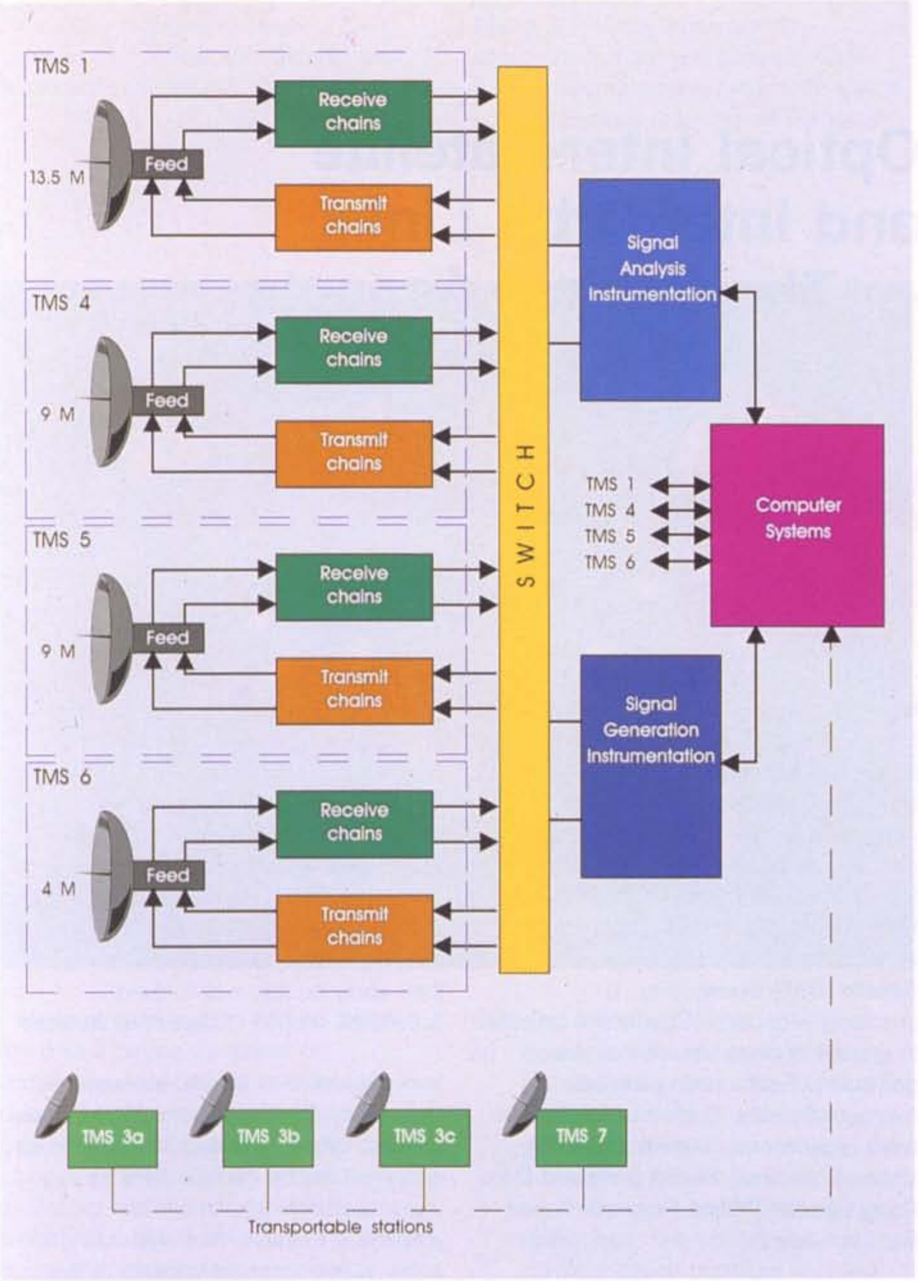


Figure 8 — Block diagram of the in-orbit-test facilities at Redu

put into commercial service at the earliest possible moment. The commissioning and acceptance testing of ECS-4, for example, lasted just over three weeks and involved ESA, EUTELSAT and the ECS Prime Contractor, British Aerospace. During this period, the transportable stations were shipped to numerous sites, chosen because they were on the edges of the satellite antenna contours, to measure coverage-dependent parameters. The measured data were then passed over normal dial-up telephone lines to Redu for analysis.

The in-orbit-test facilities are also used during the satellite's operational lifetime to measure key parameters on a routine basis, to recheck performance from time to time, to monitor the status of redundant units, and in the analysis of anomalous behaviour should such an event occur.

The Redu in-orbit-test facilities are also used occasionally for EUTELSAT Earth Station Verification Activities (ESVA), to confirm that new stations entering the EUTELSAT system are up to specification.

All payload-measurement operations are conducted from the Redu Test and Monitoring Room (TMR), with test initialisation, execution, data collection and display being performed by a computer system. Test results are also processed in the TMR and presented to the test engineer in a clear and concise manner by the in-orbit-test computer. The outputs are all in engineering units, which helps the engineer to interpret the data quickly and efficiently.

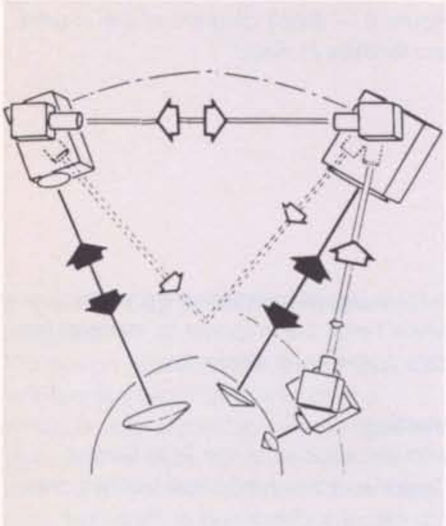
Staffing

With the addition of the ECS Control Centre and the in-orbit-test facilities, the number of staff working at Redu has risen from approximately 20 in 1980 to its current level of over 50. The majority are employed by CISET, an Italian company, which has been entrusted by ESA with the maintenance and operations tasks at the station. These tasks are carried out in accordance with network maintenance and operations procedures specified by ESOC's Network Operations Division.

However, operations specific to the ECS satellites and in-orbit testing are performed under the technical direction of the four ESA engineers at Redu. Software development and maintenance for the ECS computer system is the responsibility of two SESA software engineers, working under the technical direction of the ESA Computer Department.

Conclusion

Over the last ten years, Redu has developed comprehensive facilities and considerable experience in the disciplines of control and in-orbit testing of communications satellites. This experience will be consolidated in the next few years with the continuation of the ECS missions and the start of the Olympus mission. Redu also expects to be involved in the Agency's future PSDE, DRS and AOTS telecommunications programmes which, with their advanced technology, promise to offer new and demanding challenges.



Optical Inter-Satellite and Inter-Orbit Links — The Critical Aspects

O.B. Milliès-Lacroix & G. Berretta,
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In the 1990s, the Agency's telecommunications programmes will demonstrate experimentally new satellite communications missions involving Inter-Satellite Links (ISLs) between satellites in geostationary orbit, and Inter-Orbit Links (IOLs) between satellites in geostationary and low Earth orbits. These space-to-space links, which represent the latest developments in satellite communications technology, will play a key role in the further exploration and exploitation of space.

High-capacity orbital communications networks will be a prerequisite for the operation of future low-Earth-orbiting Space Stations, and to support future manned or automatic deep-space missions. The various low-Earth-orbiting elements of the In-Orbit Infrastructure (IOI) foreseen in the ESA Long-Term Plan (see pages 14—29 of this issue) also call for an operational Data-Relay Satellite (DRS) System (Fig. 1) providing wideband IOLs for the transfer to ground of large volumes of data, particularly Earth-observation and microgravity data. Such a capability has been regarded as a 'must' by NASA since 1972, when the Tracking and Data-Relay Satellite (TDRS) Programme was first formulated.

When implemented between two satellites in an international communications network, an ISL constitutes a basic tool for enhancing connectivity, coverage, flexibility and hence economic return (Fig. 2). That cost factor is particularly evident when the network configuration is such that implementation of an ISL allows a major reduction in the number of Earth stations needed. Its benefits are therefore not specific to any particular satellite service; they apply equally well to fixed-broadcast, mobile or data-relay services.

Implementation of an ISL between two Data-Relay Satellites, for example, allows different system architectures from those baselined for the TDRSS, DRS or Japanese DRTS systems to be employed. In these three systems, the active space segment consists of two satellites in widely separated orbital positions. The areas in which the ground

Figure 1 — Conceptual drawing of a Data-Relay Satellite (DRS)

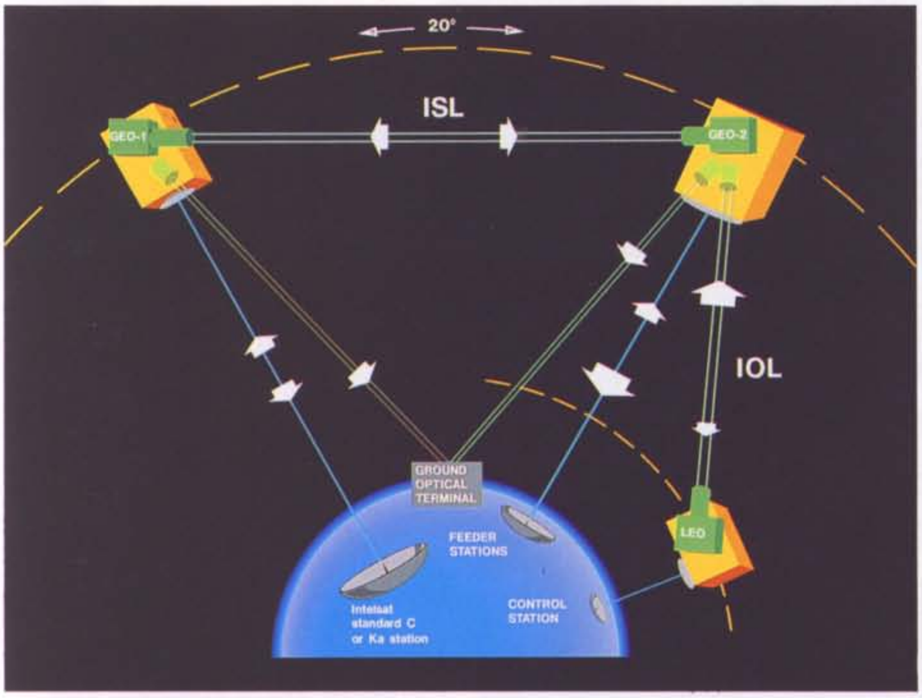

Figure 2 — Schematic of an experimental optical Inter-Satellite and Inter-Orbit Link (ISL/IOL) system

stations of each system can be installed are limited by the constraint of simultaneous visibility of both orbital positions from every station in the ground segment (elevation angle compatible with required system availability and the local statistical propagation characteristics at the chosen feeder-link frequencies).

In Europe's case, use of an ISL allows one of the two DRS satellites to be located over European territory (e.g. around 10°E) and the other spaced to the east or west by 145°. The latter would not be visible from any European station and its full capacity would therefore need to be channeled via the ISL and the satellite located over Europe. This solution not only completely eliminates the existing exclusion zone for spacecraft above 700 km, it also allows signal dissemination to ground stations throughout Europe from a much higher elevation angle than with the present DRS baseline system.

Why optical technologies for IOL and ISL?

The rationale for the implementation of Inter-Orbit Links at optical frequencies is based on three arguments:

(a) Because the wavelength of the optical laser radiation is very short (about 1 micron), it is possible to generate extremely narrow transmitting beams (typically 5 microradians) with small-aperture telescopes. The optical communication package onboard the satellite can therefore be made very small and compact.

(b) The information-carrying capacity of optical signals is inherently much greater than that of radio-frequency signals.

(c) The optical frequencies employed fall outside the crowded radio-frequency bands used for most other purposes, making system coordination easier.

For the specific case of ISL, the same rationale is valid, but point (a) becomes particularly important. Indeed while the IOL is the core element of any DRS mission, any additional watt of power consumption or kilogram of additional payload weight involved in the installation of an ISL package onboard a geostationary satellite is a penalty to be traded-off against its benefits for the communication system in terms of connectivity, coverage, flexibility and cost. The linking of two geostationary satellites has never been, and will never be, an end in itself!

The ESA development and experiment programme

The Agency actually began development work on optical communication systems in 1977. For some years, it concentrated mainly on systems using gas lasers (CO_2). Since the early eighties, with fibre-optics technology reaching maturity,

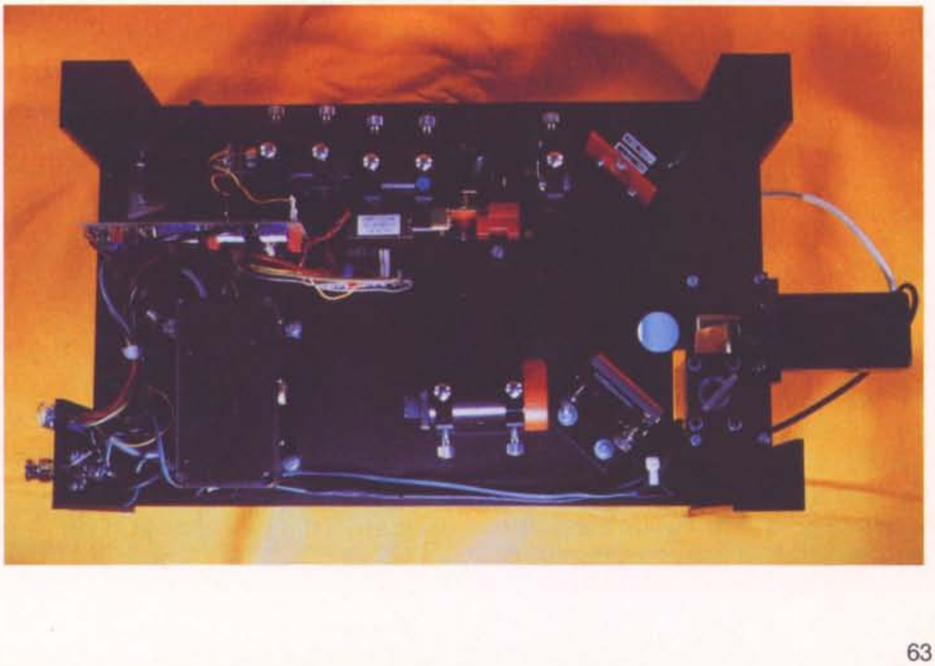

Figure 3 — Complete laboratory breadboard of an optical, laser-diode-based transmit/receive system for space communications (courtesy of Technical University of Vienna)

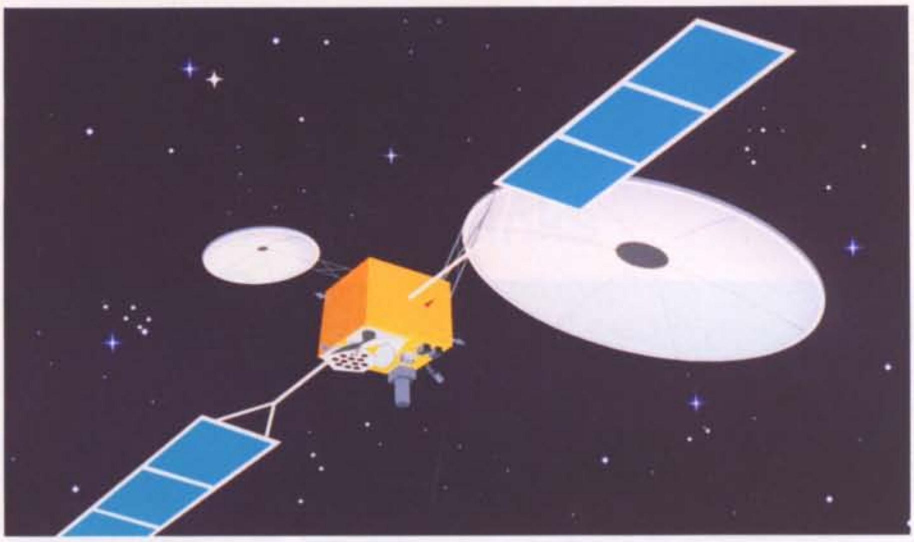

Figure 4 — Concept for an advanced communications spacecraft (PSDE Sat-2) forming part of ESA's Payload and Spacecraft Development and Experimentation Programme

semiconductor laser diodes have gradually become a stronger alternative to CO_2 lasers for telecommunications satellite applications. Nowadays, most of ESA development activities in this field rely on system concepts based on the use of GaAlAs or InGaAsP semiconductor laser diodes, with emitting wavelengths in the order of 0.8 and 1.3 microns, respectively. Increasing attention is also being given to the use of diode-laser-pumped Nd-Yag lasers (wavelength 1.06 microns) for future applications.

The basic R&D activities, essentially at component or equipment level, are funded via the Agency's Advanced Systems Technology Programme (ASTP) and Basic Technology Research Programme (Basic TRP). These activities relate to critical components like high-radiance single-mode laser diodes, wavelength division multiplexers, spectral transmit/receive isolators and pointing and tracking devices. Future activities will deal with breadboard development of the critical technology involved in optimised system design for high-rate optical inter-satellite links, using advanced technologies such as optical heterodyning (Fig. 3).

Experiments are proposed within the ESA Payload and Spacecraft Development and Experimentation (PSDE) Programme, in the 1990—1992 time frame, for the test demonstration of optical links on the ground or using stratospheric balloons. The main core of the optical activities, however, is provided by the Semiconductor Laser Intersatellite Link Experiment (Silex) aimed at developing optical terminals that will be flown from 1993 onwards on two geostationary satellites and on one low-Earth-orbiting spacecraft. Two of the three satellites to be involved in the in-orbit demonstration of both optical IOL and ISL have been identified. A terminal with IOL and ISL pointing capability will be flown on the Agency's PSDE Sat-2 satellite (Fig. 4), while the low-Earth-orbit terminal will be embarked on the French Spot-4 satellite. The spacecraft to carry the other geostationary-Earth-orbit terminal has still to be identified.

Cooperation with operating agencies
Although the Silex mission has essentially a technological purpose, close cooperation has been established in its definition with the satellite operators interested in the commercial exploitation of optical intersatellite missions.

The IOL mission, which is of a data-relay nature, has been devised taking into account the operational requirements of the Spot Image company, which is responsible for the commercial exploitation of the Earth-observation products generated by the Spot remote-sensing satellite.

ESA and CNES, which is responsible for the Spot satellite programme, have negotiated an agreement covering the preparation of that mission. The mission requirements deal essentially with link capacity, transmission quality, system availability, and link setup times. These parameters have been identified in the definition of the IOL experimental link between Spot-4 and PSDE Sat-2.

The experiment will consist of an asymmetric duplex link of 1 Mbit/s capacity in the forward (ground-to-Spot) direction, and 2×30 Mbit/s in the return (Spot-to-ground) direction, with bit error rates of 10^{-6}. Link acquisition time is specified as 50 s, and the telescope diameters are 20 to 25 cm on both the Spot and Sat-2 terminals.

The ISL mission for telecommunications applications has been defined in the framework of tripartite cooperation between ESA, Eutelsat and Intelsat. The purpose of the ISL mission is to be as representative as possible, from a system point of view, for an optimised operational ISL. System criticalities relate not only to the problem of optical transmission, but also to the interface between the two ends of the ISL and the transmit and receive sections of the payloads hosting the ISL.

Other critical aspects are those related to the need for satellite systems to follow the recommendations of the international bodies that regulate and standardise the characteristics of the World's telecommunications networks. For instance, regulations on the maximum transfer delay for a telephone link (400 ms) limit the orbital spacing of the two satellites to about 60°. Another example of particular mission requirements is the need for organisations like Eutelsat and Intelsat to be able to provide satellite communications services compatible with the quality objectives of the developing Integrated Services Digital Networks (ISDN).

It has been decided that, as a first step, the most attractive operational application for an ISL is the connection of two satellites located over the rims of the American and European continents, in order to establish a very wide coverage, single-hop system for business communications (satellite multi-services/ international business services).

Critical aspects of optical ISL/IOL
In the design of systems involving high-capacity duplex links for the transmission of either high-data-rate digital or wideband analogue signals, one has to

Figure 5 — Breadboard of tracking actuator subsystem for optical communications (courtesy of ONERA, France)

cope with many technological constraints. These include:

(a) Limited optical transmitter power
Laser diodes with the requisite optical beam quality and lifetime are currently limited in output power to typically 50 mW. Higher transmitted laser powers are needed to achieve the required link capacities (in the order of several hundred Mbit/s) with reasonably sized telescopes. Two possible means of increasing the transmitted laser power are to use power-combining or wavelength-division multiplexing techniques. Wavelength-division multiplexing is the scheme retained for the Silex IOL demonstration, where wavelength-division multiplexing of four channels is the baseline. The Silex payloads will use 0.85 micron semiconductor laser diodes with a 30 mW nominal output power, together with direct optical detection using APDs (Avalanche Photo-Diodes).

(b) Receiver sensitivity
The frequency of GaAlAs diode laser transmitters (0.8 micron) corresponds to the high-sensitivity region of silicon. High-performance, space-qualified APDs (Si-APD) are readily available, whereas detectors operating in the 1.3 micron region are less sensitive. Direct-detection optical receivers, although straightforward in their technical realisation, may have serious shortcomings in terms of crosstalk, background rejection and wavelength selectivity.

Improved sensitivity, spectral selectivity and background rejection could be achieved using optical heterodyne techniques, whereby the radiation of a local oscillator laser is added to the received signal such that the sum of these radiation fields falls on the photodetector.

The implementing of optical heterodyne receivers with semiconductor lasers is, however, still hampered by the poor frequency stability and line width of the diode laser. For free-space communication, there is also a need for frequency acquisition and Doppler tracking, calling for wide tunability of the local oscillator laser. The Doppler shift for ISLs is smaller than for IOLs, and this would make heterodyning easier for ISL than for IOL.

(c) Pointing, acquisition and tracking
Due to the extremely narrow transmission beam widths involved, optical systems have to rely on high-performance beam steering and tracking arrangements for link acquisition and continuous tracking. In addition, a variable angular offset (point-ahead) is needed between the transmit and receive optical beams in order to compensate for the line-of-sight offset resulting from the finite velocity of light (Fig. 5). The requirements on this point-ahead function are, however, less severe for ISL than for IOL systems.

For fast acquisition, a strong beacon laser source together with a wide field-of-view optical detector [e.g. using a charge-coupled device (CCD) matrix] is required. The goal is to perform initial link acquisition in approximately 1 minute. To ensure a good-quality communications link with the narrow laser beams, very precise beam-steering actuators and tracking-signal detectors are necessary.

Conclusion

The various development and experimentation programmes that have been outlined should allow the Agency to demonstrate the practicality of optical IOLs and ISLs fully in the next few years. Early identification of the requirements of the commercial satellite operators should facilitate the ultimate provision of optical transmission technologies in space. These technologies will, moreover, profit from the extensive R&D efforts taking place, particularly at component level, in other ground-based industrial sectors.

The Use of Pyrotechnics on Spacecraft

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Because of their extremely high energy-to-volume densities, explosives are an invaluable tool aboard spacecraft for single-operation functions. Highly reliable and safe actuators have been developed to exploit this useful property for a variety of applications, using only standard spacecraft supplies and controls.

Introduction

The mention of explosives usually brings to mind destruction, but their energy can be harnessed and applied for useful purposes. Explosives are the most volume-efficient stores of easily releasable energy, and this is significant where mass and volume are at a premium, which is especially true for spacecraft. Though explosive-based devices are only usable once, there are many applications where this is all that is needed and where their energy-efficiency is a distinct advantage.

As is evident in the evolution of rockets and fireworks, the harnessing of explosive energy has been attempted over many centuries. The particular subject of this article, however, will be pyrotechnic actuators, in which the released energy is converted into motion of mechanical parts, and contained so that there is no unwanted physical movement or damage. For single-function mechanical operations, their capability, reliability and speed are without parallel. We will examine both their nature and their use.

Basic principles

There are three main products of combustion which are usable: gas, hot flame and shock waves, each obtainable from different explosives. The first is used to pressurise mechanical drives, and the others for the ignition of other explosives.

Although the explosives employed can release large quantities of energy, they are chosen to have low sensitivity, so that their ignition can be controlled. Used in a series of stages, each provides the additional energy needed to overcome the threshold of the next. Besides advantages in construction and testing, this provides the possibility for the temporary removal of one stage to prevent operation until needed. It means, also, that different end-functions may be chosen according to the application.

The fundamental requirement of the pyrotechnically energised function is that it must occur reliably when commanded and must not occur under any other circumstances. Whilst this places severe requirements upon the hardware, the products that meet them are highly efficient and reliable. They have great advantages over other means of achieving the same ends, in some cases enabling otherwise impossible functions to be provided.

The initiator, cartridge and detonator

The common method of ignition is by means of an electric current, which is easy to achieve onboard a spacecraft. When this current is passed through a fine wire, the resulting resistance heating is enough to reach the ignition temperature of the first explosive, which then produces hot flame for the ignition of the next stage. Since all pyrotechnic subsystems need this stage, and to ensure consistent properties, it is usual to construct a component called the 'initiator' for this purpose.

A large proportion of the properties of the whole subsystem, related to safety as well as performance, are embodied in this single element, and this explains why it is of such importance. A modular

Figure 1 — The ESA standard initiator (22 mm long, 14 mm diameter, weight 12 g)

Figure 2 — AMD-BA 1EPAW110X cartridge (35 mm long, 14 mm diameter, weight 15 g)

Figure 3 — Aeorspatiale miniature pin-pusher (70 mm long, 15 mm diameter, weight 30 g)

Figure 4 — Aerospatiale miniature pin-puller (105 mm long, 16 mm diameter, weight 45 g)

Figure 5 — Aerospatiale normally closed valve for 6.35 mm diameter pipe (78 mm long, 38 mm diameter, weight 170 g)

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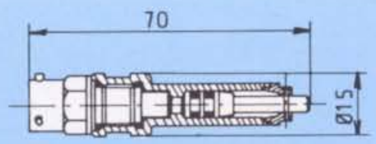

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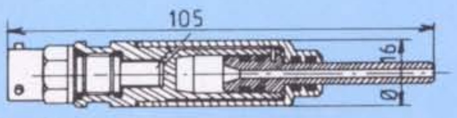

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approach allows the necessary control of its properties, and ensures consistency of the item and hence of the subsystem in which it is used.

The properties of concern relate to its sensitivity, for it must respond only to the desired stimuli, and to no other. Prevention of the desired stimuli being present at any but the desired firing time is a matter of subsystem design, and a reason why pyrotechnics must be treated as a separate subsystem.

For safety reasons, the most significant properties of pyrotechnics are their ability to sustain, without firing or degradation, 1 A or 1 W for 5 min in the firing circuit up to 100 °C, and the discharge from a 500 pF capacitance of 25 000 V DC across the short-circuited pins and body. Others include insulation resistance, and resistance to mechanical disturbances like shocks and vibration, high temperature, and various forms of radiation. The actuator must also survive conditions of high humidity, low- or high temperature and high vacuum, to provide sure firing at the desired current level*.

*For details, see the current ESA Pyrotechnic Initiator Requirement Document (TSM/PYRO/1), and its successor, currently in preparation, the ESA Pyrotechnic Requirement Document (ESA PSS–03–**).

If pressure is required, a charge of the appropriate explosive is joined to the initiator. The resulting item is usually called a 'cartridge'. To produce a shock wave, a different explosive is used and the component is then called a 'detonator'.

To meet the demands of new applications, ESA has carried out assessments of two pyrotechnic substances for use in cartridges. Both are able to survive and operate at temperatures around 125 °C, thus extending the temperature capability of actuators by some 20°. These are 'TRHA', made by NEC in Scotland, and 'HH10' from PRB in Brussels. Further activities will test them up to 150 °C and investigate ageing characteristics to establish their suitability for long-duration missions.

Pyrotechnic actuators

The pyrotechnic actuator is the assembly that converts the pyrotechnic energy into useful mechanical work. Incorporating an initiator-based cartridge or detonator, it contains the moving parts necessary to use the pressure mechanically, in a body robust enough to resist damage and with a sealing system to keep the gases from escaping and causing damage.

Given the minute input-energy needed (only 1.5 J from the supply of a current of only 3.5 A for about 5 ms), and with response times in the order of 5 ms, the capabilities of pyrotechnic actuators are impressive.

Typically, as piston actuators, they can push or pull loads of up to 750 N over distances of say 15 mm; as valves, they can open or close pipes of up to 6.35 mm diameter, such as are used in propulsion subsystems; as hermetic expansion tubes, they can sever structural metal up to 6 mm thick, and as cutters they can cut wires and bolts used as launch restraints, commonly up to 6 mm diameter and supporting a tonne in tension. For this last role, however, there are other actuators which are preferable, such as release nuts: these open the nut to release a standard bolt intact, while containing all their parts, hence giving a much cleaner, debris-free function than the cutters.

Whilst they are not mechanisms, it is worth mentioning that similar chains of components are employed for igniting the onboard solid-propellant motors used for orbit adjustment. Because of the hazard resulting from inadvertent firing, the subsystems for these motors have to include 'safe and arm' actuators, which disconnect the electrical and pyrotechnic

Figure 6 — AMD-BA 7CCD15PWH cutter for steel cable or beryllium-copper rod (49 mm long, 43 mm wide, 15 mm deep, weight 95 g)

Figure 7 — Aerospatiale miniature cutter for 1.6 mm multi-strand stainless-steel wire (65 mm long, 15 mm diameter, weight 35 g)

Figure 8 — AMD-BA 7CC60DPW cutter for 6.0 mm beryllium-copper or steel rod (84 mm long, 39 mm wide, 23 mm deep, weight 180 g)

Figure 9 — Aerospatiale release nut for hold-down and release of M6 bolt (76 mm long, 42 mm diameter, weight 300 g)

Figure 10 — AMD-BA pyrotechnic detonation cord

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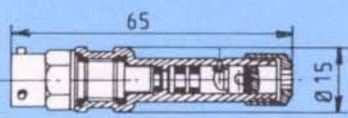

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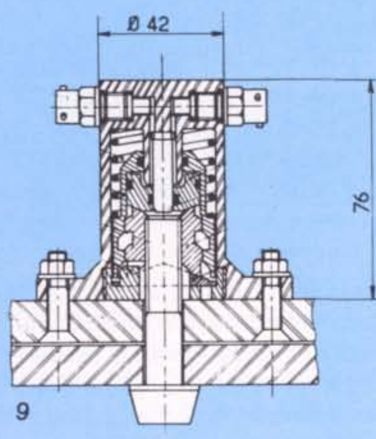

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circuits, and provide visual, mechanical and electrical signals regarding their status. They can be switched remotely by electrical command or locally by manual means.

The confined-detonation-cord principle, used in the expansion-tube systems, was initially developed for transmission of pyrotechnic signals in a system of linked functions, such as that used on launch vehicles for the separation of stages and simultaneous actions. Explosive packed into a tube propagates the detonation wave at 7 km/s, and by branching this can be used to operate several functions, with only one electrical signal to initiate the group. With the growth in satellite size, and the reductions in diameter and weight of the pyro-cord being developed, such systems look attractive for future spacecraft applications also.

There are many pyrotechnic actuators available from manufacturers in Europe which do fulfil, or are capable of fulfilling, the ESA requirements. A compilation of descriptions of these items is published by the Agency under the title 'Catalogue of European Pyrotechnic Devices for Use In Space', with the reference number ESA SP-1021. An updated, third edition is planned for issue in 1989.

The pyrotechnic subsystem

To supply the initial energy step, a chain of items is needed to condition and command the electrical pulse for application to the initiator bridge-wire. Because the current-supply needs are simple, there is a tendency to assign this as part of the electrical supply subsystem of the whole spacecraft; however, the catastrophic train of events that could result from accidental firing of the pyrotechnic means that much more severe safety requirements apply for this than for any other branch of the power-distribution subsystem.

Special precautions are needed to prevent a pulse large enough to trigger the initiator from appearing in the circuit at any but the desired time. Switches are required to isolate the initiator until firing is imminent, and afterwards to prevent a drain on the power-supply system due to a short-circuit to ground potential, which frequently occurs in initiators. Electrical screening of the electronics and of the wiring, which must be in twisted pairs, has to be provided to prevent electromagnetic radiation from generating currents in the circuit.

The chain of items included specifically for the pyrotechnic actuators must be considered as a typical spacecraft subsystem, with its own components and its own internal and external interfaces.

For reasons of safety and reliability, some components must be duplicated in series or in parallel, according to defined requirements of failure tolerance, which are particular to the responsibility vested in the functions. To protect the launcher and its crew, this usually means three inhibiting stages in series, which require three failures before any unsafe condition is produced. The parallel duplication is to ensure that functional capability is retained in the case of a component failure.

Applications

The long booms, large antenna dishes and solar arrays that are essential to the operation of satellites project too far in their in-orbit configurations to allow the launcher fairing to enclose them. In any case, in their deployed state, they could not withstand the dynamic loads encountered during the launch phase,

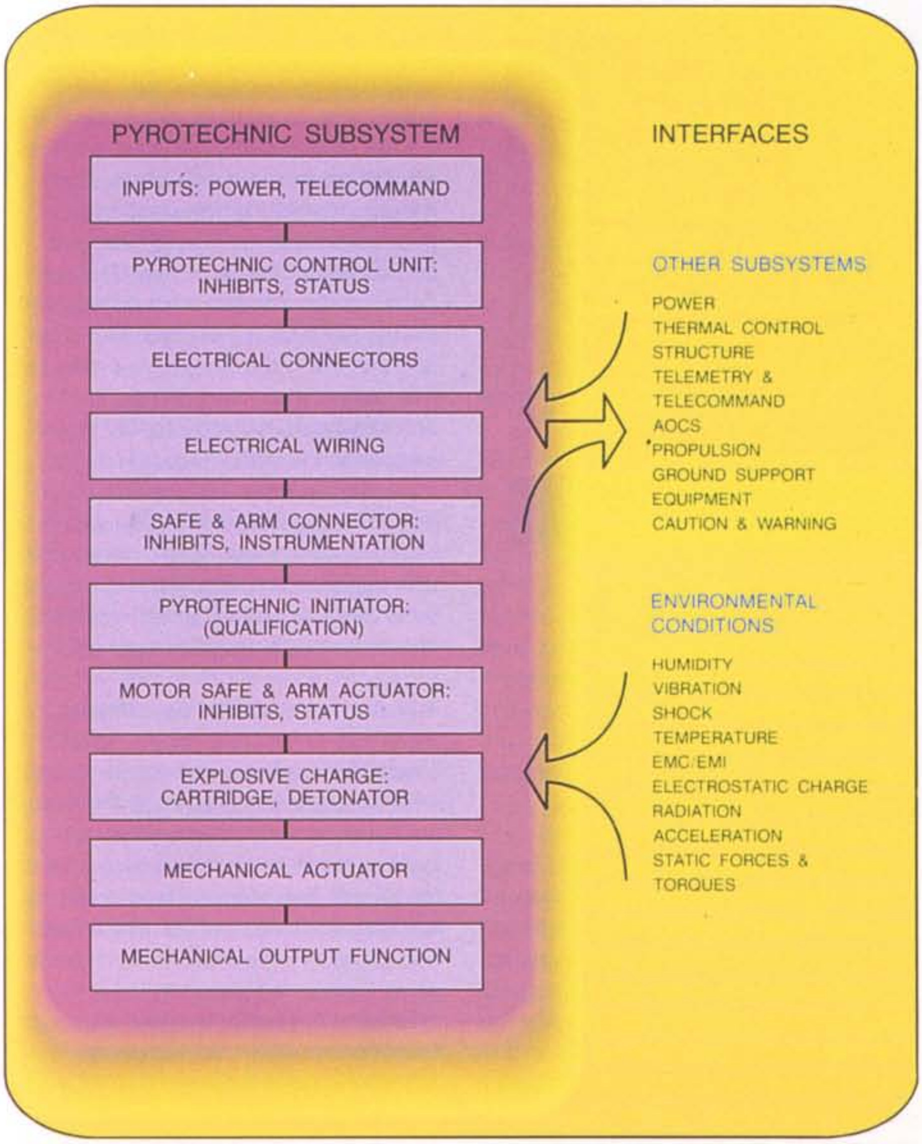


Figure 11 — The pyrotechnic subsystem divided into functional blocks to show the various interrelationships

and so they have to be folded and secured to the spacecraft structure. They must, however, be completely free to move for their subsequent deployment.

Until recently, all ESA's spacecraft were destined to stay in orbit until the ends of their lifetimes, so pyrotechnic actuators were ideal for the hold-down and release mechanisms. In the future, however, when spacecraft will be brought back to Earth for refurbishment/repair, their deployed appendages will have to be retractable and the hold-down mechanisms re-usable. Pyrotechnic actuators will then no longer be suitable. Should the retraction capability be lost, however, emergency separation systems will be needed to remove the appendages in space, and so avoid having to abandon the complete spacecraft. It is here that pyrotechnic subsystems will find a significant new role.

The most complex of such systems is that proposed for the emergency separation of the cabin of the Agency's Hermes space plane. Not only will the structure need to be severed, but also all the control and supply interfaces between the cabin and the plane's body. These functions, and the switch-on of all the rescue facilities, including beacons, parachutes and flotation system, will need to be effected by pyrotechnics, since nothing else will be fast enough.

Requirements

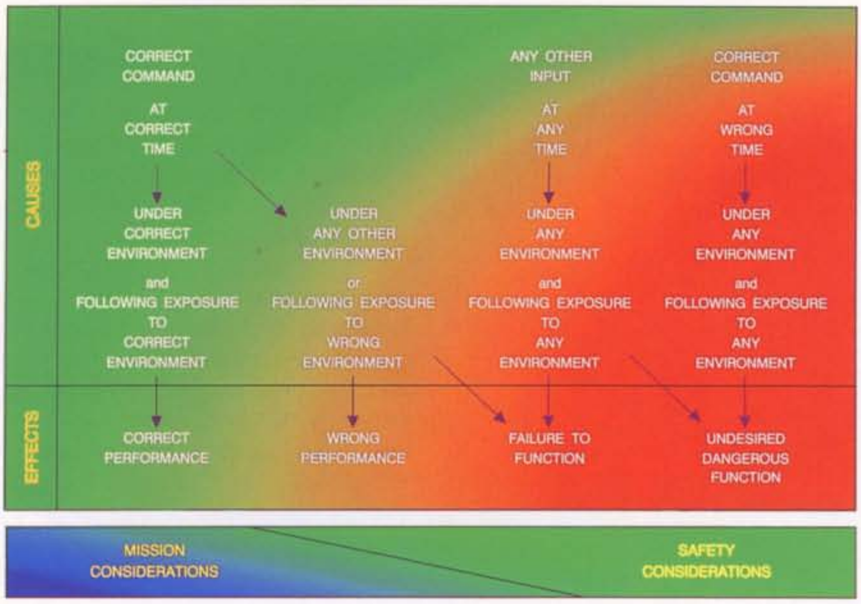
The use of pyrotechnics is governed by Requirement Documents established by the launcher or launch-site authorities, as well as by the user-programme authorities. To assist the spacecraft designers, ESA has had a 'Guide to the Use of Pyrotechnics on Spacecraft' prepared to elucidate the plethora of requirements from the different sources*.

Because of the system-level hazard associated with any pyrotechnic function, spacecraft incorporating them are closely examined in safety reviews and, due to their depth, this is often assumed to be sufficient. This, however, is not so. When payloads are to be launched by the American Space Shuttle, they are scrutinised by the NASA Safety Review Committee to ensure that the payload will not endanger either the crew or the Orbiter. Should the payload not require its pyrotechnic function to guarantee this safety, then failure to operate correctly will be immaterial to the Committee. The mission needs will not come into consideration, so it is not possible to use this exercise as the sole criterion upon which to judge the subsystem. In all cases it rests with the Project Team to satisfy itself of the integrity of the pyrotechnic subsystem.

There is a common belief that use of the NASA Standard Initiator (NSI) is obligatory, or that it is much easier to pass the NASA Safety Reviews if it is used. This is also not true, however, especially for European spacecraft. A European Standard Initiator (ESI), with

* Aerospatiale Report NT-2-01(0), August 1983.

Figure 12 — Safety and mission-design considerations



similar properties to those of the NSI, has been developed and tested by ESA, and NASA has accepted its use on payloads launched by the Shuttle.

However, to avoid possible confusion, they are deliberately neither identical nor interchangeable. Actuator performance is significantly influenced by that of the initiator, so actuator development demands initiator selection from the very start. The actuators developed by ESA and most others designed in Europe thus use the ESA Standard Initiator and not the NSI, since there is no necessity to do so.

For European industry there is a particular disadvantage in the choice of the NSI in that this automatically leads to the choice of an American-made actuator. In the short-term, whilst the NSI may be closely scrutinised by NASA, the actuators are not, and difficulties often follow due to erroneous assumptions about their status.

A large number of properties are involved in the actuator's behaviour, and all must be fully understood and controlled. ESA takes a direct interest in the actuators it uses, laying down requirements and carrying out tests, and direct access to design details and test histories is assured.

Qualification

A fundamental characteristic of the pyrotechnic element is that it can function only once. This may seem to be a statement of the obvious, but it has important implications which govern the manner in which the whole approach to pyrotechnics must be handled. Unlike all other hardware onboard, the pyrotechnic to be used for flight can never be fully tested before it is required to operate in earnest. Confidence can only be generated by the performances of like items fired for that purpose.

The item may have to work anywhere in a wide range of conditions, and as each is able to demonstrate function only under a unique set of these conditions, a large number of samples must be fired in the test programme. For the results to be of value, all of these samples must be identical. The performance of the actuator is affected not only by conditions at the instant of firing, but also by those conditions encountered during its life until then. The permutations and combinations of these must be taken into account in the pre-conditioning of all of the test items.

The test programme must be comprehensive and complete: merely firing a few items under given conditions will not be sufficient. The number of test items must be large enough to allow firings under all the various chosen conditions, all items having been pre-conditioned in the same way. The pre-conditioning and tests must be carefully planned and strictly applied. The order and content of the programme must be followed precisely, and unplanned activities rigorously excluded as they jeopardise the whole programme. To make the best of the use of the resources required, the qualification testing is performed independently under ESA supervision, using test levels at the limits of the actuator's ability in order to encompass all anticipated applications.

The term 'qualification' has different meanings for different people, so it is essential to understand from the outset what it means with respect to the use of pyrotechnics on ESA spacecraft. Many purchasers of American hardware fall into the trap of assuming the term means the same on both sides of the Atlantic and end up with many expensive problems to solve. Despite the common belief that 'off-the-shelf, qualified' pyrotechnics can be obtained in the USA, apart from the NSI, this is not the case.

Frequently, successful operation aboard a particular US spacecraft is cited by the American supplier as qualification of a certain actuator, but this has not proved that the actuator cannot malfunction, and any modification of the actuator needed will nullify its previous status; full qualification of the new configuration will then be necessary.

Qualification status can be conferred upon a pyrotechnic actuator only when it can be shown, for a defined number of items from the same production batch:

(a) by reference to manufacturing documentation and records, that the design and build standard has been defined and adhered to;

(b) by inspection, that the actuators have been correctly made;

(c) by test and measurement, according to the defined test programme, that those properties given in the Pyrotechnics Requirement are all in accordance with the defined values under the conditions stated after exposure to the defined series of environmental and loading conditions.

Qualificaton testing is conducted to establish margins on all the defined properties. The exact size of the margin will be defined by the expected service conditions of the particular application. Though one of the most important activities, it must be appreciated that this is only one part of the overall exercise of qualification, which is as much a test of the production methods as of the product itself.

Because of the applications, the testing of pyrotechnics follows the conventional scheme for spacecraft equipment by combining performance measurements with environmental exposures. But, as the performance can only be measured once, the detailed programme has a specific form, and employs special precautions and techniques to ensure that no single item is damaged, as this will jeopardise the whole programme.

Non-destructive tests have been developed especially for this purpose. They include low-current electrical measurements, thermal-response tests, helium leak measurements, and X-ray and neutron radiography.

It is appropriate here to stress that users must make themselves aware of the behaviour of any actuator before embarking on the design of the mechanism that will incorporate it. The development and qualification of the actuator is for a defined range of materials, conditions and sizes and so changes in its use are not possible.

Procurement and product assurance

As can be appreciated from the foregoing paragraphs, product assurance plays a major role in pyrotechnics. Regardless of where the hardware is to be procured, it is essential that a detailed Requirement Document be prepared by the customer, against which any candidate product may be assessed. Nobody other than the purchaser is to blame if the item, bought on the strength of the supplier's claims alone, is found to be deficient with regard to the user's needs when he finally comes to realise what they are.

No matter how good the item may actually be, nor how many tests it has passed, if it cannot be uniquely identified and its full history traced, then it is not possible to use it for flight or to support qualification. This means that the item must carry indellible marking indicating its identity, and be supported by comprehensive documentation, which is thus an essential part of the pyrotechnic actuator itself.

ESA, through its Pyrotechnics Group in ESTEC, continues to establish detailed documents that ensure adequate coverage of the subject. These documents are not intended to discourage the use of pyrotechnics, but rather to facilitate their informed, correct and safe use with the miniumum of risk, to the benefit of all programmes.

For those requiring support, there is a wealth of experience in the choice and application of pyrotechnics, from the manufacturers of actuators and subsystems to the national and international space agencies, including CNES and ESA.

Conclusion

Pyrotechnic actuators are a highly efficient means of performing mechanical tasks on spacecraft. Used with understanding, they are both safe and reliable. European companies make hardware of the required standard, and moreover NASA has agreed to the use of the European Standard Initiator for Shuttle-launched payloads. Advice and experience is available from many sources to enable both potential and current users to achieve successful subsystems with the minimum of effort and risk.

ESA maintains a specialist activity to provide advice and guidance in the use of pyrotechnics, which is available to anyone wishing to use it. The author can be reached by telephone on (01719) 83829, or by mail at ESTEC/YMM, Postbus 299, 2200 AG Noordwijk, The Netherlands. You are invited and encouraged to make use of this service!

Acknowledgement

I wish to thank the pyrotechnics groups of CNES in Toulouse, of AMD-BA in Velizy-Villacoublay, and of Aerospatiale in Les Mureaux for material used in the preparation of this article.

Les procédures et règles de vote dans la Convention de l'Agence et leur pratique

G. Lafferranderie*, Conseiller juridique, ESA, Paris

Le vote revêt une importance particulière dans un système collégial du point de vue technique et du point de vue politique. En effet, d'une part le vote met un point final à tout un processus; il est l'aboutissement de débats, le point ultime, crucial, qui va affirmer les positions, identifier les camps. Il est d'autre part l'acte qui engage, y compris celui qui n'a pas voté en faveur, le point de départ d'actions. Aussi, la question des règles de vote fait-elle toujours l'objet de longues discussions lorsqu'il faut rédiger un acte constitutif d'une Organisation internationale ou encore d'un texte d'application, comme à l'Agence, une Déclaration de programme ou un règlement d'exécution.

Qui a droit de vote sur telle ou telle question? A quelle règle de majorité adopter telle ou telle décision? Les uns chercheront à éviter un blocage dans le processus, les autres à se protéger.

Deux principes fondamentaux sont contenus dans l'article XI de la Convention (repris et développés dans le règlement intérieur du Conseil):

(a) *L'égalité du poids de vote*

Article XI.6.a. 'Chaque Etat membre dispose d'une voix au Conseil. Toutefois, un Etat membre n'a pas droit de vote sur les questions intéressant exclusivement un programme accepté auquel il ne participe pas', c'est-à-dire 'Un Etat = une voix', ce qui est à l'opposé du vote pondéré — 'le payeur est le décideur'.

(b) *La majorité simple relative* comme principe de base qui, comme tout principe, souffre des dérogations:

Article XI.6.d. 'Sauf dispositions contraires de la présente Convention, les décisions du Conseil sont prises à la majorité simple des Etats membres représentés et votants.' La Convention n'est pas chiche en exemples de décisions qui dérogent à ce principe.

Dans le cas d'un programme facultatif, Etat membre s'entend 'Etat participant'. Un Etat non membre, participant, peut disposer du droit de vote selon les termes de l'Accord de participation. Un observateur dispose d'un droit de parole mais non de vote.

* Les vues exprimées sont personnelles à l'auteur et n'engagent pas l'Organisation à laquelle il appartient.

L'égalite des Etats membres dans la procédure de vote : une égalité juridique, tempérée par la reconnaissance de facto de responsabilités inégales.

L'égalité juridique

Le droit de vote est un attribut de la qualité d'Etat membre. Toutefois, dans certains cas, l'Etat membre peut perdre ce droit, et dans d'autres cas, ce droit va appartenir à une autre catégorie, celle d'Etat participant. Avant de passer au vote, le Président de l'organe délibérant, assisté de l'Exécutif, devra donc s'assurer de qui peut prendre part au vote, afin d'éviter que les résultats en soient ultérieurement contestés ou invalidés (on fait l'hypothèse que le quorum requis pour la tenue de la réunion est bien sûr atteint) (1).

Premier cas : un Etat membre n'a pas droit de vote si l'arriéré de ses contributions à l'Agence au titre de l'ensemble des activités et programmes auxquels il participe dépasse le montant de ses contributions fixé pour l'exercice financier courant. Le même principe s'applique programme par programme. Toutefois, les Etats membres (participants) peuvent autoriser l'Etat membre (participant) en question à prendre part au vote s'ils estiment 'que le défaut de

(1) 'La présence des délégués d'une majorité des Etats membres est nécessaire pour constituer le quorum à toute session du Conseil' (art. 18.1 du règlement intérieur). Dans le cas de programme facultatif, le quorum est constitué par la présence d'une majorité des Etats participants.

paiement est dû des circonstances indépendantes de sa volonté.'

Une telle situation ne s'est jamais concrètement réalisée (bien qu'une fois les conditions aient été très proches d'être remplies); on peut penser que les Etats membres feraient usage de la porte de sortie que leur offre la Convention.

Deuxième cas : un Etat membre n'a pas droit de vote si la question mise aux voix intéresse exclusivement un programme auquel il ne participe pas. A titre d'exemple, lorsque le Conseil adopte le budget d'un programme facultatif, seuls les Etats participants ont droit de vote.

Lorsqu'un Conseil directeur de programme, comme celui des satellites de télécommunications au celui du lanceur Ariane, suit plusieurs programmes facultatifs à la fois, et que la participation peut différer d'un programme à un autre, le Président veillera à faire procéder au vote programme après programme en s'assurant chaque fois qui a la qualité d'Etat participant (le recueil des Fiches juridiques sur les programmes facultatifs tenu par le Service juridique l'y aidera). Par contre, lorsque le Comité administratif et financier est amené à émettre un avis, par exemple sur un budget de programme facultatif, l'ensemble des délégations a droit de vote.

On rappellera, pour mémoire, une disposition de circonstance qui n'a existé qu'au cours de la période d'application de facto de la Convention de l'ESA, c'est-à-dire entre la période d'ouverture à signature, le 31 mai 1975 et la date d'entrée en vigueur, le 30 octobre 1980, période au cours de laquelle les Conventions du CERS/ESRO et du CECLES/ELDO servaient de base juridique aux décisions prises par l'ESRO conduisant ses activités sous le nom d'Agence spatiale européenne. Pour les décisions qui étaient à prendre sur la base de la Convention de l'ELDO (comme par exemple la disposition des biens réalisés au titre de programmes ELDO), seuls les Etats membres de l'ELDO avaient l'exercice du droit de vote.

La pondération

Si la Convention consacre l'égalité juridique des Etats membres, reprenant un principe reconnu dans la Charte des Nations Unies (article 2, §1), elle ne méconnaît pas totalement le vote pondéré et laisse une certaine marge de manoeuvre aux Etats participants à l'occasion de l'adoption de règlements d'exécution. Lors des débats du Groupe de travail créé par le Conseil sur l'élargissement de l'Agence, à la suite de la demande de la Finlande d'obtenir le statut de membre associé, un échange de vues a eu lieu sur cette question.

La pondération est un ensemble de techniques selon lesquelles la compétence juridique des Etats membres est proportionnée à leurs responsabilités et au rôle que chacun d'eux entend jouer dans la vie de l'Organisation internationale, visant à accorder à chaque Etat membre la place et les pouvoirs correspondant à ses responsabilités. Plusieurs techniques et critères, sont utilisés dans le droit des Organisations internationales : la population (Conseil de l'Europe, UIT), le revenu national et la participation aux dépenses (BIRD, FMI), etc. La règle la plus habituellement suivie consiste dans la proportionalité du nombre de voix à la contribution financière de chaque Etat membre, ce qui favorise les pays les plus riches qui auront intérêt à verser une contribution plus grande pour acquérir un poids plus fort dans la prise de décisions.

L'Annexe III de la Convention sur les programmes facultatifs prévoit deux cas de vote pondéré, dans lesquels le nombre de voix d'Etats membres est associé au montant des contributions atteint:

— pour le passage d'une phase à une autre (article II §2). Cette disposition est appliquée pour la première fois dans le cas des programmes de développement Hermès et Columbus. Un premier exemple avait été donné dans l'Arrangement de 1973 sur le programme de satellites de télécommunications;
— pour l'arrêt d'un programme facultatif (article VI.1).

Dans ces deux cas la Convention prévoit la double majorité des deux tiers, deux tiers des voix représentant au moins deux tiers des contributions au programme. On trouvera quelques autres exemples de cette majorité double des deux tiers dans certains règlements d'exécution (par exemple, dans celui du programme Ariane-4 pour la sélection des passagers à emporter).

Notons que l'absence de vote pondéré n'a pas été à ce jour une gêne, que dans la plupart des cas, les responsabilités des 'grands' pays contributeurs sont de facto reconnues et que le plus souvent, sinon dans tous les cas, les décisions ne sont mises aux voix qu'après assurance constatée que les 'grands' contributeurs voteront pour (on est alors très proche de la pratique du consensus).

En tout état de cause, ce système ne joue, ne peut jouer que pour les programmes facultatifs dans lesquels les pays membres peuvent, s'ils en sont d'accord, adopter un barème de contributions fondé sur une autre approche que celle retenue pour le programme obligatoire (PNB), c'est-à-dire un barème reflétant l'intérêt dans le programme et la répartition géographique des travaux.

Les modes d'expression

Les délégations ont à leur disposition trois attitudes formelles face à une proposition mise aux voix: le vote pour; le vote contre; l'abstention. En fait il y a aussi d'autres modes d'expression pour signifier son attitude : l'absence, la non-participation au vote ou encore le vote ad referendum, le vote avec réserves ou conditions. L'Agence connaît d'autres pratiques, comme le vote ouvert ou différé; à côté du vote exprimé en séance, existe enfin la procédure écrite.

Dans certains cas, on s'efforcera de ne pas passer à un vote formel, et de conduire le débat aussi loin que possible, réduisant les divergences une par une jusqu'à ce que les termes d'une décision proposée ne soulèvent plus d'objection d'aucune délégation. C'est alors le *'consensus'*, le mode ultime de l'accord parfait qui évite de cristalliser des attitudes.

Dans la pratique des Organisations internationales, on note une évolution vers la pratique du consensus, vers un certain abandon de ce fait de la pratique du vote formel. Si le consensus est également recherché à l'Agence, il n'en reste pas moins que la pratique du vote reste très vivace. Le consensus n'est pas un concept juridique mais politique et il est alors mieux adapté à une Organisation à compétence principalement politique ou pour des questions 'politiques'. A un moment ou à un autre, il conviendra de trancher et donc de voter. Proche de cette pratique est celle, suivie par le Conseil, qui consiste à passer au vote formel sans débat préalable (dans le cas où la proposition mise aux voix a fait l'objet de recommandation unanime de la part de l'organe délibérant consultatif).

L'absence peut, dans certains cas, être l'expression d'un mécontentement, d'une opposition (lorsque l'organe est considéré incompétent, etc.). Une délégation présente, peut au moment de la prise de décision, demander à être considérée comme absente ou quitter la salle. L'absence a alors l'effet de l'abstention (effet examiné ci-après).

L'abstention: la délégation a une attitude partagée. Elle accepte de prendre part au vote mais elle ne veut, ne sait, s'exprimer ni en faveur ni contre la proposition mise aux voix. Si elle ne veut pas, dans la plupart des cas, bloquer la décision, si elle est indifférente et ne peut accepter l'un ou l'autre résultat du vote, il n'empêche qu'elle affaiblit le soutien requis pour l'adoption de la proposition considérée.

L'effet de l'abstention est finalement fonction de la majorité requise. Si la décision requiert la majorité simple ou celle des deux tiers, elle est sans effet pratique juridique (mais non politique), notamment dans le cas de majorité relative, c'est-à-dire lorsque seuls sont pris en compte les votes exprimés (membres présents et votants). Par contre, si la décision requiert l'unanimité, et l'unanimité de tous les Etats membres, ou la majorité absolue (c'est-à-dire lorsque le décompte s'opère à partir de tous les Etats membres), l'abstention (comme l'absence) équivaut à un vote négatif, et donc à un veto. Ainsi, un Etat membre s'abstenant, étant absent, ou ne prenant pas part au vote, lors de l'adoption soit du niveau de ressources, soit d'un Accord de coopération avec un Etat non membre, bloque la décision de la même manière que s'il votait contre.

Le vote ad referendum: comme le montre le document régulièrement soumis au Conseil, les délégations font un large usage de la procédure du vote ad referendum. Bien qu'elle ne soit pas expressément prévue par le règlement intérieur du Conseil, elle est largement pratiquée en droit international; mais elle revêt toutefois à l'Agence un caractère bien particulier.

Bien souvent les délégations font usage de cette procédure pour les motifs les plus divers: pour obtenir un délai pour consulter leurs autorités, pour faire approuver ou ratifier la décision en cause, ou pour lier leur vote positif à la réalisation de conditions étrangères à la question mise au vote. Le vote ad referendum est confondu alors avec le vote conditionné ou le vote avec réserves.

Dans la pratique de l'Agence, le vote ad referendum est considéré comme un vote positif provisoire ('oui, ad referendum'); la délégation désire voter dans un sens positif sans pour autant avoir au moment du vote les pouvoirs de le faire, sans pour autant engager encore son gouvernement de façon définitive. Si le 'ad referendum' est levé, le vote positif est réputé acquis du jour où la décision a été votée. Mais la délégation a le droit de transformer son vote positif en vote négatif qui produit lui aussi son effet du jour où la décision a été votée.

On voit donc l'intérêt et le risque d'un tel vote; il permet d'aller de l'avant, de considérer la décision comme prise, d'appeler par exemple les contributions mais par ailleurs il constitue une sorte d'épée de Damoclès', en particulier lorsque la décision requiert l'unanimité ou que les voix comptées pour atteindre la majorité requise, majorité simple ou majorité des deux tiers, contiennent des votes ad referendum. Et que dire lorsque deux délégations émettent des ad referendum pour des raisons qui sont à l'opposé l'une de l'autre!

Si cette pratique est donc utile, et permet d'éviter un report du vote et d'accroître le soutien à la proposition en cause (au contraire de l'abstention), il serait souhaitable qu'elle ne se confonde pas avec *le vote conditionné* ou *avec réserves.*

Le vote positif, conditionné ou avec réserves n'est pas non plus prévu par le règlement intérieur du Conseil. Il porte en réalité sur la substance de la décision et pourrait donc faire partie de son dispositif. Le vote positif peut être lié à un autre vote, distinct, sur une autre question ou bien marquer les difficultés propres à la délégation pour mettre en oeuvre la décision (par exemple difficulté temporaire de verser tout ou partie de la contribution).

Parfois, la mise en oeuvre est liée à l'achèvement d'une procédure interne nationale: 'sous réserve de l'achèvement des procédures parlementaires ou gouvernementales'.

Le vote différé et le vote ouvert: dans le

Figure 1 — Le Conseil en session

premier cas, une délégation demande un délai pour faire connaître son vote, ce qui ne permet pas de tenir compte de celui-ci le jour où le vote a lieu. Dans le deuxième cas, les délégations acceptent de ne pas considérer la procédure de vote comme terminée et les délégations qui ne se sont pas exprimées pourront le faire ultérieurement et les résultats seront constatés lorsque toutes les délégations se seront exprimées. Cette procédure a notamment été utilisée lors de l'extension des programmes préparatoires Hermès et Columbus.

Le vote par écrit: soit une délégation est absente lors du vote, soit il y a urgence à prendre une décision, mais l'organe délibérant habilité à la prendre n'est pas en session et ne le sera que dans un avenir plus ou moins proche. Avec l'accord du Président dudit organe, notamment dans le deuxième cas, l'Exécutif procèdera à une consultation par écrit (lettre, télex).

Les explications de vote: à l'issue du vote, les résultats étant enregistrés, les délégations, en particulier celles qui se sont abstenues ou qui ont voté contre, peuvent intervenir pour donner et faire inscrire au procès-verbal les motifs qui ont sous-tendu leurs positions. De telles déclarations peuvent éviter des malentendus.

La procédure de vote

Le passage au vote formel est un moment décisif. En effet, une fois le vote terminé, il ne pourra plus être question de revenir sur la proposition mise aux voix, avant un délai de douze mois, sauf décision de rouvrir le débat à la même majorité que celle requise pour le vote.

Aussi, peut-il être utile de procéder au préalable à un 'tour de table' ou à un 'vote blanc' pour vérifier si la majorité requise sera atteinte. Dans le cas où il apparaîtrait que majorité requise ne serait pas atteinte, il sera préférable de reporter le vote (à moins qu'une délégation ne demande par une motion d'ordre de passer au vote, motion sur laquelle le Président devra se prononcer — la décision du Président pouvant être renversée si la majorité des délégations se prononce contre elle).

Une délégation peut demander que la proposition soumise au vote le soit sous forme écrite. Ou bien la proposition peut faire l'objet d'un ou plusieurs amendements. L'amendement est mis aux voix en premier lieu. S'il y a plusieurs amendements, on votera d'abord sur celui que le Président estime s'éloigner le plus, quant au fond, de la proposition initiale. Si une délégation le demande, il peut encore être voté sur la proposition finale telle qu'amendée à la suite de la procédure précédente. Il arrive que de tels incidents de procédure viennent perturber le bon déroulement d'une séance.

Le plus souvent, les délégations votent, simultanément, à main levée, ou en levant les plaques sur lesquelles sont inscrits les noms de leur pays. Le Président (ou l'Exécutif) compte et annonce le résultat (il serait souhaitable, pour éviter des contestations ultérieures, que le Président ou l'Exécutif annonce à haute voix les noms des délégations votant pour, contre ou s'abstenant. L'Agence ne dispose pas encore de vote électronique).

Table 1 — Décisions et majorités du Conseil

Principe général: 'Sauf dispositions contraires de la présente Convention, les décisions du Conseil sont prises à la majorité simple des Etats membres représentés et votants.

Matière	Unanimité	2/3 Etats 2/3 Contributions	2/3 Etats membres	Majorité de tous les Etats
Informations et données: règles d'application			+	
Activités opérationnelles: conditions				+
Règles relatives à l'internationalisation des programmes nationaux	+			
Objectifs de politique industrielle autres que ceux visés dans la Convention	+			
Dispositions détaillées des objectifs de politique industrielle			+	
Modalités de mise à disposition des installations de l'Agence			+	
Aide de l'Agence aux Etats membres			+	
Modalités de fourniture des produits développés par l'Agence			+	
Approbation activités obligatoires: modification de décision			+	
Niveau des ressources	+			
Recommandations: harmonisation			+	
Acceptation des programmes facultatifs				+
Budget général			+	
Budget programme			+ Etats participants	
Règlement financier			+	
Statut du personnel			+	
Règles de transfert de technologies et produits			+	
Autorisation de vote (circonstances indépendantes de volonté)			+	
Mandat du SPC			+	
Création d'organes subsidiaires			+	
Nomination DG			+	
Barême de contributions (activités obligatoires) triennal	+			
Réduction contributions (circonstances spéciales)			+	
Versement spécial (Etat non partie ELDO/(ESRO)			+	
Coopération	+			
Modalités de participation à un programme			+ Etats participants	
Modalités d'association			+	
Amendements Annexes Convention	+			
Règlement d'arbitrage			+	
Cessation qualité Etats membres			+	
Adhésion Convention	+			
Définition unité de compte	+			
Commission de vérification des comptes			+	
Démarrage phase de programme facultatif		+		
Arrêt d'un programme facultatif		+		
Statut d'observateur	+			

Si une délégation le demande, le vote se fait sur appel nominal. En principe, l'appel nominal se fait dans l'ordre alphabétique français des Etats membres, en commençant par la délégation qui a demandé l'appel nominal.

Autre façon plus habituelle de procéder: le Président appelle d'abord les délégations qui sont pour — puis celles qui sont contre — et celles qui s'abstiennent; ou encore il procède selon un tour de table demandant à chaque délégation l'une après l'autre, de se prononcer, pour, contre ou abstention.

Le résultat du scrutin est porté au procès-verbal, notamment au procès-verbal sommaire distribué par l'Exécutif immédiatement après la réunion.

Le Président peut être amené à recommencer le vote si le premier scrutin a donné des résultats non conformes (plus ou moins de voix enregistrées que le nombre d'Etats ayant droit de vote par exemple).

Les majorités*

Le Conseil (ou l'organe délibérant habilité à prendre la décision en question) vote à la majorité prévue dans la Convention (y compris ses Annexes).

Selon l'article XI.6 (d) et (e) de la Convention, 'Sauf dispositions contraires de la présente Convention, les décisions du Conseil sont prises à la majorité simple des Etats membres représentés et votants' (....) et 'Pour déterminer l'unanimité ou les majorités prévues dans la présente Convention, il n'est pas tenu compte d'un Etat membre n'ayant pas droit de vote'.

Par ailleurs 'lorsqu'une décision doit être prise à la majorité simple des Etats membres représentés et votants, les abstentions ne comptent pas comme voix.' (article 18.3 du Règlement intérieur du Conseil).

Or, les dispositions contraires sont fort nombreuses et touchent aux questions essentielles; elles sont en particulier énoncées à l'article XI de la Convention mais d'autres articles contiennent des règles de vote.

Première remarque: les majorités indiquées sont toutes calculées sur la totalité des Etats membres: que ce soit l'unanimité, la majorité simple ou la majorité qualifiée (deux tiers ou double deux tiers). Il suffit de lire en particulier l'article XI.5 de la Convention qui précise chaque fois que la base du calcul est 'tous les Etats membres'. La Convention du CERS/ESRO n'était pas toujours aussi précise et, en outre, contenait des divergences entre texte français et texte anglais. Ce qu'on appelle la majorité ou l'unanimité absolue: depuis le 1er janvier 1987, la majorité simple signifie sept délégations votant pour, la majorité des deux tiers équivaut à neuf 'pour'.

Deuxième remarque : le recours à l'unanimité de tous les Etats membres est très limité. Il n'est prévu par la Convention que dans quelques cas: l'adoption du niveau de ressources quinquennal et l'adoption d'un Accord de coopération avec un Etat non membre (article XIV.1 de la Convention), l'adoption d'amendements aux Annexes II, III, IV et V de la Convention, l'adhésion d'un nouvel Etat membre, l'adoption de règles sur l'internationalisation des programmes spatiaux nationaux. Par ailleurs, les Déclarations de programme retiennent généralement l'unanimité de tous les Etats participants pour la révision de la Déclaration et de ses Annexes A et B. Le recours à l'unanimité signifie que tout Etat membre (participant) 'petit' ou 'grand' dispose d'un droit de veto. Ce sera lors tentant de mélanger les questions et de lier son vote positif à l'obtention d'un avantage sur une autre question sans lien avec celle qui fait l'objet du vote.

Nombre de décisions sont prises à la majorité des deux tiers de tous les Etats membres notamment toutes les questions financières comme le vote des budgets annuels, les questions portant sur le fonctionnement de l'Agence, comme l'adoption de divers Règlements et statuts (personnel, finances, politique industrielle, contrats, transfert de technologies et de produits, création et compétences d'organes subsidiaires, etc.).

A la majorité de tous les Etats membres sont adoptées d'autres décisions, comme l'acceptation de l'exécution par l'Agence de programmes facultatifs, l'adoption d'Accords entre l'Agence et les Etats membres, l'acceptation d'activités opérationnelles, etc.

On a relevé plus haut les quelques cas de majorité double des deux tiers (un tableau des diverses majorités prévues par la Convention figure dans le Recueil des mandats des organes délibérants publié par le Service juridique; voir table 1).

Dans les autres cas, notamment de recommandations, la décision pourra être prise à la majorité simple des Etats représentés et votants, l'abstention ne comptant pas alors comme voix. Cette décision pourra en outre contenir des votes ad referendum ; aussi, arrive-t-il d'avoir un vote pris avec quelques votes positifs et de très nombreuses abstentions, ce qui politiquement démontrera que la décision n'est pas encore mûre.

La présence de ces règles, parfois compliquées, est la contrepartie d'un système collégial et la recherche de l'intérêt communautaire. C'est leur présence qui pousse vers la réalisation d'une solution communautaire, comme la présence d'une clause d'arbitrage dans un Accord ou contrat est le meilleur gage que les parties feront tout leur possible pour parvenir à un accord.

*L'habitude s'est instaurée notamment au niveau du Conseil, de disposer de 'Fiches de décision' ('decision sheets') qui indiquent la majorité requise pour l'adoption de la proposition en cause.

The Hermes Safety Advisory Committee (HESAC)

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

The decisions by the ESA Council to develop a European manned space vehicle, the Hermes/Ariane-5, represent a significant extension of the current ESA activities. However, ESA has specific experience and expertise related to manned space flight and launchers from the Spacelab programmes and the development of the existing Ariane family.

In order to optimise its future Hermes/Ariane-5 Programme, the Agency has established a management infrastructure to accommodate all aspects of the new programmes. An area of prime importance is the human-safety aspect of the new space vehicles.

In the context of preparing the Agency for implementing the product-assurance and safety responsibilities specifically allocated to it by Council, the experience and 'lessons learned' on other similar programmes have been examined. It will be recalled that the 'Challenger' Space-Shuttle accident was investigated by a Presidential Commission; the recommendations of the subsequent Rogers Report have been assessed for their relevance to the ESA programmes. The overall result of these investigations has been an extensive updating of the ESA Product-Assurance and Safety Standards (the ESA PSS specifications), which now form the baseline requirements for the Hermes/Ariane-5 vehicle.

It was also concluded that an independent high-level committee should be established reporting to the Directors General of ESA and CNES, to provide an expert opinion on the conclusions arrived at internally by the two agencies. This committee, the Hermes Safety Advisory Committee, was convened in January 1987, and is composed of members from senior positions in aeronautical, nuclear, materials-science, medical, and space establishments in Europe. The Committee has been requested to pay particular attention to the objectives and methodology of the Hermes and Ariane-5 safety approach and to monitor and evaluate overall development, qualification and flight certification. The Committee is also permitted to take any initiative it feels necessary to facilitate the execution of its mandate. The next phase of the HESAC's activities will cover the pre-Phase-C/D development programme, during which the Hermes/Ariane-5 design will be defined.

At this time, detailed discussions have taken place between the HESAC, ESA and CNES concerning the conclusions reached by the Committee after its first year of operation. A number of areas needing further definition are:

- the design requirements and criteria concerning the selection, qualification and use of composite materials
- the design, utilisation and validation of software, and software/hardware interface aspects
- aero-thermodynamics
- characterisation of the capabilities of man, addressing for example the predictability and reliability of man's performance in critical situations
- the integration of the system-safety approach, with the proper degree of independence, into the overall programme management system.

I consider it essential that the safety element in these areas be given priority attention.

The challenge before us is to establish, within the specified cost and schedule envelope, a European spaceplane that is both safe, from the man-related viewpoint, and reliable, for the missions that have to be executed.

I am convinced that the HESAC will help us to provide the independent assessment of our activities, in the area of human safety, that recent experiences have proved to be necessary.

Une année d'activité du Comité HESAC*

P. Govaerts, Président du Comité HESAC

Créé en janvier 1987 par les Directeurs généraux de l'Agence Spatiale Européenne et du CNES, le Comité HESAC a comme mandat de donner des avis indépendants sur tous les aspects de sécurité liés aux vols spatiaux habités. Ce Comité est composé de dix personnes, choisies en dehors de l'ESA et du CNES, et d'origines variées. On y retrouve en effet des personnes dont l'expérience professionnelle est liée à la conception, aux essais, au contrôle ou à la certification, à l'exploitation, dans des domaines tels que l'aéronautique, les engins, les programmes spatiaux, l'industrie nucléaire, la médecine.

L'information a été fournie au Comité lors d'une dizaine de réunions, chacune en général de deux jours, au cours desquelles des présentations techniques ont été faites par des membres du CNES, de l'ESA ou de certains contractants importants; une abondance documentation a aussi été transmise. Le rythme de travail qui en résulte ne peut pratiquement pas être augmenté, car la plupart des membres du Comité sont encore engagés dans une vie professionnelle active.

Le Comité a remis un rapport intermédiaire, de portée générale, en août 1987 après une première phase d'apprentissage qui a permis de prendre connaissance des projets Ariane-5 et Hermès, à un moment où ceux-ci subissaient eux-mêmes de profondes modifications.

* Hermes Safety Advisory Committee.

Un rapport final, correspondant à la première année d'existence du Comité, a été déposé à la fin février 1988, et discuté ensuite en présence des Directeurs généraux de l'ESA et du CNES au début avril. Les sujets les plus importants sont évoqués ci-après.

L'évolution la plus marquante d'Hermès en 1987 a sans doute été l'adoption d'une cabine éjectable. L'HESAC a reconnu que ce projet était la solution sur laquelle le maximum d'efforts devrait être porté. Il a insisté sur la nécessité d'inclure dans le plan de développement des essais de qualification aussi représentatifs que possible, éventuellement même dans le domaine hypersonique, au moyen d'objets aérodynamiquement similaires à la cabine éjectable. Conscient de l'importance des programmes de R et D nécessaires pour mener à son terme le projet d'Hermès, l'HESAC rappelle que pouvoir se rabattre sur des solutions de rechange devrait être une règle générale à adopter; dans le cas de la cabine éjectable, une solution de repli pourrait être les sièges éjectables encapsulés, dont la faisabilité et le domaine de performances devrait être évalué.

Enfin l'HESAC souhaite qu'une revue de sécurité du projet de cabine éjectable soit entreprise dès que possible, et avant que la conception en soit complètement figée.

Dans le domaine hypersonique, un important programme d'acquisition de données expérimentales a été lancé, de même que le développement de méthodes de calcul en dynamique des fluides. L'HESAC suggère d'examiner si ce programme pourrait être complété par certains essais en vol, dans des géométries simples, afin d'ajouter des points de recoupement vis-à-vis des modèles de calcul et vis-à-vis des essais au sol.

D'excellentes présentations sur Vulcain et sur les propulseurs à poudre ont montré l'ampleur des études de développement de ces moteurs. Cependant, atteindre les exigences de fiabilité requises pour les vols habités n'est à ce jour pas démontré et le programme d'essais, en particulier des propulseurs à poudre, devra être soigneusement établi et dégager des marges suffisantes pour prouver le niveau de fiabilité recherché.

Dans le domaine des matériaux composites, l'HESAC est d'accord avec le programme de qualification et de sélection de couples fibres/résines en cours. Il a attiré l'attention sur les comportements très différents entre structures métalliques et structures composites, demandant d'examiner de plus près les facteurs de charge sûre admissibles, les pressions de timbrage des réservoirs, les températures extrêmes auxquelles Hermès pourrait être soumis en particulier en position accostée suivant une orientation fixe, les limites d'acceptabilité de défauts et les possibilités de détection de ces derniers.

Les lois de commande de vol devront être discutées ultérieurement par le Comité; à l'heure actuelle, on a noté des différences avec les pratiques de l'aviation civille quant à la redondance des gouvernes, et l'impossibilité éventuelle de la reconfiguration du contrôle, ce qui pourrait empêcher tout essai en vol de modes dégradés.

Assurer l'intégrité des calculateurs de bord et des logiciels associés au niveau de fiabilité prescrit pose le problème du degré de redondance et aussi de la redondance dissemblable, sujets dont la discussion devra être poursuivie.

En ce qui concerne le rôle de l'homme pendant les diverses phases d'une mission d'Hermès, l'analyse des risques et l'analyse des tâches à confier aux automatismes ou à l'homme dans les modes nominal ou dégradé devraient permettre de mieux objectiver les choix; l'option actuelle d'un premier vol automatique laisse la porte ouverte à toute optimisation ultérieure.

Dans l'approche générale de la sécurité des vols habités, l'HESAC reconnaît qu'un niveau quantifié pour l'objectif de risque par mission est utile au niveau de la conception en complément à la démarche qualitative, et accepte l'objectif actuellement envisagé. Tout dépassement de ce niveau devrait être rapporté aux niveaux adéquats de responsabilité.

Par analogie avec la pratique dans d'autres industries, l'HESAC confirme la nécessité de définir très précisément les systèmes ou composants liés à la sécurité et leurs limites exactes, et sur l'intérêt d'y distinguer plusieurs classes, permettant une gradation de la qualité et des exigences techniques.

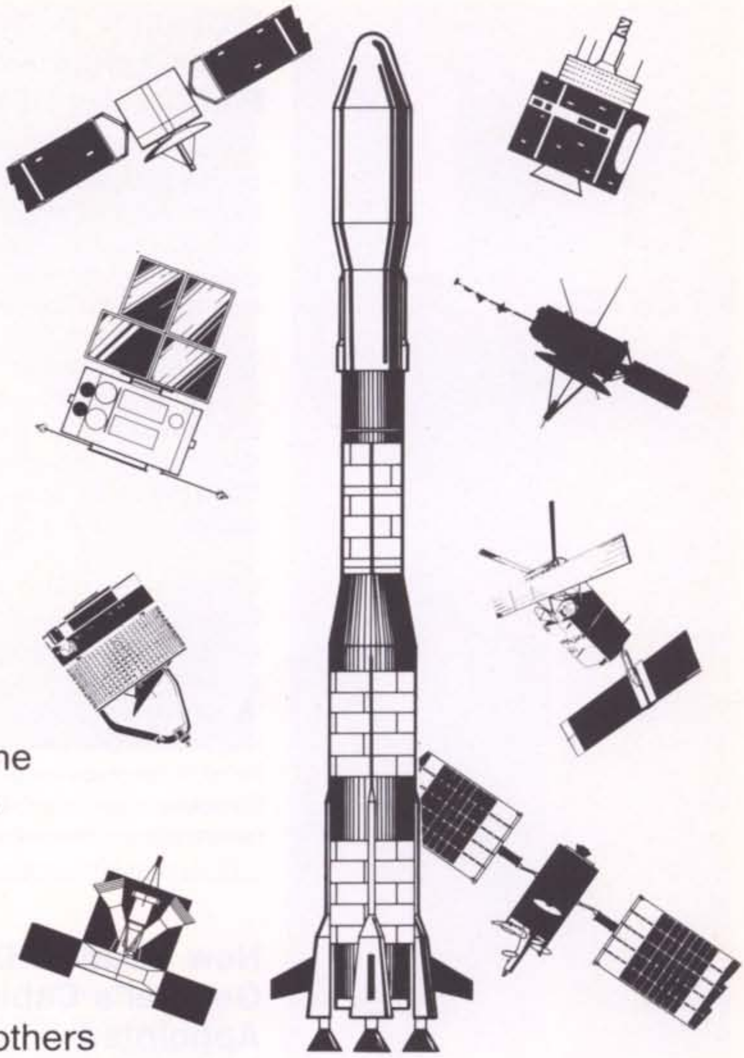
L'HESAC signale l'existence dans le domaine nucléaire de procédures accidentelles basées sur la reconnaissance de l'état du système et non sur un scénario préconçu d'accident, ainsi que des procédures de la 'dernière chance' pour le cas très improbable où des événements non pris en compte lors de la conception se seraient quand même produits; il pourrait être intéressant d'examiner si de tels concepts sont transportables dans le domaine spatial.

Il est aussi réaffirmé combien il est nécessaire que l'activité de sécurité soit partie intégrante de l'activité de conception notamment pour traduire les principes de sécurité de manière concrète à l'intention des projets et assurer les fonctions de rapport et de vérification; ainsi les exigences de l'analyse de sécurité peuvent être incorporées avant le gel du projet.

En conclusion, le Comité a été impressionné par l'ampleur de la recherche et du développement mis en place et par la qualité des études en cours; le succès d'Hermès dans les délais prévus dépend essentiellement de l'aboutissement favorable de l'ensemble de ces actions qui doivent faire l'objet d'un suivi constant et disposer des moyens et du personnel nécessaires.

Les enseignements des programmes Ariane-1 à 4 seront aussi une aide précieuse grâce au retour d'expérience qu'ils procurent et ces programmes pourront eux-mêmes bénéficier des études effectuées dans le cadre Ariane-5/Hermès; l'approfondissement des connaissances apporté par l'ensemble de ces programmes sera un atout important pour franchir cette nouvelle étape dans la sécurité que requièrent les vols habités.

Au terme de cette première année d'existence, tous les membres de l'HESAC ont apprécié l'ouverture, l'esprit de collaboration et d'estime dans leurs rapports avec le CNES et l'ESA et espèrent contribuer modestement, dans le cadre d'avis et de critique constructive défini par leur mandat, à la réussite de cette grande aventure européenne que sont les vols habités.



In Brief

Professor Bonnet Named Science Personality of the Year

At a ceremony held at the ESA Headquarters in Paris on Tuesday 15 March 1988, Prof. Roger Bonnet, ESA's Director of Scientific Programmes, was presented with the 1987 Science Personality of the Year award.

This international award, made annually in a variety of spheres of activity by an independent panel composed of past recipients, is in recognition of Prof. Bonnet's work for European space science.

Since he joined ESA in 1983, Prof. Bonnet has been heavily involved in the setting up of a large-scale science programme for the years ahead, entitled 'Space Science: Horizon 2000'. This long-term programme constitutes the frame of reference for all of the European space-science missions currently under development.

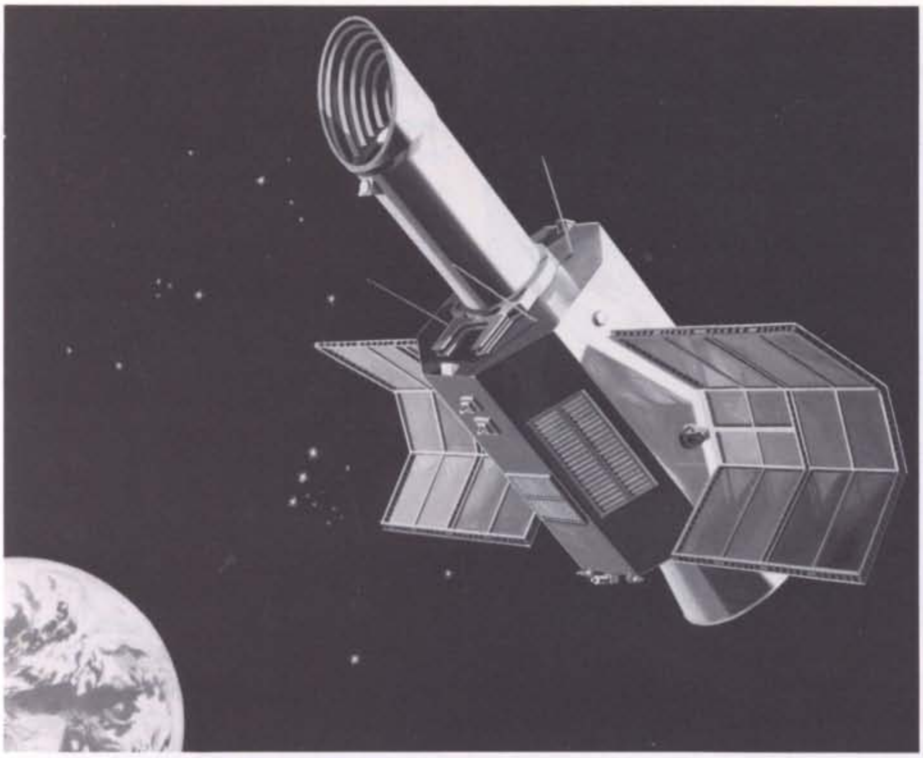
Prof. Bonnet also played a key role in the success of the Giotto spacecraft mission, whose approach to within 596 km of the nucleus of Halley's Comet in March 1986 yielded such spectacular scientific results.

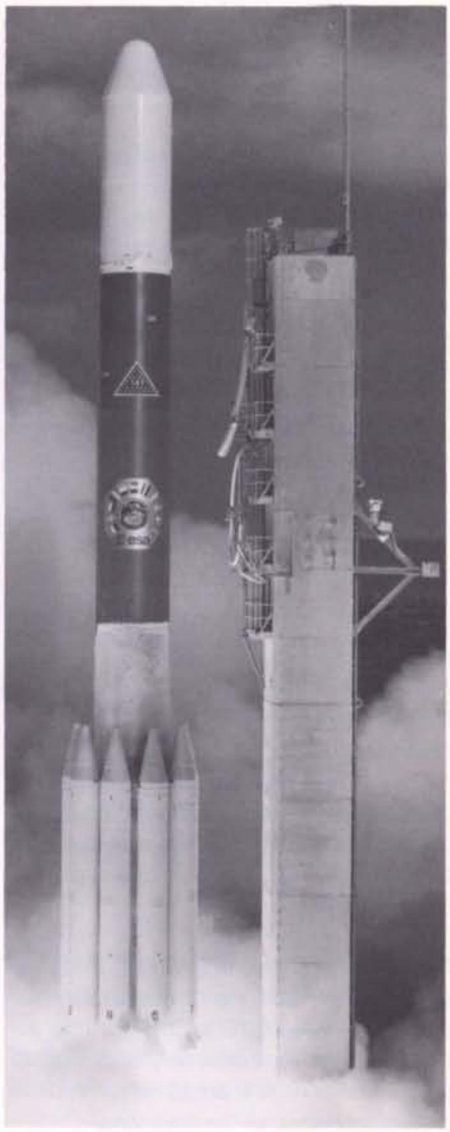
New Head of Director General's Cabinet Appointed

On 5 April 1988, Karl Reuter took up his new duties at ESA Headquarters (Paris), as Head of the Director General's Cabinet.

Born in Cologne on 15 July 1934, Karl Reuter graduated in Production Engineering at the Aachen (Aix-la-Chapelle) Technical University in 1962. After some years of research work at the Institute for Machine Tools and Production Engineering at Aachen University and the Nuclear Research Centre at Jülich, he joined ESRO in 1969. After the creation of ESA in 1975, he was responsible for the Agency's Medium-Term Planning in the Directorate for Planning and Future Programmes. He left the Agency at the beginning of 1981 to join the Franco-German TV-Sat/TDF-1 Programme, returning to ESA again in 1986 to head the Agency's Coordination and Monitoring Office, until taking up his latest appointment.

Karl Reuter (right) in discussion with ESA's Director General, Prof. Reimar Lüst





Tenth Anniversary of IUE

On 26 January 1988, the Agency's International Ultraviolet Explorer (IUE) satellite had been in orbit for ten years. An astronomical satellite that studies ultraviolet radiation, IUE is a cooperative venture involving ESA, the UK Science and Engineering Research Council, and NASA.

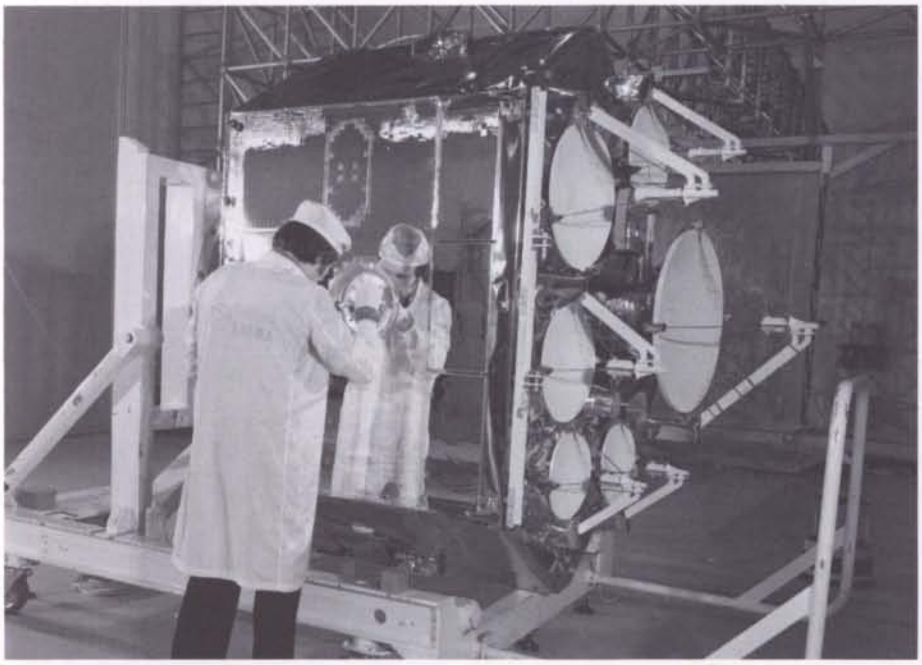
Parked in a geosynchronous orbit over the Atlantic, IUE is operated from ESA's Villafranca Ground Station near Madrid for 8 h per day and from Goddard Space Flight Center in Greenbelt (Maryland) for the remaining 16 h.

The IUE telescope has been, and continues to be, one of the most productive astronomical tools ever built, as witnessed by the steady stream of papers appearing in the professional literature.

OTS Celebrates Ten Years in Orbit

The Agency's Orbital Test Satellite OTS-2, launch of which marked the beginning of ESA's space telecommunications programme, celebrated ten years in orbit on 12 May 1988. Launched by a Thor-Delta rocket from Cape Canaveral, (above) OTS-2 has been used for telephone and data applications, as well as for TV distribution by many European countries. The satellite has now been exploited for more than three times its foreseen nominal operational life in orbit.

A detailed technical report on the satellite's performance over the last decade is currently in preparation.



OTS being prepared for antenna-alignment testing at MATRA, Toulouse

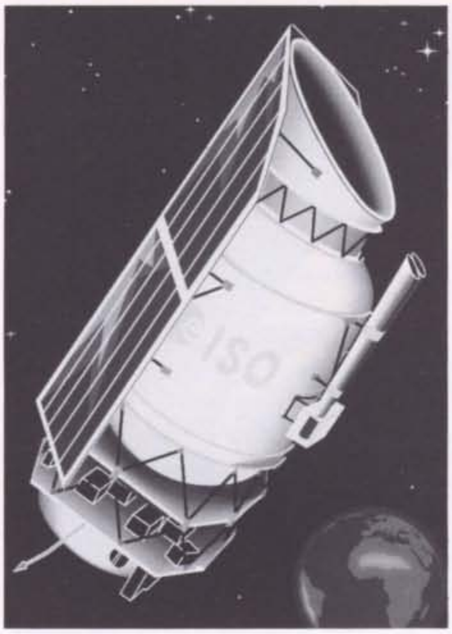
ISO Satellite Main Development Phase Initiated

The industrial Phase-C/D for the Infrared Space Observatory (ISO), the next satellite project in the Agency's Scientific Programme, started on 15 March.

ISO is a telescope-type observatory designed for making measurements of astronomical objects in the infrared at wavelengths from 2.5 to 200 microns and with sensitivities close to the limits set by the natural astronomical background. Four scientific instruments will be carried by ISO: a Camera, a Photopolarimeter, and two Spectrometers.

The mission requirements dictate that the infrared detectors of the scientific instruments must be cooled to near absolute zero (−270°C or 3 K). The satellite therefore has, as its dominating feature, a very large superfluid-helium-cooled cryostat, which will cool the scientific instruments via the slow boil-off of helium over the satellite's one and a half year lifetime.

A Sun shield on the side of the spacecraft protects the cryostat from direct solar heating. Solar cells on the shield provide the necessary electrical power. The service module below the cryostat provides all the traditional spacecraft services, such as power, attitude control and communications.



The satellite weighs 2400 kg and is about 5.3 m long and 2.5 m wide. Its short-term pointing accuracy (jitter) will be about 2 arcs. The downlink data rate will be 33 kbit/s, of which about 24 kbit/s will be dedicated to the scientific instruments.

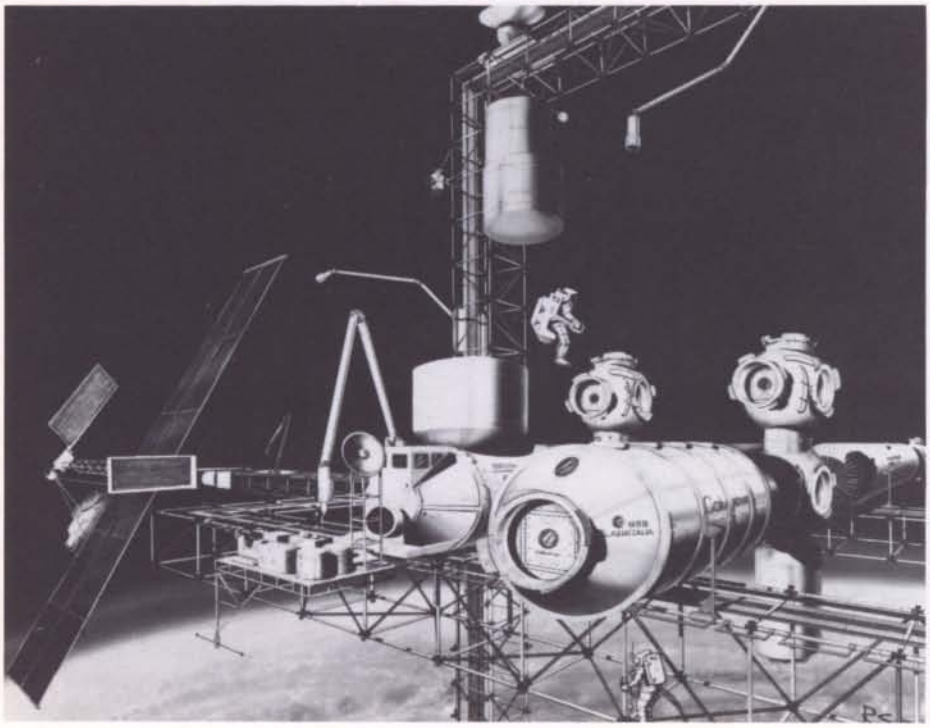
The satellite is being built by European industry, with Aerospatiale in Cannes as the Prime Contractor, leading some 35 subcontractors. The main subcontractors are CASA (Service Module Structure, Thermal Control and Electrical Harness), ETCA (Power), Fokker (Attitude and Orbit Control), Laben (Data Handling), MBB (Cryostat), MSS (Reaction Control) and Selenia (Telecommunications).

ISO will be put into its operational orbit with an Ariane-4 launcher in the first half of 1993. The nominal orbit has a 24 h period with a perigee of 1000 km and an apogee of 70 000 km. The orbit's inclination to the equator has yet to be decided, but it will be between 5° and 20°.

ESA plans to supply only one ground station, at Villafranca in Spain, which will permit ISO to be operated for the best 14 h, scientifically speaking, of each orbit. In order to be able to retrieve an additional 8 h of good-quality data, ESA is seeking to establish an international collaboration to provide a second ground station.

Being an observatory-type satellite, most of ISO's observation time (two-thirds) will be offered to the scientific community at large. Astronomers will be able to obtain observation time by submitting proposals, from which a selection will be made by a peer-review procedure. The remaining third of the total available observation time is reserved for the groups that are providing the scientific instruments, the mission scientists and the observatory operations team, who will handle the instruments and define satellite operations.

Control of the satellite (including pointing) and its safety will be the responsibility of ESA's Space Operations Centre, at ESOC in Darmstadt, W. Germany.



First Step Taken Towards International Cooperation on Space Station

The eighty-second ESA Council, meeting in Paris on 17 and 18 March, adopted by a unanimous vote the Memorandum of Understanding (MOU) drawn up between ESA and NASA to establish detailed implementing arrangements for the design, development, operation and utilisation for peaceful purposes of the permanently manned International Space Station.

Negotiations on the Inter-Governmental Agreement (IGA) — to be signed by the four 'partners': USA, Canada, Europe and Japan — are very nearly complete, and thereafter each Government involved will begin the process of its approval.

New Training Facilities for European Astronauts

At its eighty-second meeting in Paris on 17/18 March, the ESA Council endorsed the so-called 'ESA Astronaut Training Concept' and approved the setting up of the associated facilities.

A new ESA 'Astronaut Headquarters Complex' will be established at Porz-Wahn, near Cologne, in West Germany, under ESA management. The Complex, staffed by ESA personnel (astronauts, engineers and managers), will be supported for training purposes with such technical facilities as system and subsystem mock-ups for the APM (Attached Pressurised Module) and MTFF (Man-Tended Free Flyer), a man-rated vacuum chamber, a small neutral-buoyancy facility, and a complete Hermes/MTFF composite mock-up. The Astronaut Headquarters Complex will also include medical facilities, meeting and lecture rooms, and a gymnasium.

A Hermes System and Subsystem Training Facility is to be located in Toulouse.

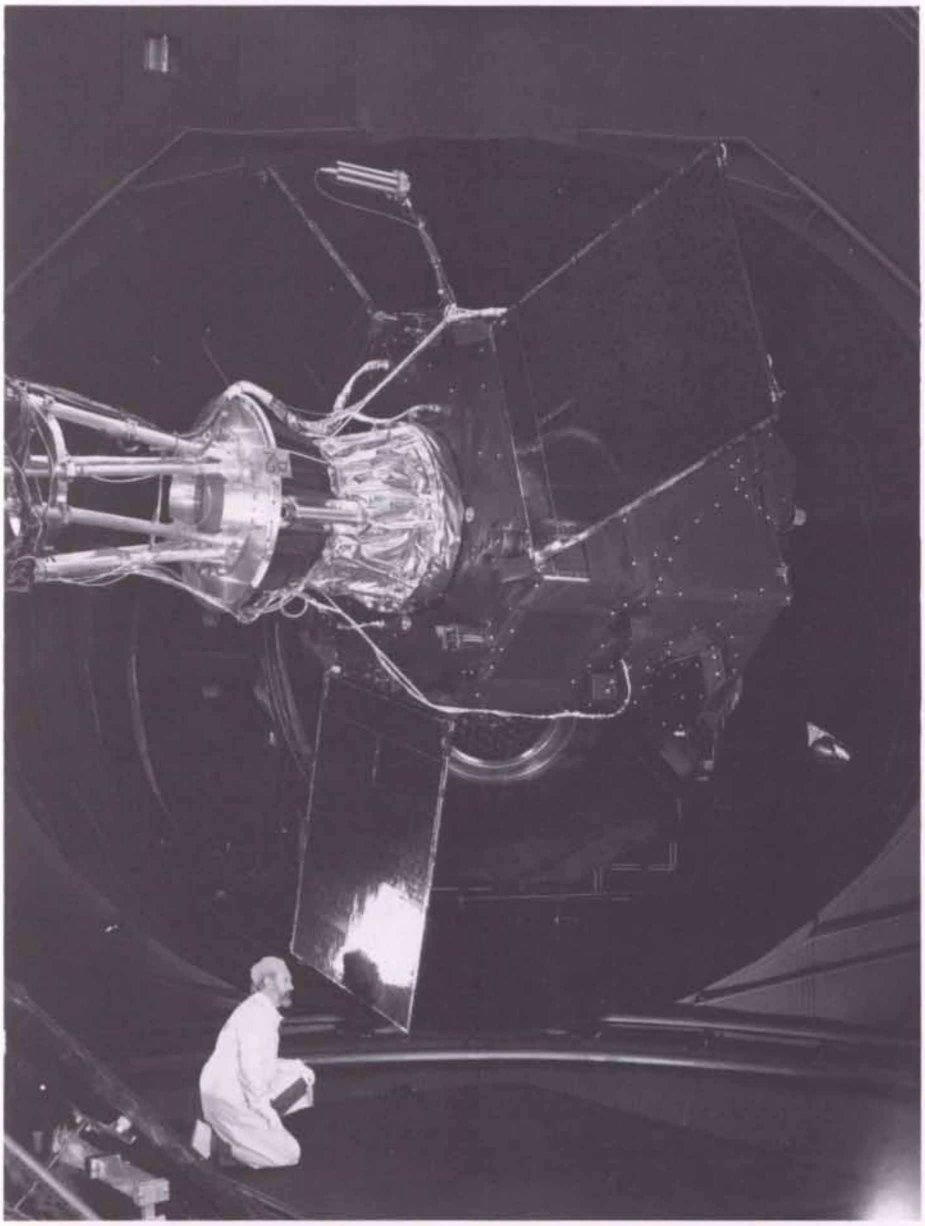
A Pilot Training Facility equipped with a six-degree-of-freedom motion base flight simulator for the training of Hermes commanders and pilots will be located near Brussels, in the vicinity of the Sabena training centre. This facility will also include the Hermes Training Aircraft, which will use Gosselies Airport in Belgium as a training base, but descent training will also take place at other sites such as Istres (near Marseilles) and Kourou (French Guiana).

The final phase of Hermes Mission Preparation, including final procedures/software validation, will take place in Toulouse.

A large neutral-buoyancy facility for EVA*-related training will be located in Marseilles.

ESTEC in Noordwijk will be provided with a specialised Robotics Laboratory and training facility for the Hermes Robot Arm (HERA).

* Extra-Vehicular Activity



Hipparcos Satellite Undergoes Final Ground Testing at ESTEC

On 9 March the Agency's Hipparcos satellite (High-Precision Parallax Collecting Satellite) entered the new Large Space Simulator facility at ESTEC for the final ground testing needed to declare this advanced scientific spacecraft 'ready for launch'.

The satellite had arrived at ESTEC on 12 February after its integration at Aeritalia in Turin (I), and dynamic testing at Intespace, Toulouse (F), which had consisted of mass-property, balance, acoustic and vibration tests.

During its final testing in ESTEC's unique new Large Space Simulator facility, the satellite was subjected to the thermal and vacuum conditions that it will experience in space. Proper deployment of the satellite's solar panels and the opening of the telescope's baffles under simulated space conditions were also verified.

The complete flight acceptance-test sequence in the Large Simulator took 16

Hipparcos under test at ESTEC

days and was the most complex so far conducted in the ESTEC facilities, due mainly to the stringent cleanliness requirements — to avoid any contamination of the satellite's very sensitive optical system — and the need for complete satellite-motion simulation inside the Simulator.

The satellite's formal Flight-Acceptance Review was concluded successfully on 14/15 April.

Hipparcos left ESTEC on 25 April for Aeritalia's premises, where it will be stored under carefully controlled environmental conditions, awaiting its launch by an Ariane-4 vehicle in April 1989.

Dr Catherine Turon (Meudon), leader of the Hipparcos Input Catalogue Consortium, handing over the operational version of the Input Catalogue to ESA's Director General Prof. R. Lüst

French Space-Astrometry Pioneer Attends Hipparcos Ceremony

At a ceremony held at the Agency's Space Research and Technology Centre (ESTEC) in Noordwijk (NL) on 11 April, in the presence of Prof. Pierre Lacroûte of France, who first proposed a space astrometry mission in 1967, Prof. Reimar Lüst, ESA's Director General, officially received a newly-compiled Star Catalogue. This Catalogue will be used both to control the Hipparcos satellite's motion in space and to determine its scientific observing programmme.

The Catalogue, which was handed over by Dr Catherine Turon of the Observatoire de Meudon (Paris), contains the positions of more than 100 000 stars. It has been built up using both existing star catalogues and newly-acquired observations made from the ground. Its compilation has involved the participation of nearly a hundred astronomers in the Agency's Member States over the past six years.

The Agency's Hipparcos satellite, which will be put into geostationary orbit around the Earth in 1989, will revolutionise many areas of astronomical and astrophysical research, by determining the distances and space motions of all of the stars contained in the new 'Input Catalogue' to an unprecedented level of accuracy. This in turn should result in great advances being made in our knowledge of the structure and evolution of our Galaxy.

The hand-over ceremony was also attended by Dr E. Høg from Copenhagen University Observatory, and Prof. J. Kovalevsky from the CERGA* Institute in Grasse, France, who lead the scientific groups responsible for the final catalogue compilation, Dr R.M. Bonnet, ESA's Director of Scientific Programmes, Dr H. Hassan, Hipparcos Project Manager, Dr M.C.E. Huber, Head of ESA's Space Science Department and Mr M. Le Fèvre, Director of ESTEC, and Dr M.A.C. Perryman, Hipparcos Project Scientist.

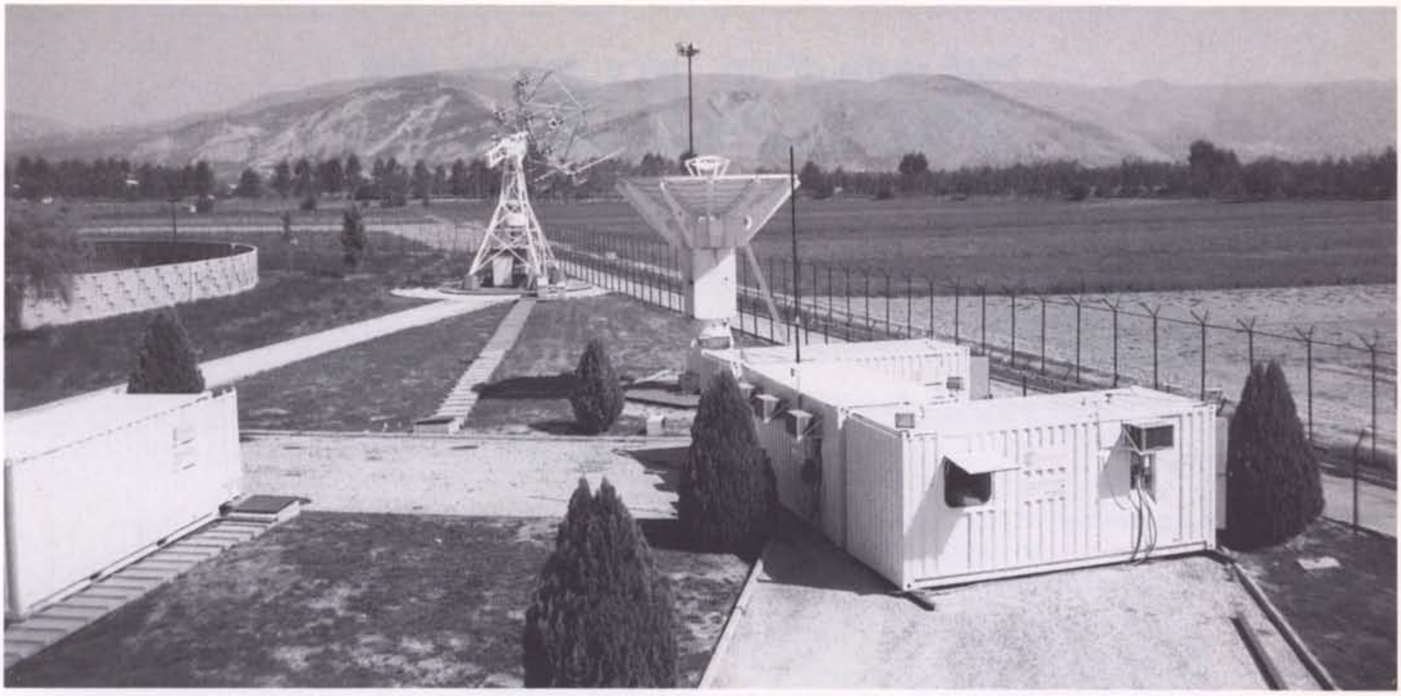
* CERGA: Centre d'Etudes et de Recherches Géodynamiques et Astronomiques

ESA Participates in 'RIENA '88'

The Agency was responsible for the coordination of a large pavilion (covering more than 1000 m^2) presenting Europe's major space programmes at the 35th International Electronics, Energy and Space Exhibition (RIENA*), held in Rome from 22 to 27 March 1988. Contributions to the stand were provided by European space industry, and many leading aerospace companies were represented.

Visitors to the ESA stand were shown displays of the Agency's scientific, telecommunications, remote-sensing, Space-Station, space platforms and microgravity-research programmes.

* Rassegna Internazionale Elettronica Nucleare e Aerospaziale



ESA's transportable ground station

ESA's Transportable Ground Station Comissioned

The ESA Transportable Station is a complete ground station installed in four 6 m ISO standard containers and designed to operate in all climatic zones except the Arctic/Antarctic.

The station consists of a 5.5 m full movement S-band dish attached to a standard baseband system providing telemetry, telecommand and ranging functions to ESA standard. It includes its own no-break diesel generator power system.

The station can be dismantled and packed by three men in seven working days and redeployed at a new site in ten working days. The only site preparation required is a foundation base for the antenna. At the moment bases exist at Perth in Australia, at the Telespazio site in Fucino, at ESOC and at Villafranca in Spain. Further bases will be constructed at Redu in Belgium, Odenwald in Germany and Kourou in French Guyana.

The Stations and Communications Engineering Department at ESOC has just finished final commissioning and testing at ESOC and the station will be dismantled and packed for transportation to Villafranca where it will be deployed and put into operation by the end of July. It will remain at Villafranca to provide general S-Band support until the former Exosat station can be configured for general network support.

The first operational use of the station will be for S-Band back-up support of MOP-1 during the Launch and Early Orbit Phase. ●

Preparing for European Space Silver Jubilee

As part of the celebration in 1989 of 25 years of European Space Cooperation, ESA Publications Division will be publishing a hardback album of pictures illustrating the events over the last two and a half decades.

We feel sure that some readers have unique photographs in their possession which will enhance the book, and I would welcome hearing from you, especially if you have photographs from the early days of ESRO and ELDO.

Please do NOT send the photographs (we know how precious they can be) but either send a photocopy, or a description. We will contact those of you whose photographs we may be able to use. Please send the information addressed to:

Head of ESA Publications Division
(Silver Jubilee)
ESTEC
Keplerlaan 1
P.O. Box 299
2200 AG Noordwijk
The Netherlands

Three More Spacecraft Successfully Launched by Ariane

On 11 March at 23 h 28 min (UT) an Ariane-3 launcher lifted-off from Kourou (French Guiana) after a perfect count-down to put two spacecraft, Telecom-1C (F) and Spacenet-IIIR (US), safely into orbit (injection parameters recorded: perigee 202.6 km; apogee 36 087 km; and inclination 7.3°). Further details can be found on page 53 of this issue.

At 02 h 58 min (UT) on Wednesday 18 May the Ariane V-23 flight lifted off as scheduled at the end of the first launch window. The Ariane-2 launcher successfully placed the international Intelsat-V spacecraft into geostationary transfer orbit (parameters: perigee 463.8 km; apogee 35 943 km and inclination 8.01°). ●

ARIANE 4

On Friday 29 April, the first of the new generation of Ariane-4 launch vehicles was tranported almost one kilometre from the Assembly Dock to the ELA-2 Launch Pad at the Agency's facilities in Kourou, French Guiana. The roll-out operation took just one-hour to complete.

Launch of this first Ariane-4, carrying one meteorological (Meteosat-P2) and two communications (Amsat-IIIC and Pan American Satellite 1) satellites, is currently scheduled for June 10.

1,2. Preparing for roll-out from the Assembly Dock at ELA-2.
3,4. Ariane-4 on its one-kilometre journey to the Launch Gantry.
5. Ariane-4 on the ELA-2 Launch Pad prior to Gantry Closure.

(Photography: S. Vermeer, ESA & D. Parker)

2

1

3

ROLL-OUT

4

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. 11 No. 4/Vol. 12 No. 1:

MECHANICAL AND ELECTRICAL CHARACTERISTICS OF TIN WHISKERS
DUNN B D

SPACEBORNE DOPPLER WIND LIDARS
SALVETTI G

AN OPTICAL MONITOR FOR SPACE APPLICATIONS
BORGHI G ET AL

SOME NEW PRODUCTS AVAILABLE ON THE METEOSAT DISPLAY CONSOLES
BOWEN R A

ESTIMATION DE LA PLUVIOMETRIE PENTADAIRE AU BURKINA FASO PAR L'INDICE DE PRECIPITATION ESOC
DIALLO A A & TURPEINEN O M

DATA STRUCTURES IN AN INTEGRATED GEOGRAPHICAL INFORMATION SYSTEM
ANTHONY S J & CORR D G

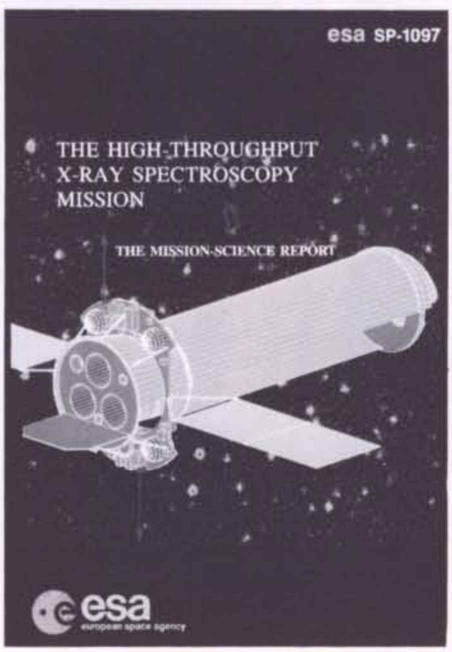
THE USE OF SPREAD-SPECTRUM CODING AS A FADING COUNTERMEASURE AT 20/30 GHZ
HUGHES C D & TOMLINSON M

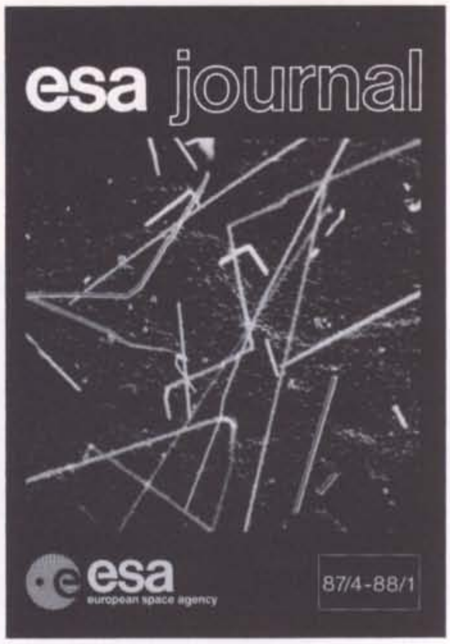
ELABORATION OF A CONTINUOUS FUNCTION OF UNIT MASS FOR VIBRATION TESTING
GIRARD A & MOREAU D

LOW-COST RECEPTION OF METEOSAT AND OTHER SATELLITE IMAGES USING TERRESTRIAL METEOROLOGICAL BROADCASTS
SANDERSON T R

ESA Special Publications

ESA SP-280 // 367 PAGES
SPACE & SEA, PROC CONFERENCE, MARSEILLES, FRANCE, 24–27 NOVEMBER 1987 (MAR 1988)
GUYENNE T D & HUNT J J (EDS)





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LONGDON & DAVID V (EDS)

ESA SP-1092 // 73 PAGES
THE HIGH THROUGHPUT X-RAY SPECTROSCOPY MISSION — REPORT OF THE INSTRUMENT WORKING GROUP (NOV 1987)
BRIEL U ET AL

ESA SP-1097 // 78 PAGES
THE HIGH-THROUGHPUT X-RAY SPECTROSCOPY MISSION — THE MISSION SCIENCE REPORT (MAR 1988)
BATTRICK B (ED)

ESA Brochures

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THE WORLD'S WATER RESOURCES — A MAJOR NEGLECT (MAR 1988)
HERSCHY R W, BARRETT E C & ROOZEKRANS J N

ESA BR-41 // 31 PAGES
ECS — FOURTH YEAR IN ORBIT (DEC 1987)
BASTON D W ET AL

ESA BR-42 // 34 PAGES
REACHING FOR THE SKIES — THE ARIANE FAMILY STORY AND BEYOND (UNDATED)
LONDGDON N (ED)

ESA BR-49 // 12 PAGES
BUSINESS TELECOMMUNICATIONS USING SATELLITE MICROTERMINALS — GAINING THE COMPETITIVE EDGE (MAR 1988)
BATTRICK B & ROLFE E J (EDS)

ESA BR-51 // 32 PAGES
SERVING SPACE — SOCIAL REPORT (MAY 1988)
LANDEAU J (ED)

ESA Scientific & Technical Memoranda

ESA STM-239 // 37 PAGES
SIMULATIONS OF THE ELECTROSTATIC CHARGING OF ESA COMMUNICATIONS SATELLITES (DEC 1987)
DALY E J

ESA Scientific & Technical Reports

ESA STR-225 // 64 PAGES
UNIFIED INTERCHANGE FORMAT FOR COMPUTER DATA (JAN 1988)
ERUP L

ESA Procedures, Standards & Specifications

ESA PSS-01-70 ISSUE 3 // 25 PAGES
MATERIAL AND PROCESS SELECTION AND QUALITY CONTROL FOR ESA SPACE SYSTEMS AND ASSOCIATED EQUIPMENT (OCT 1987)
MATERIAL & PROCESSES DIVISION, ESTEC

ESA PSS-01-700 ISSUE 1 // 40 PAGES
THE TECHNICAL REPORTING AND APPROVAL PROCEDURE FOR MATERIALS & PROCESSES (OCT 1987)
MATERIALS & PROCESSES DIVISION, ESTEC

ESA PSS-03-1201 ISSUE 1 // 254 PAGES
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STRUCTURES & MECHANISMS DIVISION, ESTEC

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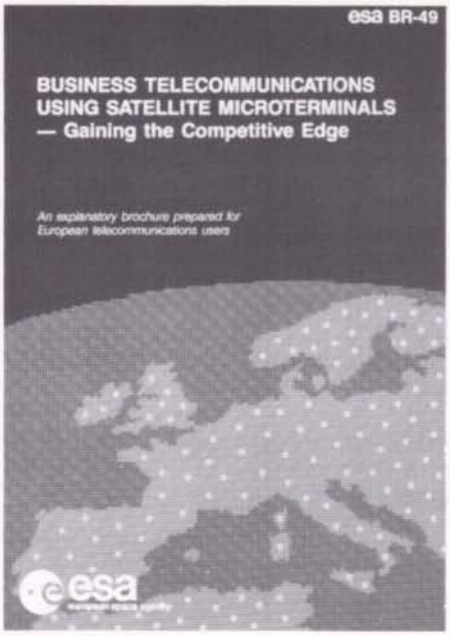

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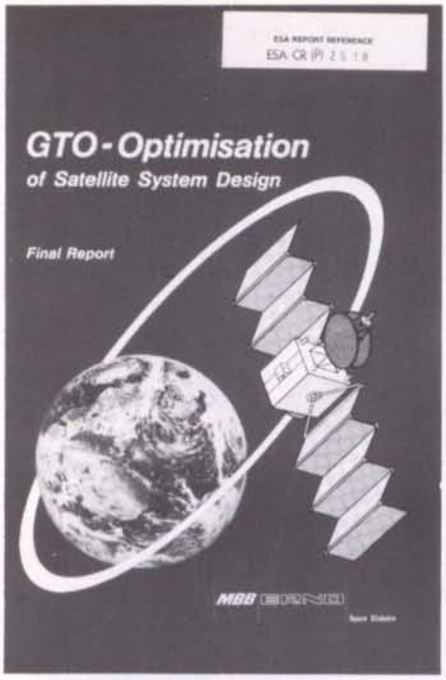

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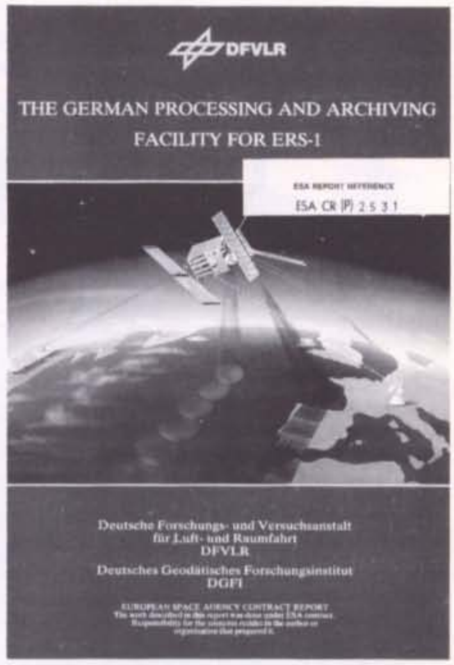

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