esa bulletin

number 48

november 1986

european space agency

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

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

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

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

The Directorate of the Agency consists of the Director General; the 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 Columbus 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: Dr. H.H. Atkinson.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

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

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

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

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ESRIN, Frascati, Italie.

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

Directeur général: Prof. R. Lüst.

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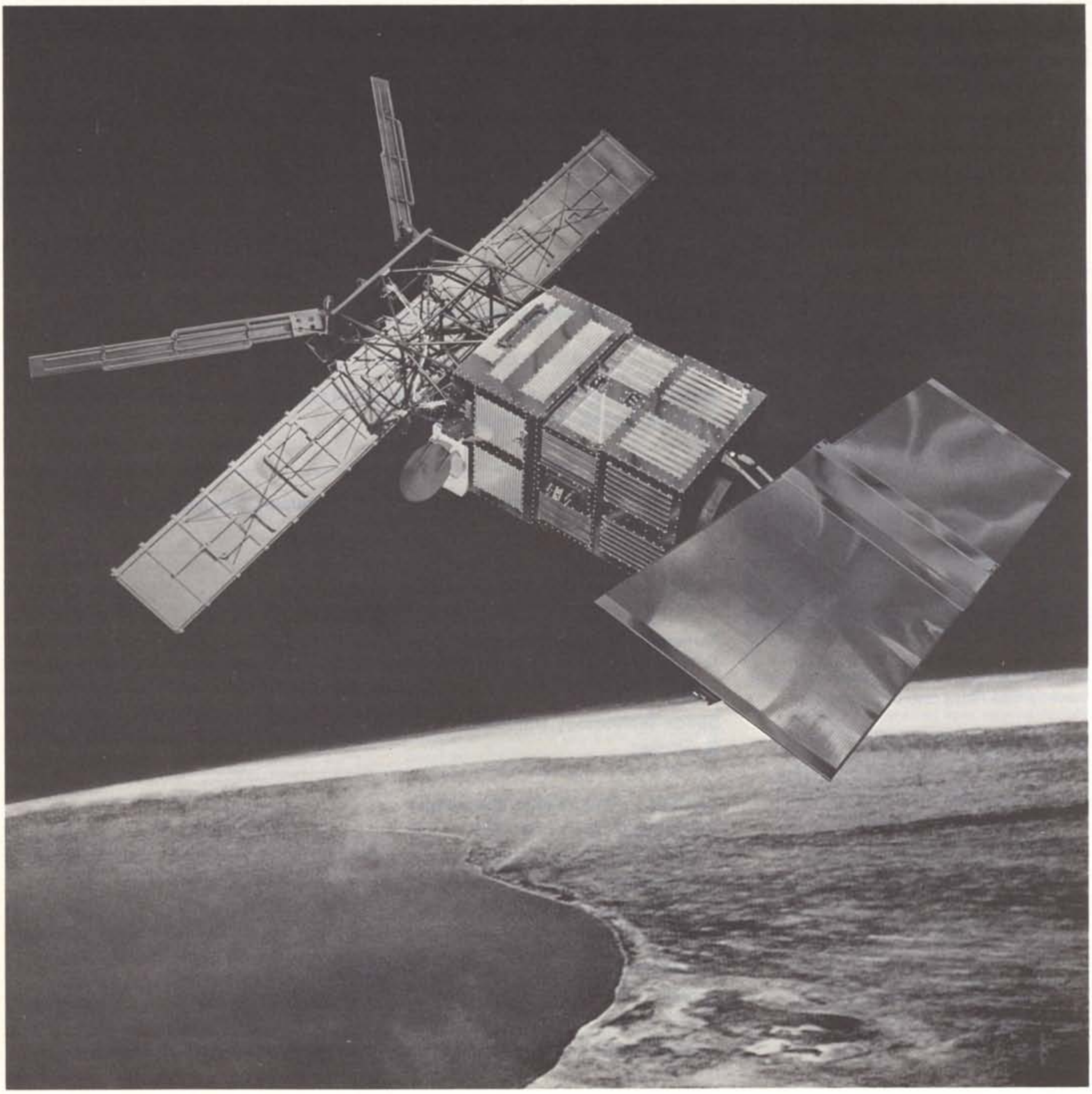
european space agency
agence spatiale européenne



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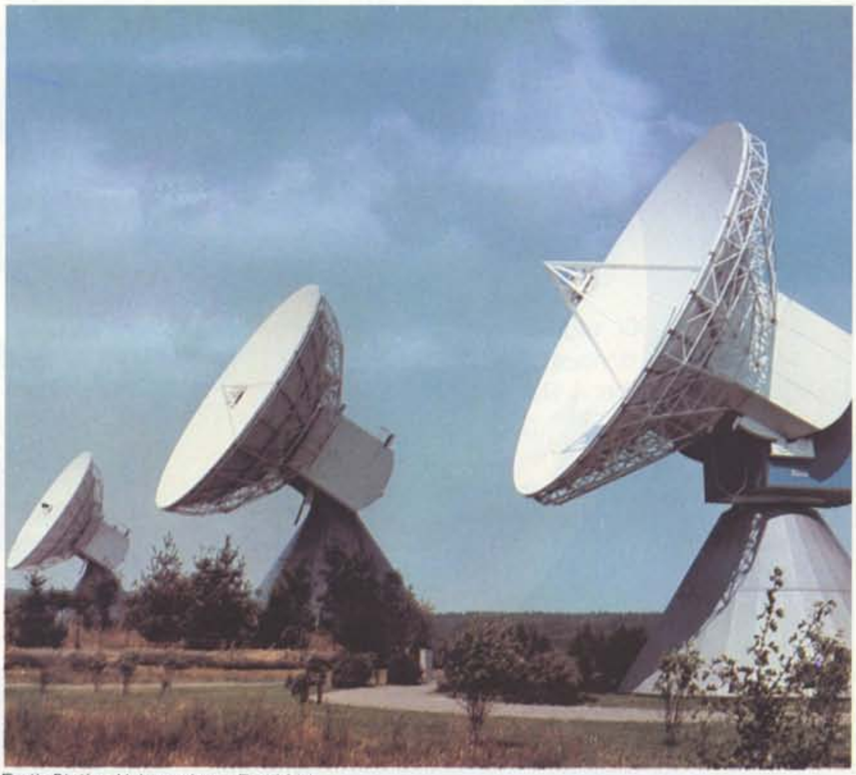
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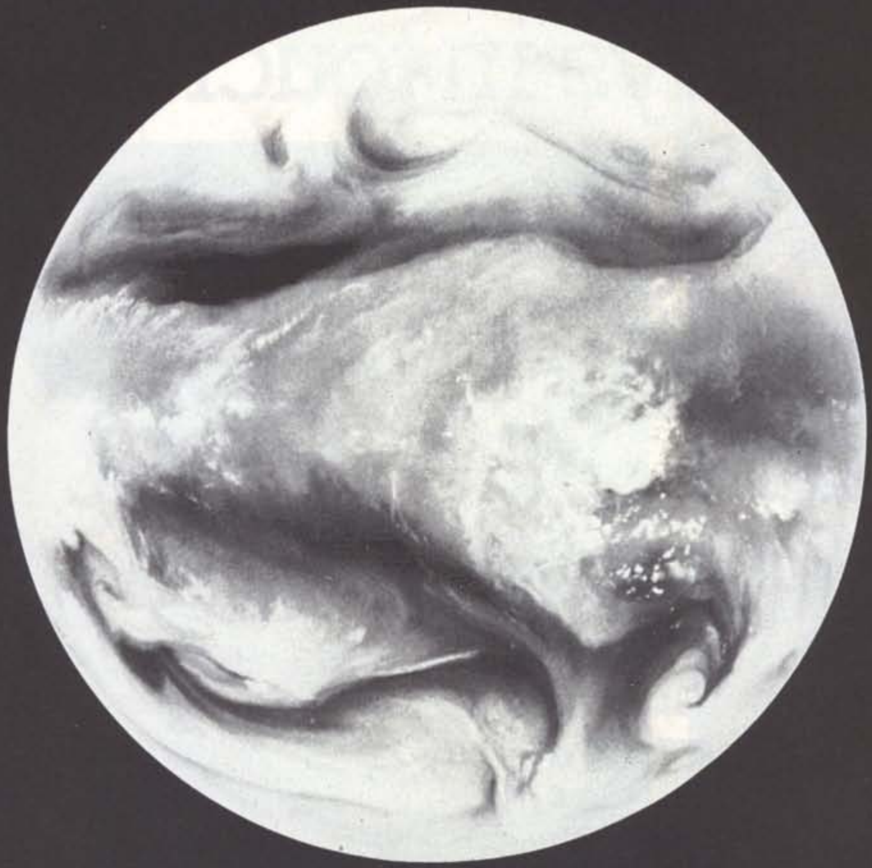
The world according to G.A.R.P.



This photograph shows the distribution of water vapor in the earth's atmosphere at about noon on March 26, 1982.
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Ceremonies in Italy Marking the Sixth Meeting of the IACG on Comet Halley

A number of prestigious events were organised in Italy in the week of 3–7 November 1986 to accompany the Sixth Meeting of the Inter-Agency Consultative Group for Space Science (IACG), composed of Delegations from ESA, NASA, the Intercosmos Council of the USSR Academy of Sciences, and the Japanese Institute of Space and Astronautical Science (ISAS).

The first event was held in Padua on Monday 3 November, with a ceremonial meeting in the Aula Magna of the University, in the presence of the Italian Minister for Scientific Research and Technology, the Honorable Luigi Granelli.

It was in Padua that the first meeting of the IACG took place in 1981 and the basis for coordination between the various projects for the exploration of Halley's Comet was established. Padua was chosen for these historic meetings for two reasons: the ESA probe 'Giotto' was named after Giotto di Bondone, the famous Florentine painter who depicted the Comet in the Nativity fresco in Padua's Scrovegni Chapel; and the late Prof. Giuseppe Colombo, who kindled European interest in the study of Halley's Comet, belonged to the University of Padua.

A Press Conference at the University of Padua on 3 November was followed by a presentation of the scientific results obtained by 'Giotto', the two Soviet 'Vega' spacecraft, the two Japanese spacecraft 'Suisei' and 'Sagikake', and the American 'ICE' spacecraft. The results obtained via remote observations from the ground, coordinated by the International Halley Watch (IHW), were also summarised.

On Tuesday 4 November, the Delegations of the IACG met in Executive Session, in the wake of the extraordinary success of the co-operative study of Halley's Comet, to examine possible new projects that would benefit from international co-ordination (see page 71 of this Bulletin).

The IACG then moved to Rome. There, on Thursday 6 November, the IACG Delegations — led by Acad. Roald Sagdeev for Intercosmos, Prof. Minora Oda for ISAS, Dr. Burton Edelson for NASA, and Dr. Roger Bonnet for ESA, under the Chairmanship of Prof. Reimar Lüst, ESA's Director General — made a presentation in the Aula Magna of Rome University on the work they had accomplished together. This presentation was attended by the President of the Republic of Italy, Francesco Cossiga, and other high-ranking scientific and diplomatic representatives.

On Friday 7 November, His Holiness Pope John Paul II granted a Solemn Audience in the Vatican in honour of the IACG Delegations and in the presence of the Sacred College of Cardinals, the Diplomatic Corps and distinguished foreign and Italian guests.

The Addresses made by Prof. Lüst in Padua and in Rome on behalf of ESA and the IACG, and the Address given by the Pope in the Vatican are reproduced in the following pages.

An Ending and a Beginning

by Prof. Reimar Lüst, Director General, ESA

As His Holiness Pope John Paul II ended his Address and rose to receive the Delegations from the Inter-Agency Consultative Group (IACG) to whom he had granted a Solemn Audience on Friday 7 November 1986, I was aware that another chapter in the long history of Halley's Comet was drawing to a close.

This had been an unusual chapter in many ways, and it boded well for the future. So often in the past Halley's Comet had been vested with the garment of ill-omen; but in 1986 this superstition had been torn from it, along with many of its long-kept secrets.

And there was a paradox, for the scientists and technologists had not only shown that such fears were groundless, but had by their enthusiastic collaboration, in the interests of science overcome many of the barriers, both real and imaginary, which had impeded progress in the past.

From 1981 until the encounters with the Comet in March 1986, the four Agencies that formed the IACG — Intercosmos headed by the USSR, NASA, the Institute of Space and Astronautical Science (ISAS) from Japan, and ESA — had worked ceaselessly and openly together to ensure that the best possible science would be the outcome. There had been a minimum of formality, and a maximum of good-will and trust, in the councils of the IACG. The result had been close ties, and the 'spring-board' effect of enthusiastic involvement in a common objective, leading to such tangible results as the 'Pathfinder Concept' without which ESA's Giotto spacecraft could not have been aimed so accurately for a close flyby within 600 km of the Comet's nucleus. And the bonds remain, for scientists are not studying their data in isolation, but cross-checking their results, and building models which all can share.

The audience with His Holiness the Pope was the final event in a week which had started in Padua with the Sixth Meeting of the IACG. Learning also from the past, the IACG, and its parent Agencies, knew that some definite single objective which all could ascribe to, was needed if the thrust was to be maintained. Much work had gone into the preparation for the IACG Meeting in Padua on 3 and 4 November. This was very much a return 'home', for it was in Padua that the first meeting had been held in 1981. In fact there was light-hearted discussion that IACG should be known as *the Padua Club*, emulating more famous international groups.

The Agencies were able to identify and agree on another common objective — *Solar Terrestrial Science*. Thus out of one 'ending' a new beginning had evolved.

I find this a happy choice, for solar-terrestrial science is of interest and importance to all nations, since it is relevant to basic space physics processes and to human habitability of the Earth. Space techniques and sensors are crucial factors in the successful measurements needed to enhance our understanding of the events taking place within the solar-terrestrial relationship.

One of the conditions for cooperative effort within the IACG is the existance of approved projects, and each member Agency has one or more solar-terrestrial science missions approved, or near approval, for launch and operation in the 1989 — 1996 time period. It was a bonus that many of these missions are bilateral arrangements between IACG Members. They also lend themselves to coordinated operations, and data sharing and joint data analysis by the science communities associated within the IACG Members.

The IACG decided that at least some degree of formality was necessary for its long-term working, and terms of reference were adopted. While accepting the arguments behind this, I trust that bureaucracy will be kept to a minimum, and that the free flow of information, so essential a strand in the success story of the encounter with Halley's Comet, will not be inhibited.

To keep the Inter-Agency Consultative Group — to which incidently it has been decided to add 'for space science' but not to change the original acronym, IACG — informed, two working groups have been set up, one to make recommendations on coordination of the scientific aspects of the missions, the other to look at the scope of data exchange, related policies and systems, data standards and formats and schedules.

So that other scientific areas might not be overlooked as subjects for future IACG cooperation, two panels were established, one for radio-astronomy, the other for planetary and primitive bodies. In this way the IACG keeps itself aware of developments, and retains the option to add other areas of interest to its activities.

So a very full meeting was over, and while IACG was looking forward, it had two further days to reflect on its past achievements. For those close to the encounter teams, Halley's Comet had been exciting, and envigorating, but

perhaps we had not always understood the degree of significance to the World in general.

During the preparations for the Padua meeting, the interest of the Italian Government and the Vatican became clearer. Minister Granelli had taken the time to be in Padua to congratulate the IACG and to hearten the Delegates with his belief in the future. Now in Rome, the President of Italy, Francesco Cossiga, met the Delegations, and heard the results of the encounters. With him was Cardinal Casaroli, the Secretary of State of the Vatican, linking as it were, the secular and the spiritual audiences, for he was also with His Holiness the Pope the following day to receive the Delegations in the Sala Regia, an audience chamber leading off the Sistine Chapel.

Most encouraging was the attendance of nineteen Cardinals at the Audience. They followed with interest as the Heads of the IACG Delegations explained the illustrations in the ESA publication 'Encounter '86', which had been specially printed for the occasion.

And finally the Pope addressed not only the congregation but the World on the significance of international collaboration in space sciences. The full text of his speech is reproduced later in this Bulletin, and the theme is one of the role international cooperation in space can play in reaching towards harmonious human coexistance.

I would like to quote one phrase which seemed to me to sum up his message. He suggested that if we continued to work together we would *'merit to be called peacemakers'.*

If the Inter-Agency Consultative Group can earn the accolade 'peacemakers', it will have achieved much beyond its immediate and future scientific aims and objectives. It will be another example of science lighting the way for others to follow.

1. ESA's Director General, Prof. Reimar Lüst, delivering an address on behalf of the IACG, in the Aula Magna of the University of Padua, on 3 November

2. Minister Luigi Granelli, Italian Minister of Research and Technology, making his address in the Aula Magna of the University of Padua, on 3 November

3

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3,4,6,7 & 8. Sixth Meeting of the IACG in progress in Padua

5. Comet Halley (upper centre) in the fresco in the Scrovegni Chapel in Padua depicting the birth of Christ, by the Florentine master Giotto di Bondone

6. Prof. K. Hirao (ISAS) presenting Japan's results to the IACG

7. Acad. R. Sagdeev (Intercosmos) presenting the USSR's results to the IACG

8. Dr. R. Bonnet (ESA) presenting the Giotto results to the IACG

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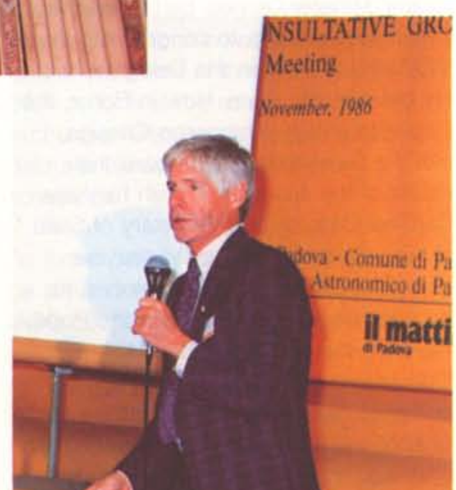

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Address to His Excellency The President of The Republic of Italy, Francesco Cossiga

by Prof. Reimar Lüst, Director General, ESA

Sala del Senato Accademico, University of Rome, 6 November 1986

Your Excellency,

We meet today to celebrate a great achievement in scientific cooperation which has captured the imagination of the World, and has laid solid foundations for future ventures. And it is right that we should hold this celebration in Italy, for it is not straining comparisons too far to draw parallels with the birth of the Renaissance, albeit that our efforts are on a much more modest scale.

It is a happy coincidence that one of the fleet of spacecraft that encountered Halley's Comet so successfully should have been named after Giotto di Bondone, to whom is traced the original impetus for the Renaissance. He in turn had been inspired to include Halley's Comet in his 'Adoration of the Magi'.

The Renaissance was a time of new departures, associated with a fresh understanding of the classical traditions. What we have witnessed through the efforts of the scientists and technologists working together under the aegis of the Inter-Agency Consultative Group has been a new departure in astronomy, one of the oldest and most traditional of sciences. The result of their labours has been a revolutionary new understanding of the nature of comets, those primordial remnants of the nebula from which the solar system originated.

The Renaissance spread from Italy to affect much of the rest of Europe. Perhaps this is the one respect in which we can make greater claims, for the Inter-Agency Consultative Group is truly global, as the four agencies taking part represent more than twenty nations.

The Renaissance was a time of movement of the human spirit, a rethinking of the lessons of the past. We see our efforts in a similar light. The spirit of cooperation kindled so enthusiastically by Professor Giuseppe Colombo when the Inter-Agency Consultative Group first met in Padua in September 1981 has burned brightly throughout the succeeding years.

To coordinate the scientific experiments to ensure the best possible data return, to exchange technical information and link widely dispersed systems and schedules into a common programme while leaving individual freedom for each Agency to develop its projects to conform with its own methods and means has called for patience, tact, understanding, and above all trust and goodwill.

The outcome was there for all to see as the data flowed onto the television screens around the World as well as into the computers of the scientists.

We, in the space agencies, have now had time to review our achievements and to put them into perspective. What we see are the advantages of working together, the challenges of melding different cultures, different approaches and different techniques, so that we may all benefit beyond the scope available to any one agency.

I am therefore pleased to report that not only are we celebrating an endeavour successfully completed, but also the decision to continue our close cooperation, extending it in the coming years to other scientific programmes of mutual interest.

The Renaissance grew from small beginnings to a general enlightenment. Let us hope that the space scientists and technologists have, by their cooperation during the many phases associated with the encounter with Halley's Comet, planted the seeds which could blossom in the coming decades into a long and fruitful cooperation based on trust and the sharing of effort.

Address to His Holiness Pope John Paul II

by Prof. Reimar Lüst, Director General, ESA

Vatican, Rome, 7 November 1986

Your Holiness,

We bring you today positive proof that science knows no boundaries when it is pursued in the name of peace and the furtherance of Man's knowledge of the Universe in which he lives.

For many thousands of years human beings have looked up at the stars, and across the panoply of the heavens they have observed the slow, majestic march of the comets. These wanderers have filled many with dread and foreboding, but at the same time they have stimulated others to think and probe more deeply.

Of all the comets that are visible from the Earth, none is better known than *Halley's Comet*, named after the scientist who first plotted its orbit, and correctly predicted its return, and by so doing gave fresh impetus to the study of comets and their place in the solar system. The regular visits of this Comet have been observed since 240 BC, and they have coincided with many of the dramatic events of history. Artists have portrayed the Comet: in particular the apparition of 1301 inspired Giotto di Bondone to include the Comet as the Star of Bethlehem in his fresco *The Adoration of the Magi* which adorns the Scrovegni Chapel in Padua, Italy.

It was therefore fitting that Halley's Comet, approaching the Sun once more on its 76-year journey, should be chosen for the first joint venture by the four space agencies to learn more of the nature and composition of this ancient traveller.

From the inception of the venture, the space agencies, and the international space-science community, strove together to ensure that this once-in-a-lifetime opportunity would not fail for lack of mutual trust and endeavour. The result was the largest space campaign ever undertaken.

Through the Inter-Agency Consultative Group, the scientists opened not only their doors, but also their minds and aspirations, and their expertise to each other. Thus was the fleet of spacecraft, which carried the instruments and hopes of Halley's successors, and the ground stations which guided and monitored them, prepared for the eventful encounter with the comet in the Spring of 1986. The American 'ICE' spacecraft, although passing at a very great distance from Halley, observed particles originating from the Comet's nucleus; the Japanese 'Sakigake' and 'Suisei' spacecraft passed closer, probing the outer layers of Halley's atmosphere, while the two Soviet 'Vega' spacecraft flew by even closer, penetrating deeply into the Comet's atmosphere. The European Space Agency's Giotto spacecraft was set to achieve the closest possible approach to the nucleus of the Comet. Yet the precise position of the nucleus within the far-scattered coma visible from the Earth was not known.

It was here that the sense of partnership manifested itself most strongly. The technologists came together to devise the Pathfinder Concept by which the Russian 'Vega' spacecraft would relay the latest information they had on the Comet nucleus through the ground stations so that 'Giotto' could be guided on its final approach. But this information, in itself, would not have been sufficient unless the exact location of the 'Vega' craft were known. The United States offered its Deep-Space Network to provide the delicate accuracy required to furnish the answer. The effectiveness of this internationally inspired collaboration was witnessed across the World as the television screens recorded the exciting last moments of the encounter. We have seen, for the first time, the nucleus of Halley's Comet, the fount of all the activity which provides such a spectacular display during the Comet's closest passage to the Sun.

During the succeeding months, the cooperative spirit has remained, as scientific data have been exchanged and analysed, and the Comet has given up many of its secrets. The recent Symposium in Heidelberg on the Exploration of Halley's Comet brought together scientists from all continents and space missions to exchange information on their discoveries. Man's knowledge of the origin of the solar system has edged a little further forward, and the way is open for fresh explorations.

Of equal importance has been the joint nature of the venture. I am, therefore, delighted to announce that the Inter-Agency Consultative Group will remain in being, bringing together scientists and technologists from many races and creeds to explore the Universe around us. We all applaud the growth of belief in a common fellowship born of the quest for knowledge, by which Man can unshackle the chains of ignorance and step confidently into the future in peaceful union.

Prof. Reimar Lüst, ESA's Director General, making his address on 7 November 1986 in the Sala Regia, in the Vatican, in the presence of His Holiness Pope John Paul II. His Eminence Cardinal Casaroli is seated on the Pope's right

photo: arturo mari, vatican

Address by His Holiness Pope John Paul II

Vatican, Rome, 7 November 1986

Distinguished Men and Women of Science, Ladies and Gentlemen,

It is my great pleasure to extend a cordial welcome to all of you this morning. I am honoured first of all by the presence of the distinguished Delegates of the Inter-Agency Consultative Group who are meeting in Rome at the invitation of the President of the International Centre for Relativistic Astrophysics. I am also pleased to greet the esteemed experts engaged in the study of this scientific undertaking. My respectful greeting also goes to the Cardinals here present and to the members of the Diplomatic Corps accredited to the Holy See, who have joined us and who give this occasion a special solemnity.

I wish to commend this splendid initiative which brings you together and which seeks to foster even more effective international collaboration in the space sciences. It is indeed a kind of celebration of scientific cooperation, a celebration that can offer hope to men and women of science, as well as to all people of good will, as they seek to identify those areas of knowledge and concern that unite the human family rather than divide it. The participation of the Vatican Observatory serves to illustrate the desire of the Church to encourage these worthy endeavours and to contribute, as far as possible, to the realisation of the noble goal of harmonious human co-existence, in the achieving of which science can play an active and vital part.

Many means have been employed in the search for lasting peace in our World. These include negotiation, political compromise and economic bargaining. Recently at Assisi I proposed to the World that peace must be sought through another means, namely through prayer, 'which, in a diversity of religions, expresses a relationship with a supreme power that surpasses our human capacities alone'.

There is yet another way, one that we commemorate today, namely that of collaboration in a scientific endeavour which transcends all national boundaries and requires knowledge and dedication to science and technology by men and women of many nations, races and creeds. Last week, in commemorating the Fiftieth Anniversary of the Pontifical Academy of Science, I spoke of the great esteem which the Church has for scientists, not only for their intellectual prowess, but also for their moral character, their intellectual honesty and objectivity, their self-disciplined search for truth, their desire to serve mankind, and their respect for the mysteries of the Universe which they explore.

As an example of this kind of scientist, I would like to recall today the late Giuseppe Colombo, beloved member of the Pontifical Academy of Sciences, who encouraged a unique way of exploring the material from which our own solar system was formed: a space mission to Halley's Comet at its approach to the Earth earlier this year. He proposed this project from one of the World's oldest universities, located in the city of Padua, where the modern scientific era had its beginning through the research and teaching of such great scientists as Galileo Galilei and Giovan Battista Morgagni. Near that University — in the Cappella degli Scrovegni — Giotto, from his vivid memory of an early passage of the Comet, depicted it as the star of Bethlehem in his painting of the Adoration of the Magi. It was in this setting that your Inter-Agency Consultative Group was formed in 1981 and began the planning of the now famous space mission to Halley's Comet.

This 'Padua Group' made the dream of Giuseppe Colombo come true. I congratulate you not only for the progress you have thus made in the understanding of the physical, chemical, and astrophysical aspects of this Comet, but also for the example you have set by this dedicated collaboration. It is an impressive achievement that so many scientists and so many means have been employed in a real-time collaboration over the whole surface of the Earth in order to obtain scientific results from space.

It is a source of pride for all of us to realise that in just four decades, with the collaboration of Government leaders and politicians, scientists have redirected the space technologies, which saw their first rudimentary steps in the horrors of the Second World War, towards the exploration of God's Universe. Through your dedicated efforts, based on high moral standards, you have brought space science from systems carrying death to systems designed for the peaceful pursuit of knowledge: on issues ranging from the large-scale structures of the Universe, to the life and death of stars, to the analysis of our own planet Earth.

As part of your collaboration, from Kagoshima, in Japan, only a short distance from Nagasaki, the World witnessed the beautiful lift-off into space of the two satellites 'Sakigake' and 'Suisei'. Through the efforts of the people of the Soviet Union, which also had been

photo: arturo mari, vatican

Pope John Paul II receiving Prof. Lüst, in the presence of Cardinal Casaroli

desperately tested by the horrors of World War II, were developed and launched the 'Vega I' and 'Vega II' satellites, first directed to Venus and then deployed in your comet mission. In a truly remarkable collaboration of your agencies, the Deep-Space Network of the United States of America was then able to use those four satellites in order to direct the course of the European space probe 'Giotto' to be aimed very accurately at its encounter with the Comet. This is one example among many in which you and your colleagues, through your talent and courage, have shown the way to the collaborative exploration of the marvels of the Universe.

I hope and pray that all of the scientists and engineers in your space agencies will continue to work together in your explorations and thus merit being called 'peacemakers', in addition to your other worthy titles.

As we celebrate this day of achievement, let us all remember the brave men and women who have courageously given their lives for the conquest of space, in an effort to reach beyond the horizon.

I take the opportunity of this solemn occasion, when you are all gathered here together, to beg you to continue in the direction of peace and harmony, which has characterised the progress of the space missions that we commemorate today, and to renew your efforts to avoid any possibility that space technology should ever become any type of hostile endeavour.

The pictures that space missions have transmitted back to Earth, some examples of which we have seen today, show us how small and delicate planet Earth is, and indeed how tiny the planetary system itself is, in comparison with our Galaxy and with the immensity of the Universe.

Yet we live in a special time. Using the talents given by God, people of science have been able to develop unprecedented means of obtaining knowledge. Extraordinary means of transportation and communication have been developed. Computers have reached capacities and speeds previously unimaginable. Serious plans can now be made for space stations, space colonies, and for manned missions to planets as far away as Mars. Scientists and technologists are developing the possibilities of making the whole planetary system a home for the human family. But all of these developments will lead to truly significant results only if they are employed within the framework of a new humanism, where spiritual, moral, philosophical, aesthetic, and scientific values are developed in harmony, and where there is a profound respect for the freedom and rights of the human individual.

May your work continue to be an inspiration for all humanity and may Governments devote their political power to guarantee that the new era of the 'planetary system as the house of man' will be for the spiritual and material well-being of all humanity.

I wish to express my gratitude to you for the book 'Encounter '86', which you have presented to me and for the explanation that you have given of the photographs which it contains. I compliment you on this achievement and thank you for sharing it with me.

I also wish you to know how much I appreciate your field of science, and how much I admire the contribution that you are making to it. Your science opens up to man so many of the wonders of the Universe, and leads him in a new and deeper way to be aware of its greatness. Your scientific research and discoveries are likewise capable of becoming effective instruments for a more profound understanding of man, for whose well-being the whole adventure of science is conducted.

In penetrating the depths of the Universe with its laws and marvellous secrets, science leads man to understand the incomparable level of his own greatness. And it is precisely at this point that man can perceive ever more clearly his dependance on the Creator and the centrality of his own role in relation to the Universe. The greatest glory of the Universe is to lead man to a true perception of himself as he grasps the reflection of the Creator in nature. And in this perception of himself, he is led to acknowledge and adore the glory and majesty of God. The majesty of God, the dignity of man and the beauty and order of the Universe are all linked in the discoveries of science.

May the Lord of Heaven and Earth bless you and strengthen you in all your work for the good of man, who is made in his own image and likeness.

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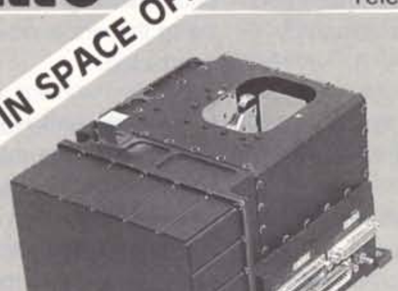

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Terrestrial Mobile Communications

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Whilst national mobile communications are already provided or will be provided soon through ground-based cellular networks in a number of European countries, there is as yet no European standard system for international mobile communications traffic. Various market surveys have shown that even if a pan-European ground-based system were in operation, a satellite-based system would still have a role to play. In particular, it could serve the low-density areas within Europe where the installation of cells might not be economic, and also trucks and cars travelling further afield, for example in the Middle East and North Africa. It would also provide potential users of private wide-area mobile communications networks with direct access from small earth stations, for both voice and data communications.

Introduction

Terrestrial mobile communications are expanding rapidly in Europe. Whilst private mobile communication systems have already been used for many years by professional organisations to communicate with their mobile fleets (taxis, ambulances, etc.), public systems of the cellular type are relatively new in Europe. The latter consist of transmit/receive stations, each serving a cell (coverage area associated with a given station) and interconnected with the switched telephone network. They are basically wide-coverage systems enabling any subscriber to communicate with any suitably equipped mobile unit within the coverage of the transmit/receive stations.

The first cellular system in Europe, the Nordic Mobile Telephone (NMT 450), was established in 1981. Operating at 450 MHz, it covers Denmark, Sweden, Norway and part of Finland. Since its inception, the number of subscribers has grown by 25% per annum, which is 300% above initial forecasts. The NMT 900 system currently being implemented to cope with this growth in traffic is likely to give the Scandinavian countries the worldwide leadership in mobile communications.

In the United Kingdom, two cellular systems (operating at 900 MHz) were put into operation in January 1985: the 'Cellnet' and the 'Vodaphone' systems. By June 1985 the number of Vodaphone subscribers had already reached 7000, and the Cellnet membership 9000. The total number of subscribers is expected to reach 500 000 by the end of 1989.

Cellular systems are also being implemented in Germany, France, Belgium and Switzerland, and other European countries are likely to follow suit. All of the cellular systems already in operation in Europe, or coming into operation shortly, are national systems, and most are mutually incompatible.

In 1982, the CEPT established a working group — 'Groupe Services Mobiles' (GSM) — with the specific task of defining a standard for the future pan-European cellular system. Their time schedule foresees completion of the specifications for the pan-European system in 1988 and the starting of operations in 1991. This system will operate at 900 MHz and will provide high-quality digital voice as well as data communications. One of the problems that remains to be solved by the GSM is the choice of modulation, encoding and access schemes, for which a number of proposals have already been submitted by various CEPT Member States.

Market surveys performed by ESA and other organisations have shown that the potential number of subscribers to the pan-European cellular system could exceed 7 million by the year 2000. Table 1 shows a breakdown of this expected subscriber population in terms of types of services and mobiles. Not surprisingly, the majority of potential subscribers are in favour of the telephone service, though the total number that would use either a message/data service or both telephone and data services is significant and might well increase in the future.

Mobile satellite telecommunication services

In the light of this rapid expansion of cellular systems in Europe and the prospect of the future pan-European system planned for the 1990s, the two questions that come to mind are: What is the future of satellite-based systems in Europe? and, What role can they play?

Clearly, a satellite system could not compete with the existing European mobile systems, let alone with the future pan-European system, in terms of system capacity, cost, spectrum efficiency, etc. However, a satellite system should be considered for what it can best provide, namely

— wide-area coverage
— flexibility.

Wide-area coverage is certainly a major point in favour of satellites, as it allows the extension of system coverage into coastal waters and into regions economically important to Europe, such as the Middle East and North Africa. It also offers the possibility to complement radio cellular systems in low-density areas, albeit with the problem of system and frequency compatibility.

Flexibility is also a major advantage of the satellite system, translating into rapid implementation of new services, and the ability to adapt to new and changing situations. A satellite-based system would also enable the provision to potential users such as large trucking companies of private wide-area mobile communications networks with direct access to the satellite from small earth stations on the user's premises. Such a facility might also be offered in a cellular system, but only for local applications (e.g. in one or two cells).

Table 1 shows the breakdown of the potential subscribers to a satellite-based system as a function of service type. As for cellular systems, the majority are in favour of the telephone service. At least 1500 telephone channels would be needed in order to meet forecasts for the year 2000, which is currently a very ambitious objective as it would require a satellite antenna of at least 10 m diameter and a transmitter power of a few kilowatts, assuming toll quality for the telephone service and use of very light, cheap mobile terminals with isotropic antennas. It goes without saying, therefore, that prior to any final decision with regard to major hardware developments in preparation for an operational satellite system for the 2000s, very detailed investigations of both mission and technical aspects need to be carried out.

Among the key factors that could strongly influence the required satellite performance characteristics, first comes the mixture of telephone/data channels to be provided. As telephone channels require much more satellite power than low- and medium-rate data channels, the user needs must be carefully analysed. The establishment of an initial pilot system that would provide experimental/pre-operational data and telephone channels on a limited scale would allow assessment of the user needs in a real environment. Those who are not used to message/data services might finally find them very convenient for most of their professional communications. The higher tariffs that will have to apply to voice communications could lead them to limit their use of the telephone service to exceptional communications only.

The adoption of a very efficient modulation scheme for voice

Table 1 — Market survey of potential subscribers from CEPT countries

User categories	1995 Cellular	1995 Cellular + satellites	2005 Cellular	2005 Cellular + satellites	Types of service
Cars/trucks <10 t	1 200 000	25 000	1 400 000	30 000	Paging (uni-directional)
Trucks >10 t	63 000	5 000	77 000	6 000	
Cars/trucks <10 t	340 000	9 500	400 000	11 500	Message + data (bi-directional)
Trucks >10 t	46 000	3 600	56 000	4 400	
Cars/trucks <10 t	3 900 000	197 000	4 500 000	240 000	Telephone
Trucks >10 t	200 000	27 000	246 000	33 000	
Cars/trucks <10 t	636 000	30 000	744 000	36 000	Telephone + data
Trucks >10 t	35 000	12 000	42 000	14 000	

communications is another key factor. 16 kbit/s vocoders providing toll quality are already available in Europe at low cost. Vocoders for civil applications operating at 9.6, 4.8 and even 2.4 kbit/s are being studied in a number of European firms and laboratories. It can be taken for granted that 9.6 kbit/s vocoders will soon achieve the quality standard normally associated with terrestrial telephone networks.

Very promising results have also been obtained in Europe with vocoders operating at 4.8 kbit/s, which provide a quality that might eventually be acceptable as a standard for mobile applications. Finally, the 2.4 kbit/s vocoders would be suitable for those mobile applications that could be satisfied with 'intelligible' voice communications.

The satellite performance requirements are also highly dependent on the mobile terminal's characteristics. The adoption of mobile terminals with higher antenna gain for voice communications would make a satellite telephone service more economic. The drawback of such enhanced terminals is not really the size of the antenna nor its cost, which could be kept within reasonable limits, but rather the need that may occur under certain circumstances for repointing of the antenna.

Another important consideration that could strongly influence the satellite performance requirements is the number of users of private satellite networks. Whilst in public systems a quality standard that satisfies the majority of users must be adopted, the situation is different in a private system: toll quality is no longer required and vocoders with lower bit rates (e.g. 4.8 and even 2.4 kbit/s) could be adopted.

The combination of the above factors could well lead to a significant relaxation of the satellite performance characteristics, particularly in terms of satellite antenna size and radiated power. An initial pilot system in the early 1990s would allow new technical options to be assessed and demonstrated, new services (e.g. paging, bi-directional message/data delivery), to be promoted, user requirements to be refined and finally freezing of the specifications for an operational mobile satellite to be put into orbit by the year 2000. It would also enable operational mobile communication services to be provided earlier, albeit on a limited scale, and hence stimulate traffic expansion in preparation for the future operational system.

The frequency question and the system architecture

It is not the purpose of this short presentation to dwell on the problem of frequency allocation for the satellite—mobile links for land-mobile applications, this matter being dealt with in another forum in preparation for the next mobile World Administrative Radio Conference (WARC). ESA does not have a very strong preference for either of the two possibilities now under consideration, namely UHF (800 MHz) and L-band (1500 MHz). The most important need is to have a frequency allocation established in order to kick-off the technology development programme.

For commonality with other fields of mobile satellite communications and the possibility of better system integration, L-band is preferable, but this choice in fact has little influence on the system architecture. The US Administration has already taken steps in favour of a frequency allocation at L-band shared with aeronautical satellite services. More important is the selection of frequencies for the feeder links between the base stations and the satellite. The 6/4 GHz band is very congested and would imply the use of large antennas to access the satellite, thereby ruling out 'business services'. Higher frequency bands offer better prospects; 14/11 GHz would certainly be a good compromise, but the 30/20 GHz band would be less congested. The use of high frequencies presents major technical problems for low-data-rate satellite systems, but it could ease the implementation of private land-mobile networks with base stations installed on the user's premises.

ESA activities in the field of land-mobile satellite systems

ESA is conducting several types of activities in order to prepare itself for these satellite missions, which are very challenging in terms of technology. These activities encompass promotion activities as part of the PROSAT programme, now in its second phase, and long-term technological developments such as large antenna structures and onboard processing techniques. Phase I of the PROSAT programme provided valuable information concerning the design of terminals and their propagation characteristics (Fig. 1). Phase II has as its objective the demonstration of various low-data-rate services with full interconnectivity to public data networks. This will illustrate how satellite-based communication systems can in future play a complementary role to conventional terrestrial systems.

The PROSAT programme encompasses the three basic fields of applications of mobile communications, namely maritime, aeronautical and land mobiles. Of the 30 terminals that are being developed for the purpose of Phase II demonstrations, 10 are land-mobile terminals that will be installed on trucks and other types of vehicles. Because the PROSAT programme relies on the use of an existing satellite (Marecs) that is being exploited by the Inmarsat Organisation, the scope of the programme had to be restricted to data communications only, the satellite already being loaded with maritime communications traffic.

ESA is now proposing to proceed with the next step, which will be aimed primarily at the immediate development of a pilot satellite system and

Figure 1 — Test vehicle equipped with low-gain antennas, used during the PROSAT phase-1 campaigns

corresponding infrastructure. This will involve the placing in orbit, as soon as possible, of a payload with sufficient capacity to achieve these aims. The services provided will include (as in PROSAT II) low- and medium-rate data transmissions to small terminals and in addition voice communications at 9.6 kbit/s (or less) with enhanced terminals. The pilot system will also be used to demonstrate new mobile private-network satellite services.

The satellite performance characteristics envisaged for the pilot system are summarised in Table 2. A typical coverage pattern is shown in Figure 2. Detailed payload definition is likely to be completed by mid 1987, but a decision on the frequency allocation is needed before the final payload configuration can be frozen.

In addition, long-term developments are taking place in the domain of large antenna structures and onboard processing techniques, which will be required to cope with the expected traffic in the late 1990s. Several study contracts aimed at identifying the technological developments required and assessing the feasibility of such concepts have been placed with industry.

The low-data-rate PRODAT system
As already mentioned, a comprehensive test programme to investigate propagation conditions and their impact on end-to-end mobile link performance was carried out in the framework of Phase I of the PROSAT programme. Based on the experimental data that were gathered, a number of system concepts were defined and analysed. One of them, called 'PRODAT', a low-data-rate system suitable for very simple land-mobile terminals, is currently being implemented for the purpose of Phase II demonstrations.

The PRODAT system will provide the full range of low-data-rate services that could interest potential mobile users, including:

- sending of messages from fixed to mobile users and vice-versa, and from mobile user to mobile user
- sending of messages to multiple mobile users (broadcast)
- request/reply functions
- periodic polling of mobiles
- paging.

The system has been designed to operate with communications satellites of the present generation, such as Marecs, and to cope with the deep fades or even complete blackouts that may occur in a land-mobile link under certain circumstances, particularly at low elevation angles and when link visibility is affected by buildings, bridges, trees or mountains.

A communications system designed specifically for such extreme conditions would be inefficient as it would involve protocol and coding overheads that are unnecessary for most of the time. PRODAT is a system that adapts itself to the link characteristics, and minimises protocol and coding overheads when the link is good, but is still able to cope with most of the bad link conditions. This is achieved by means of a new Automatic Request for Retransmission scheme and bi-dimensional Reed—Solomon coding. The same concept is used in both satellite-to-mobile and mobile-to-satellite links, although the access/multiplexing schemes are different. Time-division multiplexing is used in the satellite-to-mobile link, and code-division multiple access in the other link. The latter scheme is particularly well adapted to the random-access function required in the mobile-to-satellite link. It also has a number of other advantages, such as good protection against interference and simplicity of the mobile transmitter.

Conclusions
Market surveys have shown that there is a potential demand for future land-mobile satellite communication services in Europe. However, a number of critical issues need to be clarified prior to freezing the specifications for the first operational satellite system. The most important are without doubt the mix of telephone/data channels to be provided and the communications traffic volume that would eventually be generated if private satellite networks were to be offered to potential users. The course of action that has been briefly described in this article should allow an accurate and realistic mission scenario and associated satellite system configuration to be defined for an operational space segment to be put into orbit by the year 2000.

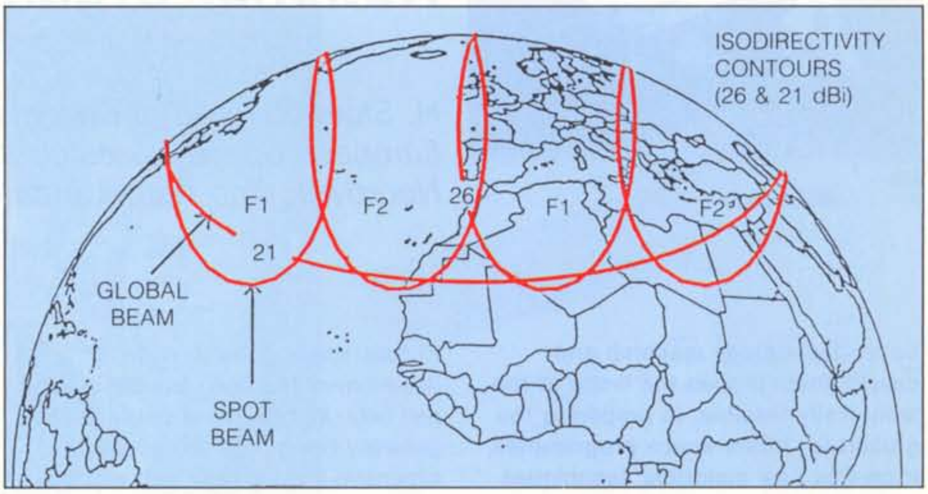
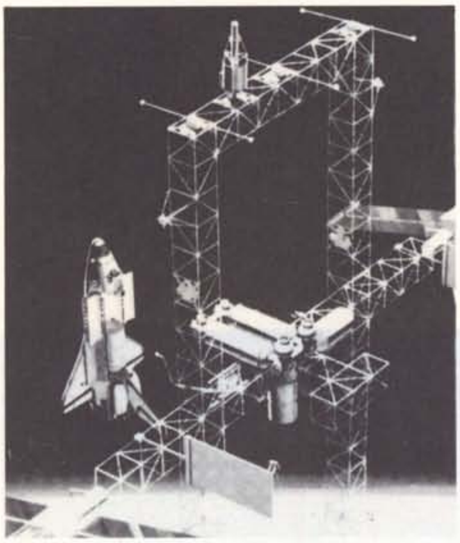


Figure 2 — Typical communications satellite coverage pattern for the northern hemisphere relying on reuse of two transmission frequencies (F1 and F2) in non-adjacent beams

Table 2 — Satellite-performance characteristics envisaged for the pilot system

System capacity	
— **Land-mobile system**	
Private networks	30
Public telephony channels	30
Low-speed data:	
• Forward-link TDM carriers	4
• Return-link CDMA channels	100
— **Aeronautical system**	
Public telephony channels	30
Comms.-quality telephony channels	5
Low-speed data:	
• Forward-link TDM carriers	4
• Return-link CDMA channels	50
Minimum L-band EIRP	44 dBW
Satellite L-band G/T	−2 dB/K
L-band coverage	cf. Figure 2



Space Technology Utilisation — The Role of ESA and National Organisations*

H. Stoewer, Head of Systems Engineering Department, European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands

Space technology research and development probes the limits of the technically feasible. In preparing the ground for future space programmes, it creates new materials, techniques and products — both hardware and software — that eventually find their way into commercial applications and 'everyday' industrial and household consumer goods. Past investments in space research and development have already led to the creation of numerous organisations exploiting space-derived technologies for commercial profit, and there are more opportunities to come.

*Based on a presentation made at the Space Commerce '86 conference, 16–20 June 1986, Montreux, Switzerland.

To date, space research and development has been feasible in large part only on the basis of public funding, generally being regarded as too expensive and too risky, and with too small a market, to attract investment from private enterprise. This is, however, no longer true for some areas and one can speculate to what extent these barriers to progress will still apply in the 21st century!

Technology transfer to non-space products — the 'micro perspective'

Myths and truths are strongly intermixed even when insiders discuss the question of the 'pacemaker' function of space technology and the associated 'spin-off' and technology-transfer questions. Articles like this one often start by recounting the overworked stories of the Teflon pan and the transistor radio, but there are many genuinely better examples of space-derived spin-offs. In the methodology domain, for example:

— One European car manufacturer, who more on an occasional than a systematic basis participates in space R&D, noted that one of the more important things appreciated from the recent development of the high-temperature furnace for materials-science research on Spacelab was the rigour and quality of ESA's electromagnetic compatibility (EMC) specifications (Fig. 1). These, apparently, are now being used for automobile development!

— The ESA-developed software standards and management guidelines have been noted by a broad community of non-space software developers as a useful tool (Fig. 2). They delineate a step-by-step development and verification approach and enhance the configuration control, interchangeability and efficiency of complex software packages during their life cycle and should thereby help to reduce costs substantially.

In the area of space hardware, it is particularly noticeable how quickly advanced space technology is nowadays being applied in the medical field; for example:

— An ESA-developed breath analyser, which registers changes in the constituents of a person's breath on a real-time basis and was developed to monitor the health of astronauts in orbit, is already finding clinical applications (Fig. 3).

— A microbiological safety cabinet, developed for storage and containment of pure or harmful biological substances in orbit (Fig. 4), seems to be finding its way into hospitals for similar applications.

— New infrared array detectors are being pursued for thermography in general (thermal mapping of, for example, residential or industrial areas to detect temperature differences, heat wastage, etc.) and medical mammography in particular (a technique used in the medical field to detect minute temperature differences in human tissue, caused for example, by a developing tumour)(Fig. 5).

Figure 1 — ESA astronaut Ulf Merbold working in orbit with the Gradient Heating Facility aboard Spacelab-1 in December 1983

Figure 2 — Two examples of ESA-developed software standards now finding much wider application

Figure 3 — Early prototype of an infrared respiratory-gas analysis system developed by the Sira Institute (UK) under ESA contract

Figure 4 — The microbiological safety cabinet, or 'glove box', originally developed by ESA for use on manned spacecraft

Figure 5 — Example of infrared detector arrays for optical imaging, developed under ESA contract

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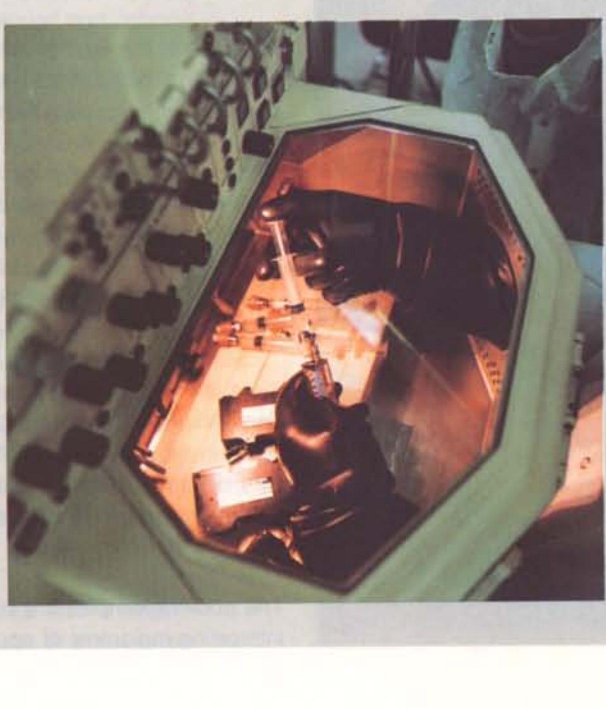

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Figure 6 — The Space Telescope's solar-array blankets deployed on a water table at British Aerospace in Bristol (UK)

Some of the more classical examples of spin-off originate from the fields of energy generation and thermal insulation. Here the space requirements are particularly severe in that on the one hand every Watt of electrical energy is expensive in terms of mass and launch cost, while on the other the extremes of space (temperatures ranging from near zero degrees absolute to many hundreds of degrees) dictate the use of highly effective, lightweight insulation materials and coatings to ensure a proper temperature balance for the spacecraft:

- The photovoltaic solar generators that convert sunlight into electrical energy and which today find application in electricity plants in countries with good sunshine statistics or even on ocean buoys in the far northern hemisphere, were orginally developed for space applications (Fig. 6).
- Super-insulating materials which have many applications in today's most modern buildings, in our winter clothing, and in emergency blankets for accident victims, are derivatives of the aluminised or goldised mylar or kapton multilayer insulation foils so prevalent on the majority of space-vehicles (Fig. 7).

Although in the field of 'robotics and automation' two distinct lines of development can be observed:

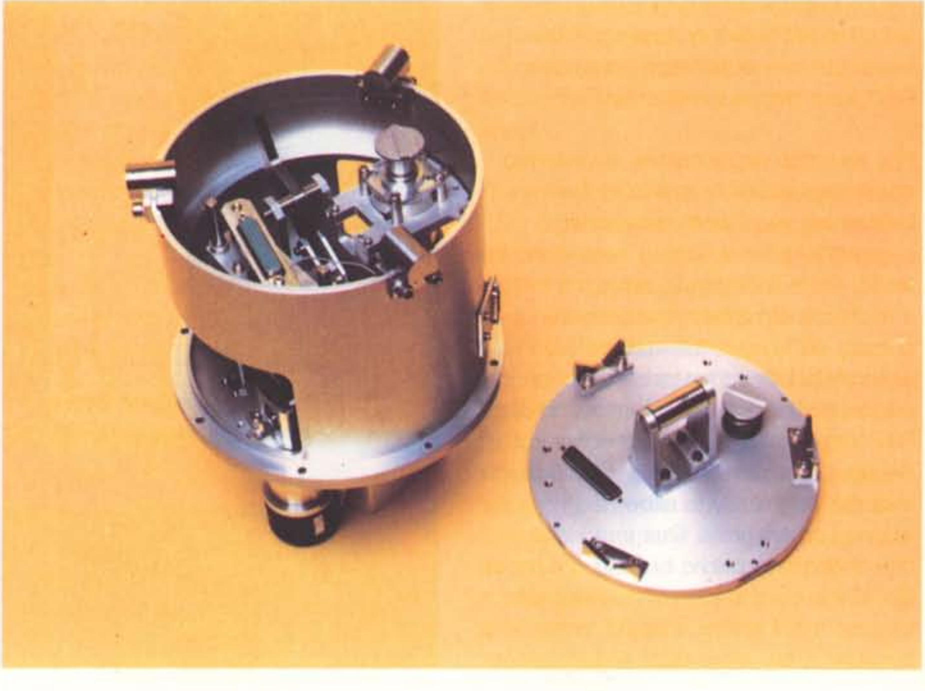
- one for terrestrial applications, e.g. as aids in the car manufacturing or nuclear materials handling processes
- and one for space applications, for example, on lunar and planetary probes and as manipulators for the Space Shuttle,

there is every likelihood that the more demanding requirements of space will result in the foreseeable future result in very dextrous, sensory-feedback, fine-control systems that will generate spin-off terrestrial applications (Fig. 8).

The above examples are but a few interesting indicators of applications

Figure 7 — Thermal blanketing (gold-coloured film) on the Agency's ECS-3 spacecraft photographed at Matra's premises in Toulouse (F)

Figure 8 — Breadboard model of a robotic end effector



pursued by researchers or companies who work outside the space domain. The president of a large European industrial conglomerate with one space division once noted in a throw-away remark that he systematically 'grows' his system engineers and managers in the space division and then assigns them to his terrestrial-products divisions — certainly a novel form of space technology (know-how) transfer if it is indeed true.

Reflecting back on the theme of this article, the role of ESA and the other space organisations must certainly continue to be to encourage the transfer of technologies, the spin-off to the commercial 'terrestrial' sector of industry. Technology resides in patents, in researchers, scientists and engineers, in drawings, block diagrams, materials, components, methods and software. It is important therefore that their exploitation be encouraged, that technology accomplishments be published and made accessible to a broad industrial community having a right to use them, and that the inventors and knowhow bearers are motivated to apply their knowledge in the commercial world. This is not an easy process, and it relies on a good interplay between industry, the research laboratories and national institutes.

ESA's patent and intellectual-property conditions are designed to be commensurate with the promotion of technology transfer. They grant broad rights for commercial exploitation to those companies and organisations that have accrued specialised knowhow in the context of their space technology research for ESA.

ESA's publications are also widely disseminated. The Agency operates an extensive database at its ESRIN facility in Italy which is accessible to a broad community.

There is, of course, also a lot of technology transfer in the reverse direction from terrestrial-product R&D to the space domain, such as in the fields of microelectronics and software, where adapting advanced commercial products to space applications very often proves a worthwhile course of action. Nonetheless, the impact of space R&D on the terrestrial industries is substantial and highly effective, considering the space sector's relatively modest funding in Europe compared with other areas of the economy.

Investment and utilisation potential — the 'macro perspective'

At the height of the Saturn/Apollo Programme, Wernher von Braun was quoted as saying that space technology had taken over the 'leading edge' of scientific and engineering advance from the military field, which, as he saw it, had fulfilled this 'pacemaker' function for many centuries. The role of such organisations as NASA and its European equivalents ELDO and ESRO, which later merged to become ESA, was then to provide the stimulus, money and methods to enable space technology to develop for roles which, setting aside political motives, were mostly scientific in nature in those early years. This role has not changed with the passing of the years, but true applications of space R&D have become more plentiful.

The few state organisations sponsoring space work have multiplied in the intervening years and many sister organisations have sprung up around the world. More importantly, there are today a multitude of organisations whose primary purpose is not space R&D in general, but its commercial utilisation in particular. Through the sponsorship of R&D organisations, in just a couple of decades, space technology has indeed matured sufficiently to allow its exploitation for profit. One important objective of the public funding of space would therefore seem to have reaped tangible initial results. I would stress initial because many more such organisations will doubtless follow in the coming decades.

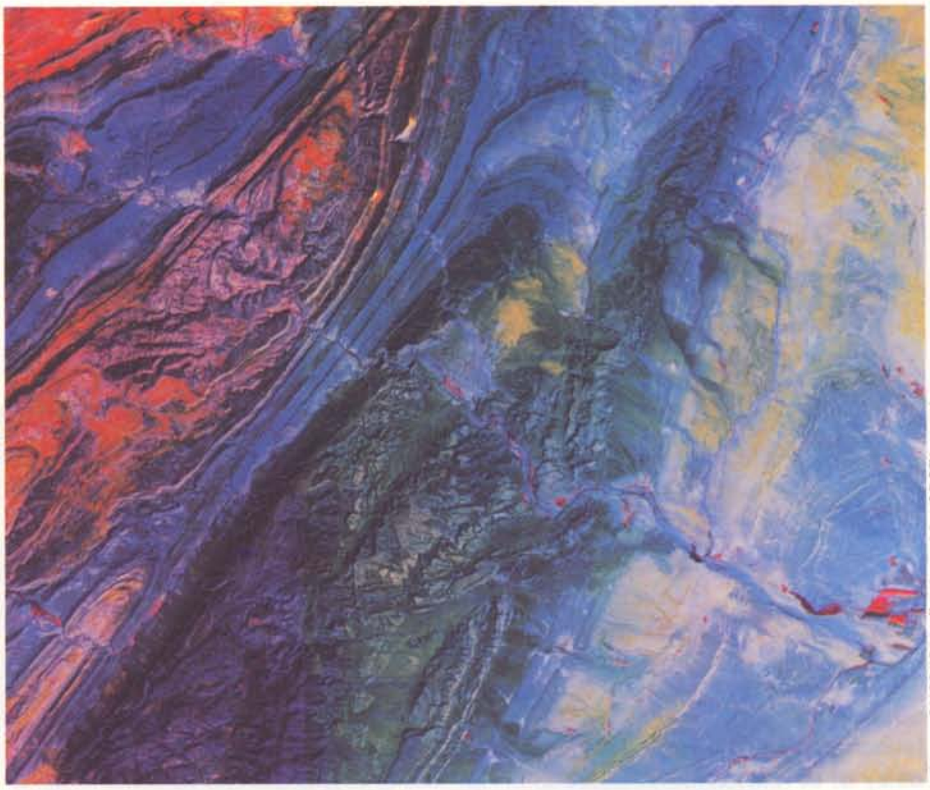
Figure 9—An Ariane launcher on the pad at ESA's Kourou launch base (French Guiana)

Some of the more noteworthy organisations that have already been set up to exploit space technology are:

- EUTELSAT, the European Telecommunications Satellite organisation, charged by the PTTs with setting up and operating European telecommunications services. This they do with spacecraft developed by ESA or by national space agencies.
- EUMETSAT, the European Meteorological Satellite organisation, charged with the utilisation and dissemination of meteorological information derived principally from ESA-developed satellites.
- INMARSAT, the International Maritime Satellite organisation, providing ship-to-shore communication services on a global basis, using both European-developed and other spacecraft.
- INTELSAT, the International Communications Satellite Organisation, providing a variety of telephony and other communications services for the industrialised and the developing countries. INTELSAT's satellites are derived from the technologies sponsored originally by governmental organisations such as ESA and NASA.
- ARIANESPACE, the European organisation set up to provide launch services to worldwide customers based on the ESA-developed Ariane launcher family (Fig. 9).
- INTOSPACE, a newly-founded German company set up to market microgravity research and manufacturing based on the ESA-developed Spacelab and Eureca vehicles.
- SPOTIMAGE, a company offering global Earth-resources data obtained from the SPOT Earth observation satellite(s), developed by CNES.

These examples suffice to underline the

Figure—10 Early image taken over Algeria (Atlas mountains) by the French SPOT earth-resources satellite



(Photo CNES-IGN, distributed by SPOT-Image)

fact that one of the roles of ESA and state organisations alike is to create space technologies and capabilities that can form the basis for later (commercial) exploitation by newly-created organisations or companies. This approach has already borne ample fruit in an amazingly short period, bearing in mind that Europe's first small scientific satellite was launched only in the 1960s.

To appreciate the magnitude that some of these enterprises have assumed, one needs only to look at their business turnover and their profit margins. The total cumulative investments of INTELSAT over a recent nine-year period (1976–1984) amounted to over 2000 million US$, reaching levels of 400—500 million US$ per year in the later years. This includes a total cumulative investment in the space segment alone of about 1400 million US$.

INMARSAT, in its first years of existence, with investments still running well below 100 million US$ per year, has experienced growth rates in the 40 to 70% ranges, for telex and telephony services, respectively, and today operates its own satellite network.

ARIANESPACE currently has launch orders from customers around the globe totalling billions of US dollars.

Looking towards the 21st century, one could well imagine new commercial organisations blossoming, such as:

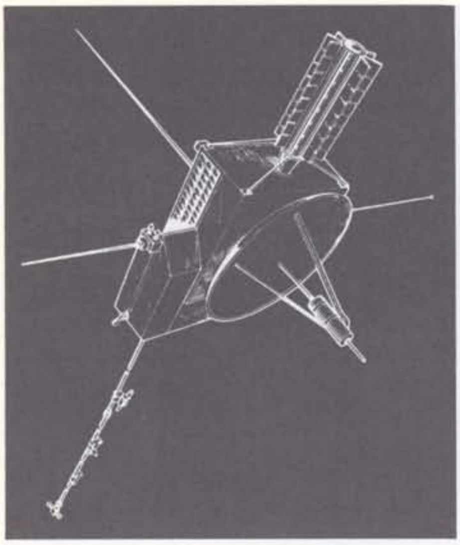
— 'SPACEMAC', a company providing services for manufacturing new products in space and operating a (free-flying) space factory e.g. not far from the International Space Station, of which the European Columbus will form a part.
— 'SPACERESCUE', an organisation specialising in providing emergency telecommunications, navigation and positioning services for disaster-relief operations anywhere on Earth.
— 'ECOLOSPACE', an organisation set up to monitor Earth resources and pollution, i.e. water quality, soil purity and air-cleanliness, on a global basis.
— 'AGRISPACE', an organisation charged with collecting data on the agricultural outputs of all countries, from earth-observation satellites. Such data could be used to coordinate future planning for agricultural products and reserves leading to more effective food production, to the benefit of all.
— 'ENERSPACE', an organisation collecting and converting solar energy in space and beaming it to the industrialised nations.
— 'SPACEMINES', a company that could take over the task of mining and retrieving rare materials from the Moon, planets or asteroids, an activity that is thought by several far-sighted entrepreneurs to be very attractive once the transportation costs have dropped sufficiently.

Which of these and other such enterprises might actually materialise depends not so much on the 'space technology' needed to provide the basic data, but more on the economic trade-offs between space and alternative technologies. Their initiation and growth will also be strongly influenced by the political will of Governments to work together and utilise such new services. Even in the fields where organisations are already operating successfully, this political aspect been a much more serious obstacle to the application of space technologies in the past than the ability of the scientists and engineers to provide the necessary capabilities. It is more the fundamental human resistance to change, and the fear of 'opening the flood gates' for space exploitation, as well as deep-seated economic interests, that may pace the progress of space-technology utilisation in several new fields.

Conclusions

In the less than three decades of its existence, space R&D has spun-off a variety of viable space-exploitation organisations, a trend that ESA and other national space organisations not only encourage, but actively help to bring about.

The role of ESA and of similar national R&D organisations in this process will continue to be one of serving as the 'motor' for advanced high-risk developments, and as the 'promoter' of their commercial application. The space industry is still a dwarf beside the world's established multinational industries, but the growth perspectives are extraordinarily good. Clearly, the ratio between public expenditure and private investment in space will continue to shift as the market and profit prospects for space products increase.



Ulysses — The Voyage Must Wait

R.G. Marsden & K.-P. Wenzel, Solar and Heliospheric Science Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

The joint ESA—NASA Ulysses mission that was scheduled for launch in May of this year faces a delay of at least three years as a result of the Challenger explosion. Declared ready for flight at the beginning of the year, the spacecraft and its scientific payload have now entered their second storage period.

Introduction

The ill-fated launch of Shuttle Mission 51-L on 28 January 1986, ending in the loss of Challenger and its seven crew-members, has had far-reaching consequences for many aspects of space exploration and utilisation. Among the scientific missions affected by the current hiatus in the Shuttle programme is Ulysses (formerly the International Solar Polar Mission), the joint ESA—NASA international project to study the inner heliosphere as a function of solar latitude. Originally planned for launch in 1983, Ulysses was to have started its long-awaited journey aboard the Shuttle Challenger in May of this year — a delay of at least three years now seems inevitable.

Following a brief summary of the Ulysses mission and its scientific aims, this article gives an overview of the present status of the project and examines the consequences of the launch delay from both the technical and scientific viewpoints.

The Ulysses misson

As noted above, the primary scientific objective of the Ulysses mission is to explore the inner heliosphere over the full range of solar latitudes. The heliosphere is the vast region of space around the Sun that is dominated by the magnetised stream of ionised gas, or plasma, that flows radially outward in all directions from our star. This flow, which is called the solar wind, is the only large-scale astrophysical plasma that is available for in-situ study, just as the Sun is the only star close enough for its surface structure to be resolved. Observations of the Sun and the heliosphere are used as a basis for deciding what is possible in other astrophysical settings.

Our knowledge of the heliospheric plasma environment to date is based largely on the vast number of observations made during the past 25 years by spacecraft close to the plane of the ecliptic — the plane in which Earth orbits the Sun. If further progress is to be made in understanding the physics of the heliosphere, a comprehensive database of in-situ measurements made at *all* solar latitudes is required. To obtain such a database is the fundamental goal of Ulysses' unique, exploratory mission. Specific topics to be addressed are:

- the three-dimensional structure of the solar wind and heliospheric magnetic field
- solar radio bursts and heliospheric plasma waves
- solar hard X-rays
- the propagation and acceleration of solar-flare particles
- the propagation and deceleration of galactic cosmic rays
- the distribution of interplanetary /interstellar neutral gas and dust.

Detailed descriptions of the Ulysses scientific investigations can be found in ESA Special Publication SP-1050 (The International Solar Polar Mission — Its Scientific Investigations), and ESA Journal Vol. 7, No. 2, 1983.

Direct ballistic injection of a spacecraft

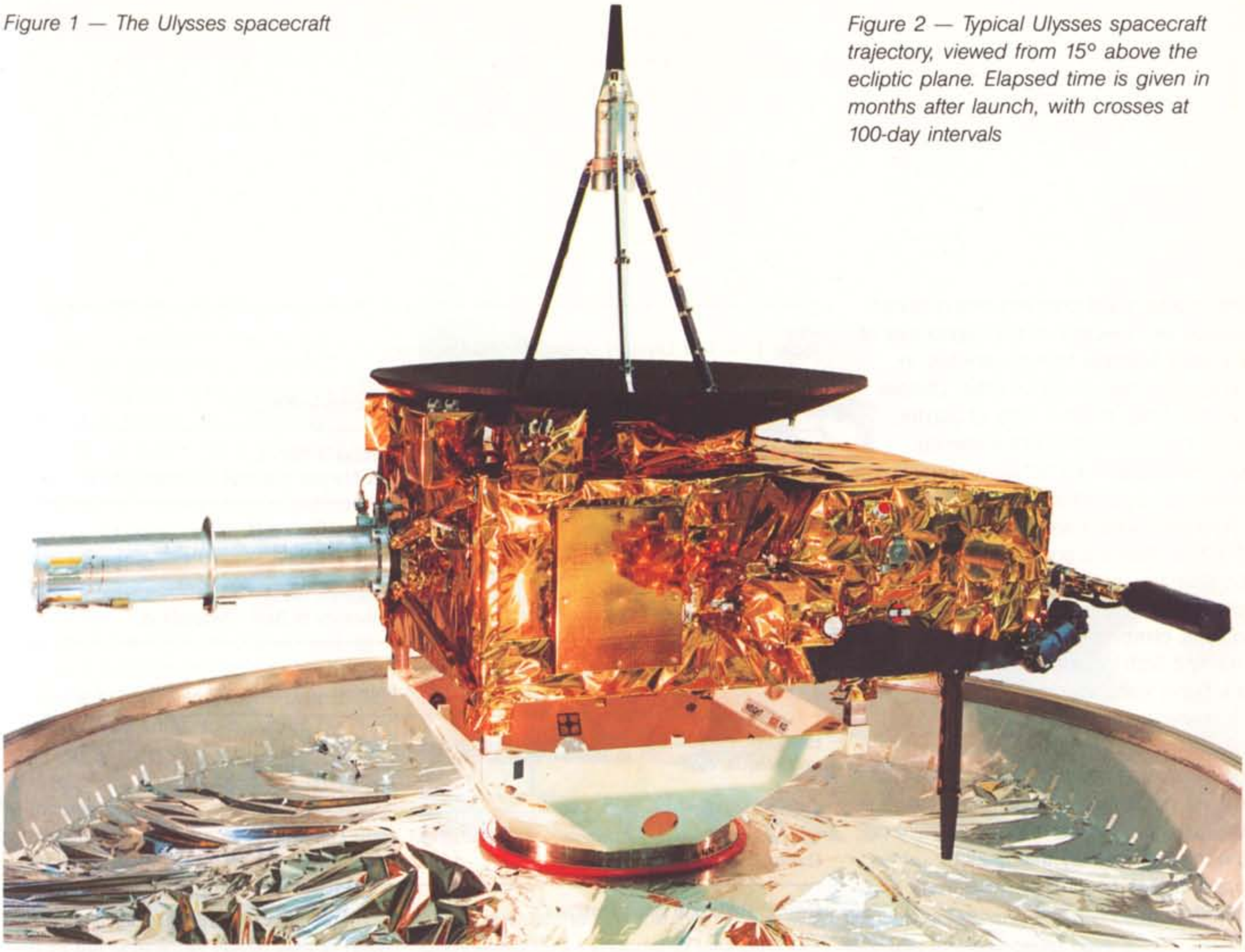


Figure 1 — The Ulysses spacecraft

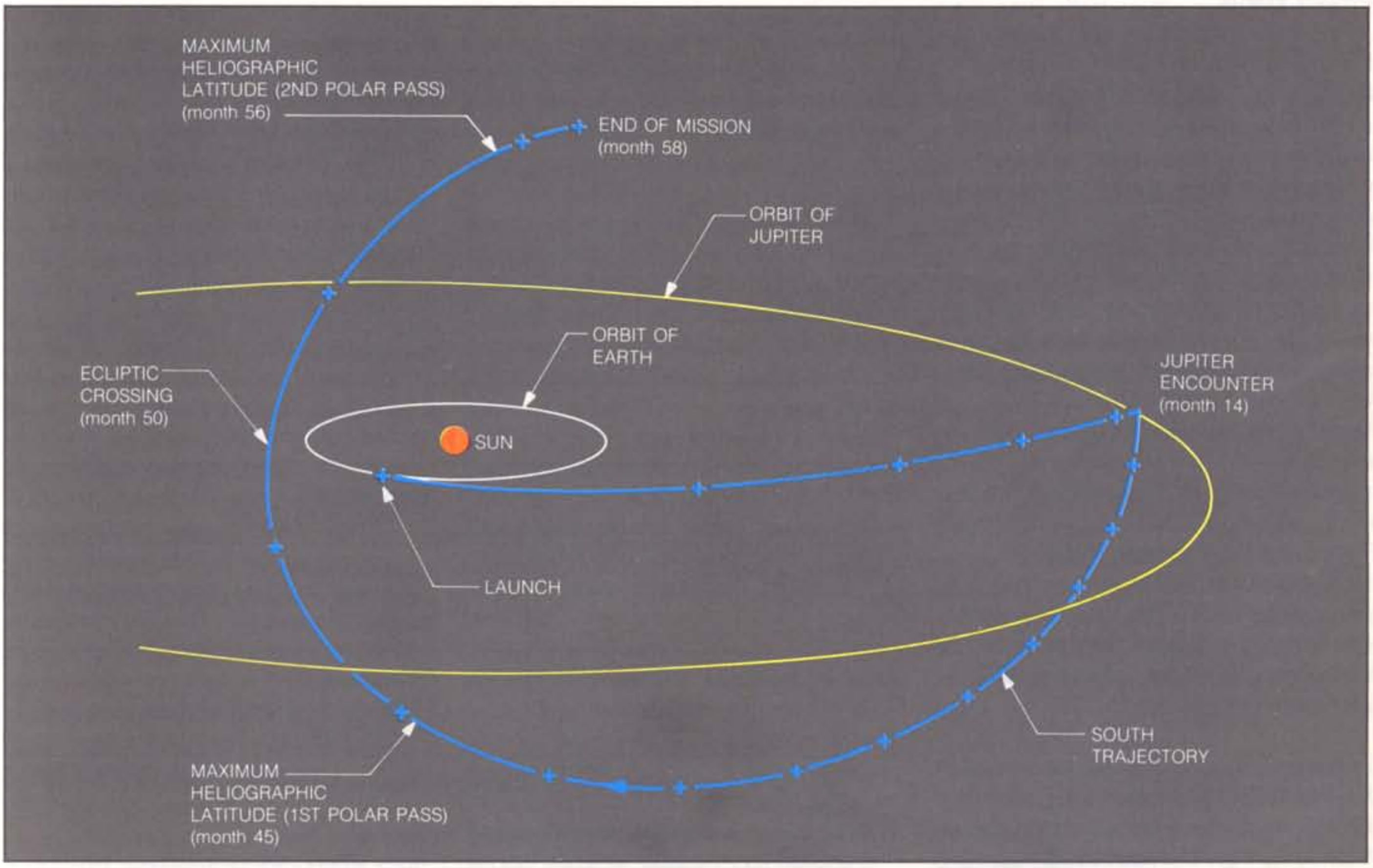


Figure 2 — Typical Ulysses spacecraft trajectory, viewed from 15° above the ecliptic plane. Elapsed time is given in months after launch, with crosses at 100-day intervals

into a solar polar orbit requires a launch energy far in excess of the capabilities of currently-available launch vehicles. In order to achieve such an orbit, Ulysses will first make a close flyby of Jupiter, during which the planet's immense gravitational pull will act as a sling-shot to propel the spacecraft out of the ecliptic plane and send it arcing back towards the Sun. After the encounter, Ulysses will be travelling in an elliptical orbit in a plane almost at right-angles to the ecliptic, climbing slowly in solar latitude. The first high-latitude pass will be over the Sun's southern pole, followed one year later by the second (northern) polar pass. Although enabling the spacecraft to get what amounts to a free ride on a natural booster, the Jupiter swing-by manoeuvre places a major constraint on the mission, namely that launch opportunities occur only once every 13 months.

Project status

At the time of the Challenger accident, the Ulysses spacecraft, which is provided by ESA, was undergoing final integrated system testing at Kennedy Space Center (KSC) in preparation for the scheduled mid-May launch. These tests were completed successfully, and at a review held in the first week of February the nine experiments that make up the scientific payload were declared flight-ready. On 10 February, however, NASA announced its decision to postpone the Ulysses launch, and as a result the launch campaign was terminated after completion of a limited number of additional activities. These included a fit-check with the Radio-isotopic Thermoelectric Generator (RTG), the spacecraft's electrical power source provided by NASA. The fully-integrated spacecraft was subsequently placed in its transport container for storage at KSC in anticipation of a launch in 1987.

At the end of April, a further delay beyond 1987 was announced. ESA then decided to bring all Ulysses hardware back to Europe. The spacecraft was

Table 1 — The Ulysses science investigations

Investigation	Principal Investigator*
Solar-Wind Plasma	Samuel J. Bame Los Alamos National Laboratory, USA
Solar-Wind Ion Composition	George Gloeckler University of Maryland, USA Johannes Geiss University of Bern, Switzerland
Magnetic Fields	Andre Balogh Imperial College, London, UK
Energetic-Particle Composition and Neutral Gas	Erhardt Keppler Max-Planck-Institut für Aeronomie, Lindau, Germany
Low-Energy Charged Particle Composition and Anisotropy	Louis Lanzerotti Bell Laboratories, USA
Cosmic-Rays and Solar Particles	John Simpson University of Chicago, USA
Radio and Plasma-Waves	Robert G. Stone Goddard Space Flight Center, USA
Solar X-Rays and Cosmic Gamma-Ray Bursts	Kevin Hurley Centre d'Etudes Spatiales des Rayonnements, Toulouse, France Michael Sommer Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
Cosmic Dust	Eberhard Grün Max-Planck-Institut für Kernphysik, Heidelberg, Germany
Coronal Sounding**	Hans Volland University of Bonn, Germany
Gravitational Waves**	Bruno Bertotti University of Pavia, Italy
Solar-Wind Directional Discontinuities†	Joseph Lemaire Institut d'Aeronomie Spatiale de Belgique, Brussels, Belgium
Solar-Wind Mass-Loss and Ion Composition†	Giancarlo Noci Osservatorio Astrofisico di Arcetri, Florence, Italy

* Co-Investigators from other scientific institutes in Europe and North America are participating in these investigations

** Radio science investigations using the spacecraft communications system

† Interdisciplinary investigation using data from more than one Ulysses experiment

Figure 3 Ulysses Radio-isotopic Thermoelectric Generator (RTG) during fit-check with the flight spacecraft at Kennedy Space Center

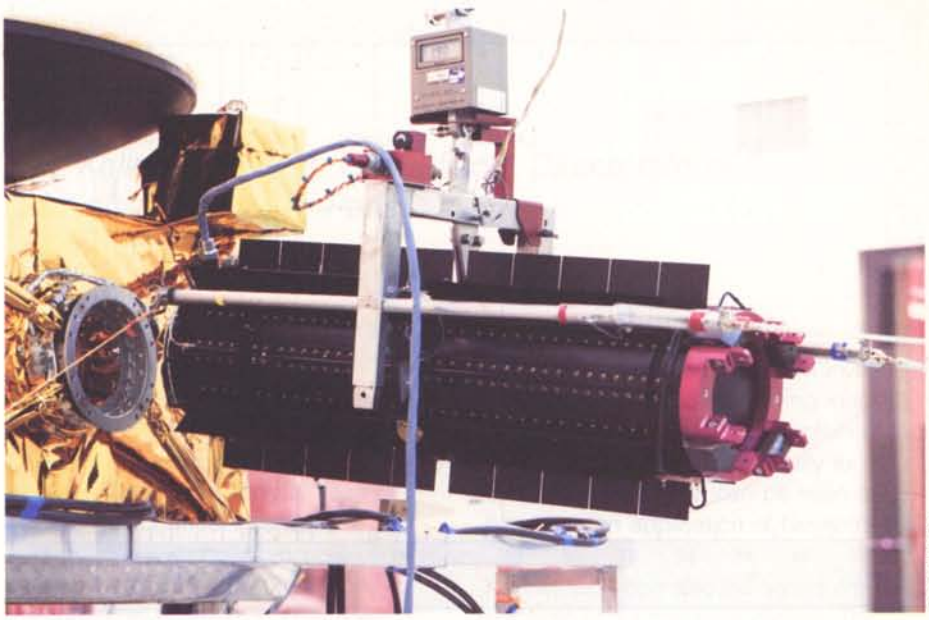


Photo: NASA

shipped to ESTEC in mid-June, where the majority of experiment units were removed and handed back to the Principal Investigators for storage at their respective institutes. The remaining spacecraft hardware was transported to Dornier System (the Ulysses Prime Contractor) in Friedrichshafen (Germany), where it is to be stored until a new launch schedule has been established.

Although not a large spacecraft (370 kg at launch), Ulysses requires a high-energy launch vehicle in order to exploit fully its unique out-of-ecliptic orbit by spending as long as possible at high solar latitudes. The scientific requirement to observe the Sun's polar regions during as many solar rotations (one solar rotation corresponds to ca. 27 days) as possible has assumed an even greater importance following the cancellation in 1981 of the spacecraft NASA was to have provided for what was originally a two-spacecraft mission with simultaneous viewing of both solar hemispheres. At the present time, only the combination of the Shuttle, with its large cargo capacity, and a powerful upper-stage motor to inject Ulysses from the Shuttle parking orbit into a heliocentric orbit en route to Jupiter, is able to fulfil the launch-energy requirement. The upper stage selected for the 1986 mission was a wide-body version of the liquid hydrogen/oxygen-fuelled Centaur. On 19 June, however, NASA announced its decision to terminate development of this upper stage for use onboard the Shuttle. With this decision, another chapter was added to the troubled history of the interplanetary injection vehicle for Ulysses; since project approval, the type of motor to be used has changed no fewer than five times. Presently under consideration for a future Shuttle launch of Ulysses is a two-stage Inertial Upper Stage (IUS) solid-rocket motor with an added Payload Assist Module (PAM-D).

A possible alternative to the Shuttle, now under development, is the Titan 34D7 Complementary Expendable Launch Vehicle (CELV) in combination with Centaur. However, this vehicle will not be available until 1990 at the earliest. Regardless of which launch system is used for Ulysses, a delay of at least three years appears unavoidable.

Technical impact of the launch delay

As mentioned earlier, the electrical power onboard Ulysses is provided by an RTG, the large heliocentric distances involved precluding the use of a solar array. A major concern in the face of a launch delay of several years is the power loss experienced by such generators due to the radioactive decay of the fuel source and other factors. This problem is exacerbated by the long (5 years) mission duration, and could result in the need for power-sharing during critical periods.

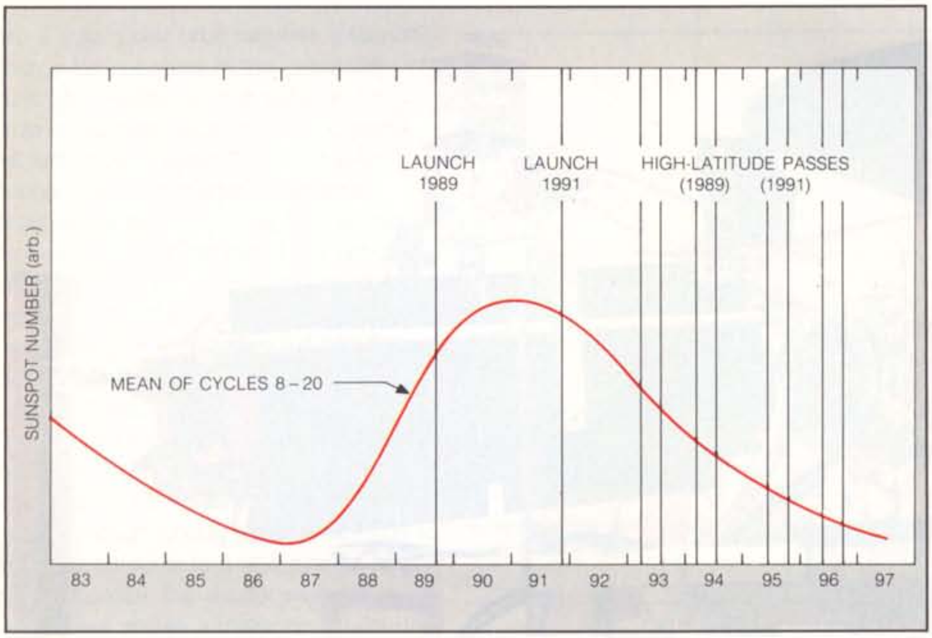
An additional concern associated with the RTG is the potential requirement to mount a so-called 'blast shield' to prevent rupture of the plutonium fuel elements in the event of an explosion during launch. The introduction of such a shield would almost certainly require modifications to the spacecraft, and the associated increase in mass could have a detrimental effect on the overall mission performance.

Following a storage period of the extent envisaged for Ulysses, and before resumption of the launch campaign, the flightworthiness of both spacecraft and scientific payload will need to be verified in detail. Many of the experiment units, for example, contain sensitive detecting elements which, even when stored under stringently-controlled conditions, are prone to failure as a result of aging in the laboratory environment. In order to identify and correct problems of this type, a thorough recertification programme, including the necessary environmental testing, will have to be carried out. Although clearly essential, such an additional test programme is not wholly without risk. As a result of the previous launch delay, Ulysses has already undergone more ground-testing than is usual.

Scientific impact of the launch delay

The character of the heliospheric plasma environment is not constant in time; it changes considerably during the course

Figure 4 — Relation of Ulysses high-latitude passes to the solar cycle, shown for launches in September 1989 and November 1991



of the 11-year sunspot cycle. At sunspot maximum, the solar-wind flow is dominated by transient features that are often associated with solar flares, whereas sunspot minimum is characterised by steady, recurrent flow patterns that may persist for many solar rotations. The solar corona, the source of the solar wind seen as a pearly white halo at times of solar eclipse, shows similarly marked changes with the solar cycle. Particularly striking features at solar minimum are the large so-called 'coronal holes' extending from the Sun's polar regions down to low latitudes. Most prominent in soft X-ray images of the Sun, these coronal holes are recognised to be the source of solar-wind plasma emitted in fast, generally uniform, streams. As the solar cycle progresses toward sunspot maximum, the coronal holes recede poleward, giving rise to a more uniform corona. If launched in 1983 as originally planned, Ulysses would have been at high latitudes during solar minimum, permitting detailed measurements of a plasma environment dominated by the polar coronal holes. A mission launched in 1986, on the other hand, would have arrived over the poles near sunspot maximum. In this case, the scientific emphasis would have been on the study of transient phenomena at high latitudes. Because of the mission's exploratory nature, the scientific instrumentation was designed to incorporate a high degree of flexibility, enabling measurements to be made under a wide variety of conditions. From this point of view, therefore, the launch delay will not fundamentally affect the scientific objectives of the mission, but rather change the emphasis depending on the phase of the solar cycle at which Ulysses makes it polar passages.

An aspect that is of concern, however, is the availability of in-ecliptic reference data. In order to decide whether changes seen by Ulysses as it climbs out of the ecliptic are true latitude-dependent effects, it is highly desirable to have simultaneous measurements made onboard a spacecraft located in the ecliptic. For the 1986 launch, the Intercosmos Phobos mission and NASA's IMP-7/8 missions had been identified as the strongest candidates for providing such data; a delay of three years removes these possibilities. In addition to the potential lack of in-ecliptic reference data, certain investigations on Ulysses, for example the gamma-ray burst experiment, rely on coordinated observations with similar instruments on other spacecraft. Here again, it is doubtful whether those spacecraft envisaged for this purpose will still be operational.

Finally, the problem of scientific instrument and spacecraft subsystem aging becomes more critical with each additional 13-month delay. Reliability is of paramount importance for a mission that not only starts its prime measurement period 3 years after launch, but also has to pass through the harsh radiation environment of Jupiter en route.

Conclusion

The launch delay of at least three years now facing Ulysses is a serious blow, not only to those directly participating in the mission, but also to everyone involved in the fields of solar and heliospheric physics. The unique measurements to be made onboard the spacecraft from its high-latitude vantage point are essential if we are to gain a fuller understanding of the global behaviour of the inner heliosphere. Although its voyage must now wait, Ulysses will be the first, and for the foreseeable future the only spacecraft to make such measurements.

ESA Inventions and Patents

P.A. Kallenbach & R. Oosterlinck, Directorate of Administration, ESA, Paris

The number of patents held by an organisation is often regarded as an indication of its technical innovativeness and is usually directly proportional to the organisation's R&D budget. As ESA is an organisation centred around R&D activities, and moreover these are in technologically advanced fields, the Agency could be expected to apply for an appreciable number of patents. The fact that this is not always true in practice could at first sight be thought to be due to two reasons:

- **actual R&D activities do not take place within the Agency, but are undertaken by contractors**
- **Agency staff are mainly involved in management of the contractor's work.**

An attempt will be made here, by providing a general review of the Agency's invention and patent efforts, to show that this reasoning is not completely valid. A number of articles on the subject of patents and inventions have already appeared in previous issues of the ESA Bulletin*.

* De Reuse J. 1979, Brevets et savoir-faire technique dans une organisation de technologie de pointe, ESA Bulletin No. 17, pp. 30–35.

Oosterlinck R. 1981, Les inventions de l'Agence et leur protection, ESA Bulletin No. 27, pp. 22–27.

Oosterlinck R. 1985, The Evolution of the Agency's Patent Policy, ESA Bulletin No. 44, pp. 80–83.

Patentable inventions

An invention results from a creative process associated with the solving of a problem in a technical field. This creative process is not necessarily a 'flash of genius'. In fact, most inventions stem from small but essential improvements to existing technology. The knack of making an invention is to combine existing structures and/or operations in a way that yields a new and different effect or result.

An invention is different from a mere idea or discovery. An idea involves a process including a mental step. An example of such an idea is attributed to Gauss when he was set the following problem in the classroom as a young man:

$$1+2+3+4+5+6+7+8+9+10 = ?$$

Instead of going through the painstaking process of addition, Gauss paired (10+1), (2+9), etc. and, since there are five of these pairs, obtained the result simply by multiplying 11 by 5! Theories, algorithms and computer software therefore generally fall into the category of ideas, and thus are not considered to be inventions. This, however, does not exclude them from legal protection.

A discovery brings to light that which existed before, but was not known. An example of such a discovery was Newton's formulation of the law of gravitation, based on the force of attraction between two bodies. This relationship always existed, even before Newton announced his celebrated law.

It is nevertheless true that most inventions involve one or more underlying ideas or discoveries. In a way, the invention of the drop tower, a free-fall test facility to simulate zero gravity, can be seen as based on an application of Newton's law.

An invention can also be based on the principle of a previous invention. The universal joint was invented in 1676 by Robert Hooke for use in his helioscope, a system of reflecting lenses and mirrors that he devised to allow safe observation of the Sun. It was not until centuries later that the joint was applied in fields other than astronomy, such as in vehicle technology.

In a recent invention by an ESA engineer, a variation of the universal joint is used for quite a different purpose from that originally envisaged by Hooke. The new invention is a flexible mount element for a telescope mirror that provides freedom of rotation around two perpendicular axes and a high load-supporting capability. The design incorporates the crossed forks of Hooke's universal joint.

An invention normally relates to a method or a device having an industrial or similar application, and it should be 'useful' in the sense that the invention provides some benefit in use. The degree of utility is unimportant. With this in mind, the category of 'ideas' can in some cases be reconsidered. In fact computer programs or methods having a clear engineering application, in that their use results in a concrete hardware modification or improvement, can be considered as inventions.

What is a patent?
Inventions form part of the assets of an organisation. To protect an invention, which can be the fruit of years of research and development, from illegal use by third parties, there are two possibilities.

The first is to keep the invention secret, so that third parties cannot gain access to it. An example of this would be a recipe for preparing a beverage (e.g. Coke). Protection by trade secret is simple in that no formalities are required, but the legal status of this is rather poor and it can be jeopardised by leaks that can occur, for example, via an employee leaving the organisation or through industrial espionage.

Other legal means were therefore developed which give better protection, but which are subject to strict rules. In some cases, however, secrecy is the only possible means of protection.

A second possibility is to apply for a patent. A patent is in fact an agreement between an inventor and the representatives of a certain country whereby, in return for full public disclosure, the inventor is granted the right for a fixed period of time to exclude others from making, using or selling the invention in that country. It is important to note that this monopoly is granted not primarily to reward the inventor, but to encourage public disclosure of inventions. Even inventions protected by a patent may by used for experimental purposes to facilitate the progress of science and technology.

The legal protection is then limited in geographical extent, i.e. to the countries in which a patent has been filed, and in time (normally between 15 and 20 years).

The act of legal protection by patents may appear at first sight to compromise the interests of the Agency, since it could impede the transfer of technology between ESA, its Member States, and other countries participating in the Agency's programmes. The Agency can, however, provide 'royalty-free' licences to industry in participating states, provided that its patented inventions are then used only in European or national space applications.

Interest of patents to the Agency
ESRO was set up originally as an organisation for scientific programmes and consequently there was little interest in patents, as science is related to discoveries rather than to inventions.

When ESRO was transformed into ESA and applications programmes were also undertaken, involving technological research and development, the importance of patents to protect inventions by the staff of the Agency grew considerably.

Since most inventions made in the Agency relate to space applications, i.e. one-off products which are far from commercial, one could ask whether the investment in patent applications is worthwhile, or whether it would not be better just to publish an article about the invention and thereby prevent others from obtaining patents for the same invention (see 'Patentability' below).

Experience with some patents related to space applications that have led to legal battles has, however, shown how important it is that inventions be patented, even when no commercial exploitation is envisaged. It is only in this way that the Agency can safeguard its Member States' interests vis-à-vis industry in other states.

The patent application
In order to apply for a patent, a document is drawn up containing: a description of the invention and the problems it can resolve with respect to known methods or equipment, an example of an 'embodiment', drawings and claims.

The claims form the most important part of the patent application, because they state the scope of the legal protection sought, and also because patentability of the invention is judged on the basis of the content of these claims. Generally the main claim contains a preamble in order to define the state-of-the-art in the field of the invention, and then a statement describing the characteristics of the invention itself that are considered to be novel and patentable. Usually, an attempt is made to formulate the claim in such a way that it covers not only the invention itself, but also similar devices or processes.

Patentability of inventions
For an invention to be patentable, it should be novel and, according to the patent laws of many countries, involve an 'inventive step'. Generally, an invention is considered to be novel if it has not been patented or described previously in any printed publication, or otherwise disclosed to the public before the first filing date of the associated patent application. An invention made in the United States, however, is still considered novel if it has been 'reduced to practice', and in the process disclosed, within the year before filing. It is therefore important to know that any element making the invention accessible to the public prior to filing destroys its novelty and thus eliminates its patentability. This includes prior publication in a journal, presentation at a conference, and also dissemination in internal working papers, unless the readers are bound by secrecy.

It should be stressed at this point that it is of capital importance that an invention should not be divulged to the public in any way prior to filing, i.e. before the official filing date of a first application. If contractors or third parties need to know about the details of an unpatented invention, as may be necessary for progressing work under contract, they should be informed in writing that the information provided is of a confidential nature in view of a patent action outstanding. It is even advisable to be careful in disseminating the invention after first filing, until the patent application as a whole is published. In some countries this can be a couple of months after filing, in others such as France and the USA longer.

Documents opposable as anticipating an invention should have been published before its first patent application's filing date and they may originate from anywhere in the world and have been published in any era. A German manual on rockets and fireworks dating from 1564 (Schmidtlapp von Schorndorf) in which two- and three-stage rockets are described and illustrated, could in principle have anticipated the present-day multi-stage rocket launchers.

An invention is not considered to be patentable over what is known, if it was obvious to a man having ordinary skill in the art at the time the invention was made. This criterion, translated in the requirement for the invention to have an 'inventive step', is applied if the invention is not fully anticipated by one single document, but if several documents containing different elements could make the invention obvious when combined in a manner suggested in these documents.

Marconi's basic patents on radio (1896) were infringed in the USA. Following lengthy law suits lasting until 1943, the US Supreme Court held the broad claims of the patent to be invalid on the grounds of lack of an inventive step, and considered it 'ordinary skill in the art'. In other words, it was held to be obvious in 1940 that someone skilled in the art could have made a radio back in 1900!

Evaluating the presence of an inventive step using the criterion of 'non-obviousness' is not always a straightforward matter either, as experience has shown with the US Patent Office, where it is rare that an invention is found to be non-obvious 'prima facie'.

In this context, the so-called 'negative rules of invention' can be applied to determine patentability. For instance, a straightforward aggregation of elements is *not* patentable, e.g. a pencil with an eraser affixed to one end. A combination of known elements, however, can be patentable if it provides new results, e.g. the combination of sulphur with india rubber to produce vulcanised rubber.

It would be going too far to discuss these aspects of patentability in any greater detail in the context of this article. It should merely be noted that the so-called 'objective subtests of invention' are of further assistance in evaluating non-obviousness. These include evidence that the claimed innovation met with commercial success, or satisfied a long-felt demand, or met with commercial acquiescence. Subjective subtests can also be applied which relate to the aspect of problem-solving by the invention, such as the difficulties overcome in the steps leading to the invention, the lack of suggestion of the invention in prior literature, or if there was a need to overcome technical prejudice in order to make the invention.

Application procedure

An ESA staff member is bound, by virtue of his contract, to declare to the Director General any invention made during the period of his employment with the Agency [ESA Staff Regulations Rule 4.2/5(ii)]. This also includes inventions made privately.

Before filing a patent application, there is an internal Agency procedure to be followed by which a Patent Group, appointed by the Director General, examines inventions declared by the staff and makes recommendations for:

- filing of patent applications
- publication of inventions
- waiving of Agency rights in favour of inventors.

If a patent application is filed by the Agency, the inventor will receive an award per patent, applied for at first filing.

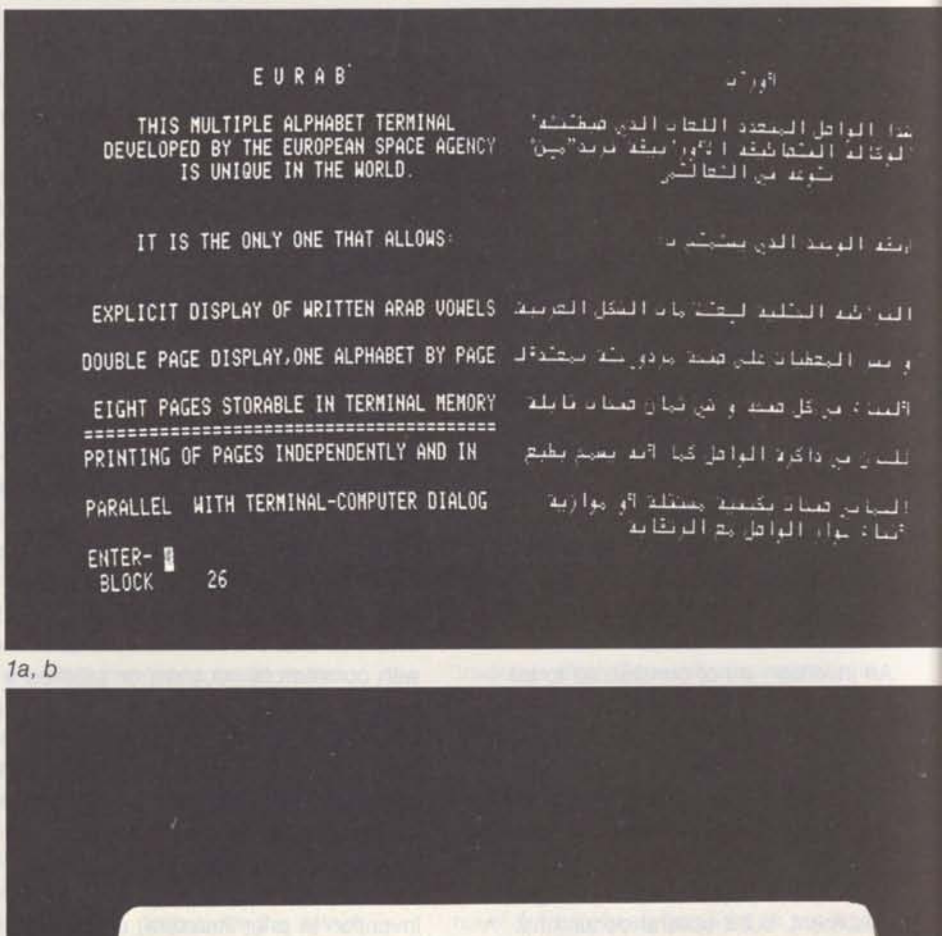
Present-day patent laws allow first filing of a patent application in one country, thereby establishing a 'priority' date, and further filing in other countries within a year following this priority date, these secondary applications then having the benefit of being based on the same priority date. The advantage of such a procedure is that the intervening year of 'reflection' provides an opportunity for more extensive investigation of the patentability and usefulness of an invention. A novelty search report, which is normally required for official examination and produced by the European Patent Office in The Hague, may shed some light on these matters. In this search report, patents and other publications are cited which are either anticipation or prior art of the patent application examined. From the search report, conclusions can be drawn with respect to novelty, inventive step and application(s) of the invention. The Patents Group will base decisions regarding extension of protection of the invention to other countries mainly on these criteria.

Another advantage of the reflection period is that it allows the filing of an application before a complete feasibility analysis of the invention has been carried out. This may be important to gain time in a field of 'high technology', where several competitors may be working on the same problem and similar solutions may be found. It should, however, be noted that this advantage is less pronounced when filing in the United States, since here the law is in favour of the first to invent rather than the first to file, laboratory records being

SPIN-OFF FROM SPACE

Most inventions made by ESA engineers are related to the exploration or exploitation of space. There are, however, a small number that could find or have found 'down-to-Earth' applications. Some examples of this spin-off are the following:

- An invention that has already met with commercial success is a generator of Arabic script in response to digital character codes provided by a keyboard or other data source. The invention can be used in combination with display devices and printers in data processing or other applications (Fig. 1a,b) (Inventor: H. Orrhammar).
- A deployable trussed mast, originally intended as a space-based support structure, has various features that make it amenable to applications on Earth, where masts or towers need to be transportable in a folded state and quickly erectable, to support antennas, video cameras, flood lights, etc. In its erected state, the trussed structure has good resistance to wind-induced loads. (Inventor: D.C. Richard).
- A stepper-motor-driven swash-plate mechanism allowing remote pointing of antennas, telescopes or any other instrument that has high pointing accuracy requirements. Due to its robust construction and hermetic sealing, the mechanism can be used under adverse environmental conditions (Fig. 2) (Inventors: R.H. Bentall and M. Briscoe).
- A small, precision, rotary magnetic bearing capable of supporting loads of up to several kilograms in an entirely contactless way, and which therefore does not require any



1a, b

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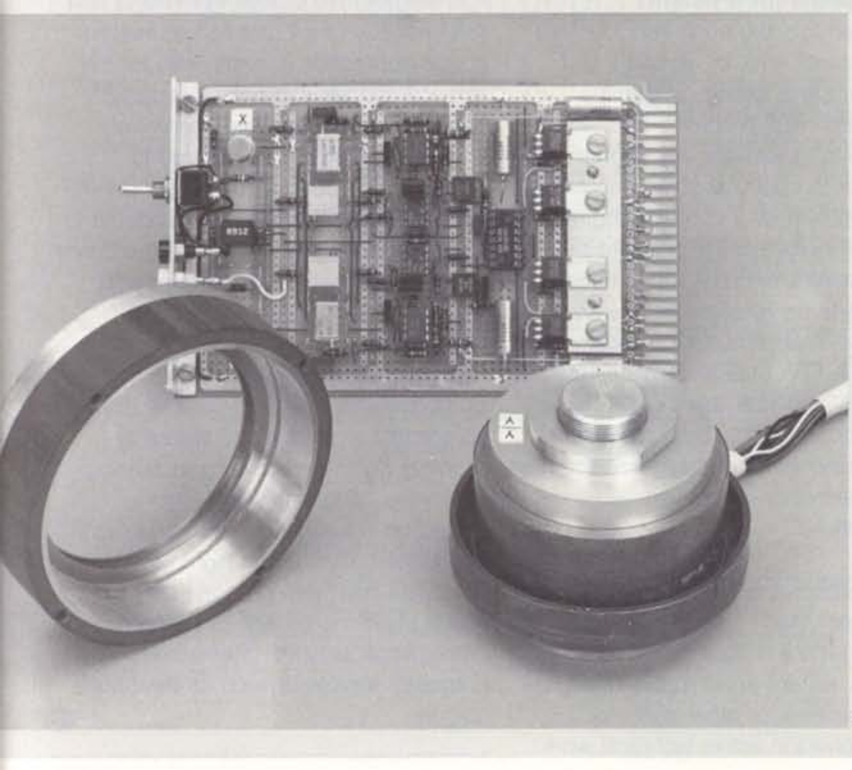
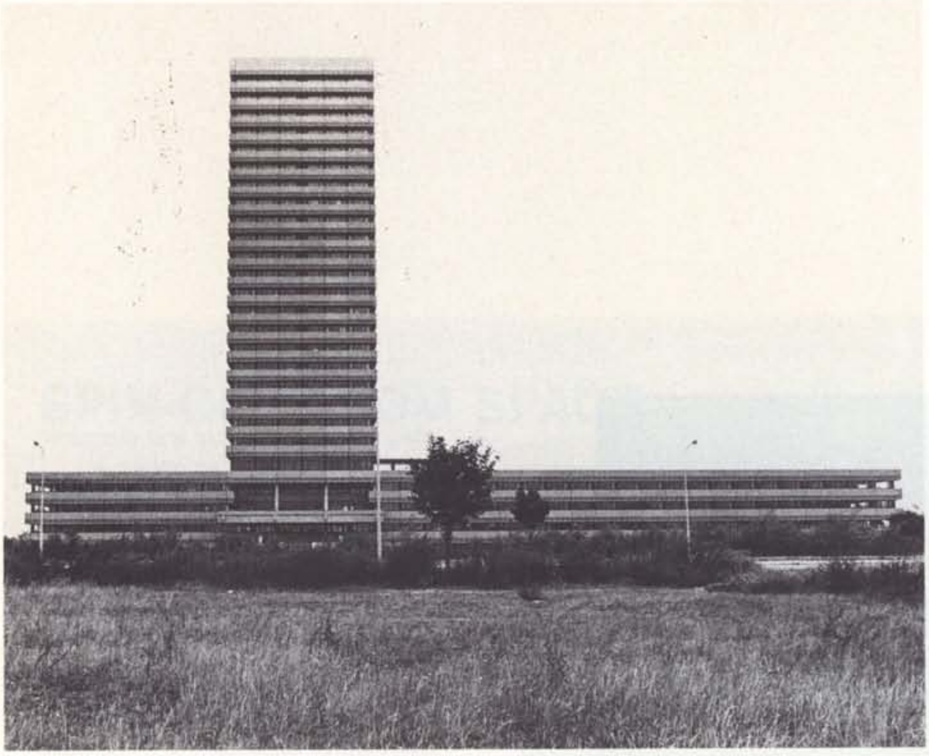


3

lubrication. Its compactness and low degree of mechanical and electronic complexity make it an attractive alternative to ball bearings in such applications as flywheels, disk drives, etc. (Fig. 3) (Inventor: A. Robinson).

- Flexible mountings for supporting elements of optical instruments, capable of eliminating the effects on instrument pointing of a difference in the thermal expansion of the ground support and the optical elements while maintaining a high load-supporting capability. A typical application of such mountings is in the support of astronomical telescope mirrors. (Inventor: T. van der Laan).
- A filament-wound flywheel allowing a large amount of energy storage with a small wheel diameter, as a result of a novel construction that tends to stress fibres to their design limits. Typical applications are, for instance, in electric utilities for coping with peak loads, in the powering of vehicles, in gyroscopic systems, etc. (Inventor: C. Stavrinidis).
- A tetrahedral wedge device that can be used for joining two structural members, but also for temporarily fixing an item. Because of the ease with which the joint can be made and released and the elimination of jamming, single-handed operation is made possible. The joint can be used in the assembly of structures, the fixing of small objects, as an end-effector in robotics, as a clutch mechanism, and as a structural element in electrical or fluid connectors. (Inventor: N. Cable).

Any enquiries concerning the above inventions should be addressed to the Office of Space Commercialisation at ESA Headquarters in Paris.



The European Patent Office in The Hague, The Netherlands

used in order to prove this as being the case.

The decision in which countries to file first or subsequent applications is very important, since an invention is only protected in those countries where it has been patented. A typical example of an alleged misjudgement on this point is the case of the 'miracle keel' that supposedly helped Australia to win the 1983 America's Cup. This keel has been patented in a number of European countries since 1978, but not in Australia, implying that anyone on Australian soil could make such a keel and use it in international waters without infringing the law, as has been demonstrated.

If the Patents Group decides to extend protection to at least three other countries that are members of the European Patent Convention, it becomes financially interesting to make use of the application procedures recently introduced for obtaining either a European Patent or a patent under the Patent Cooperation Treaty (PCT), the main advantages being reduced requirements for translations and a further gain in time.

Patent granting
In countries in which a formal examination of a patent application takes place, patents may be granted between 2 and 6 years after filing, based on a positive outcome to this examination. A monopoly in the making and use of the invention is conceded to the inventor or his assignee for a duration of at least 10 years, the actual duration of the patent depending on the country in question. These patent rights are in force as from the filing date of the patent, except in the United States where the date of publication is the operative date. It is normally from the granting date that the patent can be opposed by those interested.

Who can apply for a patent?
Usually, inventors are engineers involved in either project work or research and development and testing, where particular technical problems need to be resolved. Such problems are normally discussed with contractors, and so either an ESA engineer or a contract engineer may find a solution to the problem that may be patentable. Some agreement then needs to be reached as to who is the inventor. In case of an ESA staff member, the ESA Staff Regulations and Rules apply, and ESA takes out a patent. If not, the contractor takes out a patent, and ESA may obtain a royalty-free licence from the contractor for its own requirements.

As was mentioned above, an invention does not necessarily have to be realised in practice before filing a patent application, except again in the United States. Engineers, or other staff, not directly involved in active technical work can therefore also basically become 'inventors' based on an invention that is a concept, the patentability and usefulness of which still needs to be examined 'on paper' before the filing of a patent application.

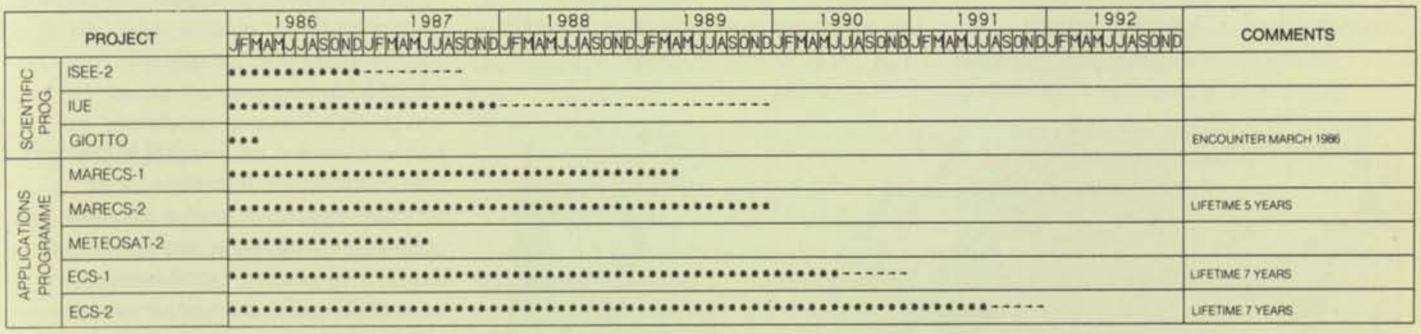
Is there a reward for inventors?
The Staff Rules and Regulations include provisions for rewarding the individual merit of inventors, initially by a token payment for a first patent application, but as the invention is patented in more countries and licences are granted, more and higher rewards can be expected. Good technical ideas and improvements are also rewarded as a function of their value to the Agency.

Inventions made by contractors
ESA contractors making inventions while undertaking work funded by the Agency are allowed to retain the related property rights and to apply for patents as long as they keep the Agency informed. In some cases, however, the contractor may prefer to assign these rights to the Agency for possible patent action. In both cases, the licensing of third parties to make or use the invention in a European or national space application is royalty-free for the Agency and firms in participating ESA Member States. This free transfer of intellectual property is intended to stimulate European industrial cooperation in advanced-technology areas related to space, and thereby to improve the overall competitiveness of European industry.

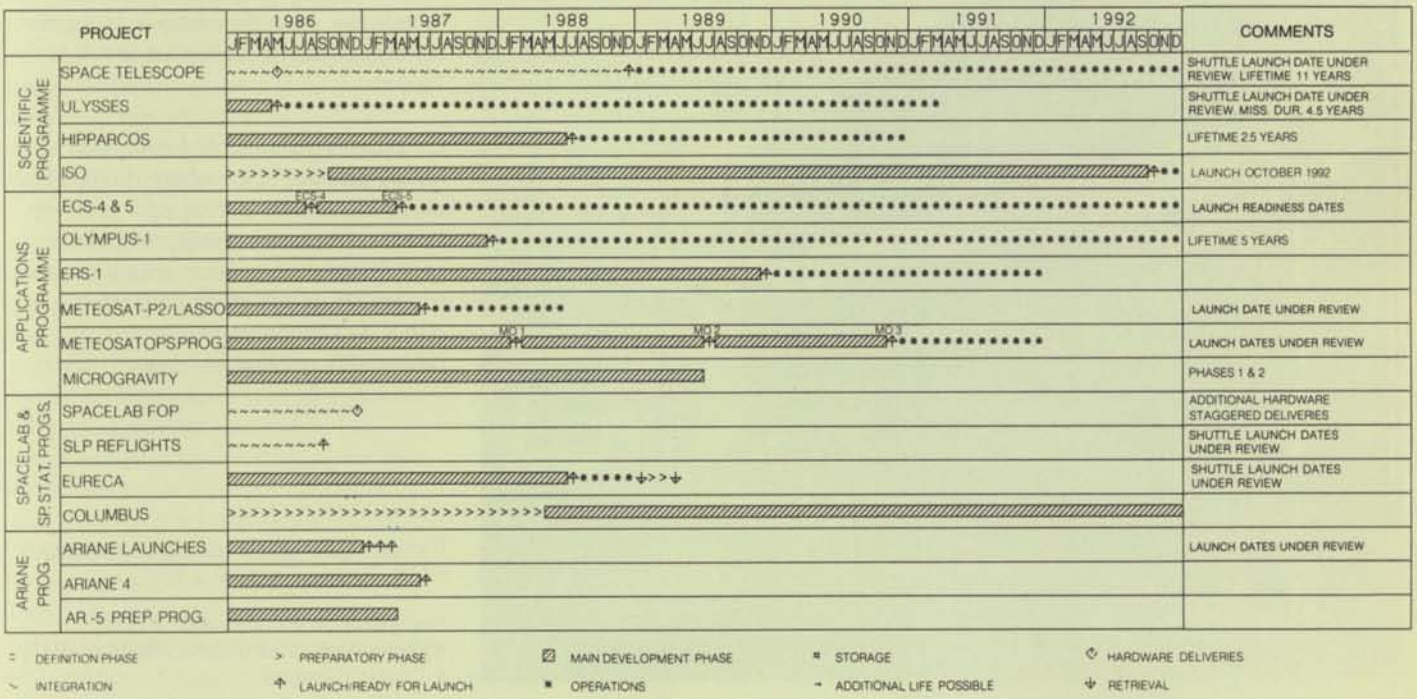
Conclusion
Patents are of importance to the European Space Agency as well as its contractors in protecting intellectual property rights and thereby increasing worldwide competitiveness. This protection is becoming more and more important in view of the flight of European hardware on non-European space platforms as well as Europe's participation in future international cooperative projects such as the Space Station.

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

In Orbit / En orbite



Under Development / En cours de réalisation



Télescope spatial

Activités de la NASA
L'essai en vide thermique du Télescope a duré 57 jours et s'est achevé avec succès début juillet. Il a révélé que la consommation électrique du Télescope dépassait les prévisions; ce problème est donc à l'étude.

On a établi un calendrier préliminaire fixant la nouvelle date de lancement à décembre 1988 et prévoyant un second essai de recherche de modes et un autre essai en vide thermique.

Générateur solaire
Les ailes du modèle de vol livrées à la NASA à la mi-mai sont prêtes à être intégrées au Télescope spatial.

Chambre pour objets faibles
La FOC continue à fonctionner sans problème dans le Télescope spatial.

Olympus

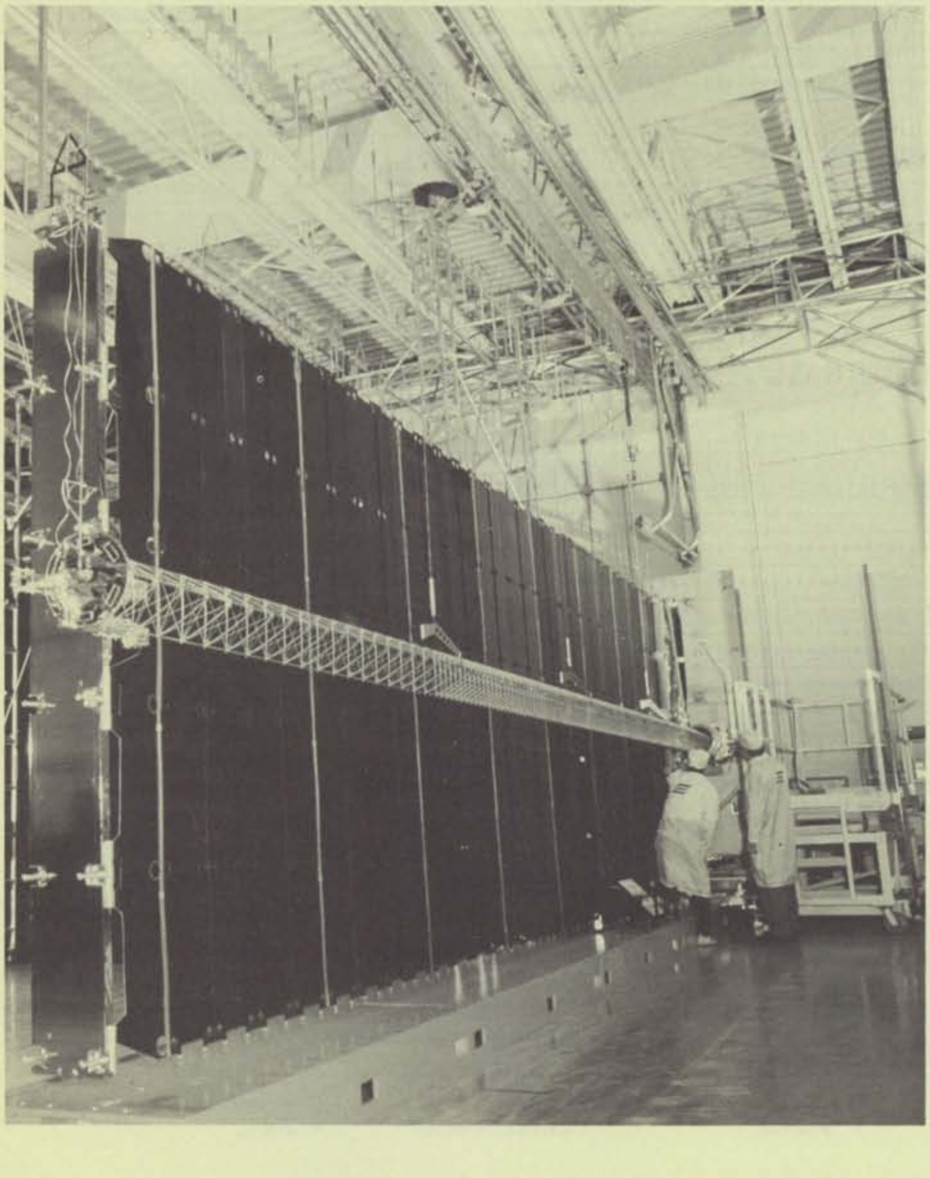
Des progrès considérables ont été accomplis à l'issue des revues critiques de conception relatives aux sous-systèmes de la plate-forme du satellite, notamment des sous-systèmes d'alimentation électrique, de télémesure et de télécommande dont l'examen a donné des résultats satisfaisants. La revue du sous-système de stabilisation et de correction de l'orbite doit avoir lieu bientôt, la revue du sous-système de propulsion combiné, dernière des revues de la plate-forme, devant se tenir une fois terminés les essais voulus sur le développement de la propulsion. Etant donné que les revues critiques de conception de la charge utile sont déjà terminées, l'Agence pourra tenir dès le début de l'année prochaine la revue critique de conception des systèmes.

Les essais sur le modèle d'identification du satellite se sont poursuivis. Les essais des répéteurs de communication intégrés sur le satellite ont pris fin début juin. Des essais ont ensuite été menés à bien sur tous les canaux des quatre charges utiles opérant simultanément, antennes déployées, dans la chambre anéchoïque afin de vérifier la compatibilité radioélectrique des charges utiles. Les essais de compatibilité électromagnétique et de décharge électrostatique des systèmes sur le modèle d'identification totalement intégré ont été effectués début août. Les équipements du SCAO ont été ensuite retirés pour une série d'essais dynamiques sur le sous-système qui doivent avoir lieu au NLR (Pays-Bas) en septembre. D'autres essais au niveau système sur le modèle d'identification du satellite après réintégration du SCAO sont prévus pour le reste de l'année.

L'intégration des modules de servitude et de propulsion du modèle de vol du satellite s'est poursuivi dès que l'on a pu disposer de l'équipement de vol. La charge utile 'services spécialisés' du panneau nord a été livrée et la charge utile à 20/30 GHz transférée de sa structure temporaire sur ce panneau. Les commissions de revue des essais qui devaient se réunir à l'achèvement de ceux-ci doivent à présent se retrouver début septembre pour discuter de la charge utile de télévision et de la charge utile à 20/30 GHz.

La charge utile de mesure de propagation est en cours de montage et d'essai et elle sera livrée au maître d'oeuvre à Stevenage. Les essais de recette des deux panneaux solaires de vol sont en bonne voie chez SPAR à Toronto.

On s'apprête à entamer l'intégration au niveau système et les essais du modèle de vol du satellite prévus pour la fin de l'année. Le premier essai d'ambiance sera l'essai de simulation solaire qui aura lieu au JPL à Pasadena en Californie, au début de l'année prochaine. Les préparatifs sont déjà en cours.



Olympus flight solar array under inspection at SPAR, Toronto (Canada)

Exemplaire de vol générateur solaire d'Olympus en cours d'inspection chez SPAR, à Toronto (Canada)

Space Telescope

NASA activities
The Space Telescope (ST) thermal vacuum test lasted 57 days and was completed successfully in early July. The most significant finding was that the ST power utilisation was above prediction and a power audit is therefore underway.

A preliminary schedule with a revised launch date of December 1988, and which includes a second modal test and thermal vacuum test, has been issued.

Solar array
The flight wings, delivered to NASA in mid-May, are awaiting integration with the Space Telescope.

Faint Object Camera
The Faint Object Camera (FOC) continues to operate without problems in the Space Telescope.

Olympus

Considerable progress has been made in completing the critical design reviews for the platform subsystems of the spacecraft, including the power and telemetry and telecommand subsystems which have been reviewed with satisfactory results. The attitude and orbit control subsystem review will be held soon, leaving the review of the combined propulsion subsystem, the last of the platform reviews, to be held as soon as the relevant tests on the propulsion development model have been completed. Since the payload critical design reviews have already been completed, this will allow the system critical design review by the Agency to be held early next year.

Testing of the engineering-model spacecraft has continued. Baseline testing of the communication repeaters integrated on the spacecraft was completed in early June. Tests were then completed satisfactorily with all channels of the four payloads operating simultaneously and with their antennas radiating in the anechoic chamber in order to check the radio-frequency compatibility of the payloads. The system electromagnetic-compatibility and electrostatic-discharge tests on the fully integrated engineering model spacecraft were conducted in early August. The AOCS equipment was subsequently removed for a series of dynamic tests on the subsystem, which are planned during September at NLR's facility in The Netherlands. Further system-level tests using the EIM spacecraft, after re-integration of the AOCS, are scheduled for the remainder of the year.

Integration of the flight spacecraft's propulsion and service modules has continued as flight equipment has become available. The specialised-services payload on the north-radiating panel has been delivered and the 20/30 GHz payload transferred to this panel from its temporary structure. The test review boards to be held after the completion of testing are now expected to meet early in September for the television-broadcast and 20/30 GHz payloads. The propagation payload is being assembled and tested and will be delivered to the prime contractor in Stevenage. Acceptance testing of the two flight solar arrays is in progress at SPAR's facility in Toronto.

Preparations are being made for the start of system-level integration and testing of the flight spacecraft later this year. The first system-level environmental testing of the flight spacecraft will be the solar-simulation test in the JPL facility in Pasadena, California early next year. Preparations for this test are already in progress.

ERS-1

The Development Baseline Review for the Kiruna ground station was held at the end of June, with in general satisfactory results. The last Development Baseline Review to be held, that for the Mission Management and Control Centre, is scheduled for the end of October.

The structural-model programme continues close to schedule. The structural model of the platform successfully passed its acceptance review and was handed over from CNES to the ERS-1 contractor to initiate the necessary modifications. The building and testing of subsystem development and engineering models is continuing.

A Workshop involving about 50 external participants was held in early June to develop guidelines for the geophysical validation and calibration of the ERS-1 wind/wave instruments (published in special publication ESA SP-262).

An ERS-1 Operations Advisory Group has been established to address the requirements and priorities for a first issue of an ERS-1 Mission Operations Plan. An ERS-1 Announcement of Opportunity calling for proposals for scientific investigations, application demonstrations, and support for geophysical data validation has also been issued.

Meteosat

Preoperational programme
The Meteosat P2 spacecraft underwent final testing at Aerospatiale in Cannes before its scheduled departure for the launch site. The Ariane launch failure, however, caused all launch preparations to be halted and the satellite is now in storage at Aerospatiale.

Lasso
The go-ahead was given in June to Telespazio to proceed with preparation of the Lasso Coordination Centre.

Operational programme
Space segment
Hardware for the first flight model, MOP-1, is either undergoing acceptance testing at co-contractors' premises or has already been delivered in preparation for satellite integration, scheduled to start in September. Following the Production Baseline Review in May, a supplementary data package was prepared and delivered to the Evaluation Panel. This Panel will deliver its report to the Board in September.

Ground segment
The Meteosat F2 satellite has continued to support both the image-acquisition and data-dissemination missions, while the GOES-IV satellite has been used to maintain the Data-Collection Platform (DCP) mission.

The inclination of the F2 spacecraft with respect to the equatorial plane has been brought back to 0° through a manoeuvre conducted on 13 August 1986. The launch of the next satellite, Meteosat P2, has been delayed following the Ariane

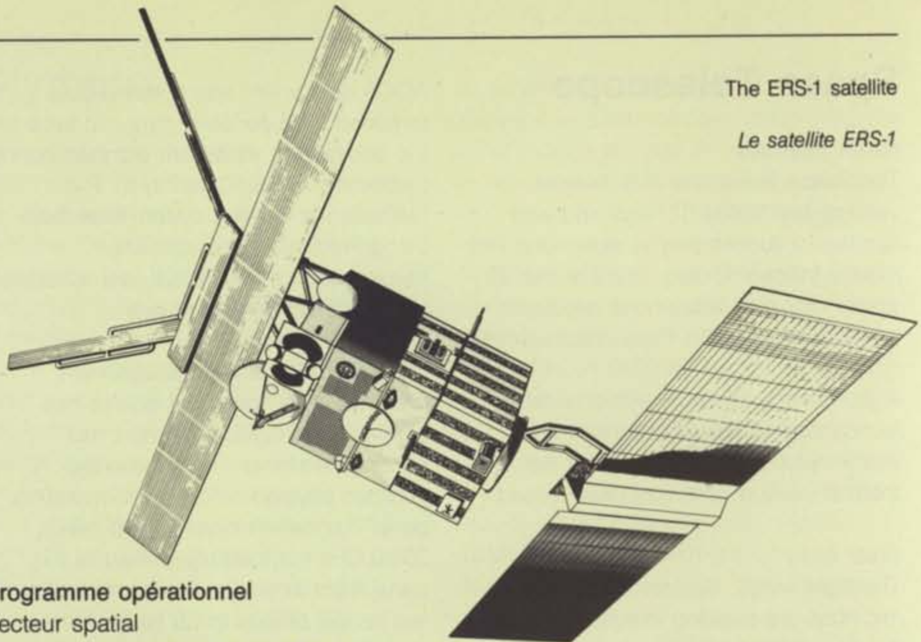
ERS-1

La revue des bases de référence du développement de la station sol de Kiruna s'est tenue fin juin et ses résultats ont été plutôt concluants. La dernière de ces revues qui est prévue pour la fin octobre concerne le Centre de gestion et de conduite de la mission.

Le programme du modèle mécanique se poursuit dans les délais prévus. Le modèle mécanique de la plate-forme a passé sa revue de recette avec succès et il a été transféré au CNES, au maître d'oeuvre d'ERS-1 en vue d'entreprendre les modifications nécessaires sur ERS-1. La construction et les essais des modèles de développement et d'identification des sous-systèmes se poursuivent.

Un atelier comprenant environ 50 participants s'est tenu en vue de fixer des lignes directrices pour la validation et l'étalonnage géophysiques des instruments de mesure de vents et de vagues (ESA SP-262).

Un groupe conseil des opérations ERS-1 a été mis sur pied en vue d'étudier les exigences et les priorités à observer pour une première version d'un plan des opérations de la mission ERS-1. Une offre de participation ERS-1 sollicitant des propositions de recherches scientifiques, de démonstrations d'application et d'assistance pour la validation des données géophysiques a également été lancée.



The ERS-1 satellite

Le satellite ERS-1

Météosat

Programme préopérationnel
Le satellite Météosat P2 a subi une dernière série d'essais à l'Aérospatiale à Cannes avant son départ pour la base de lancement selon le calendrier préétabli. Mais après l'échec d'Ariane, tous les préparatifs de lancement ont dû être interrompus; le satellite est à présent entreposé à l'Aérospatiale.

Lasso
Le feu vert a été donné en juin à Telespazio pour mettre en route les préparatifs du centre de coordination Lasso.

Programme opérationnel
Secteur spatial
Une partie de matériel destiné au premier modèle de vol MOP-1 est en train de subir des essais de recette chez les cocontractants; le reste a déjà été livré en vue des préparatifs d'intégration du satellite qui doivent débuter en septembre. Suite à la revue des bases de référence de la production qui s'est tenue en mai, un ensemble de données supplémentaires a été préparé et transmis au comité d'évoluation qui doit communiquer son rapport au comité directeur en septembre.

Secteur terrien
Le satellite Météosat F2 a continué à remplir sa mission de prise d'images et de diffusion des données, la mission de collecte des données étant assurée par le satellite GOES-IV.

L'orbite du satellite F2 a été ramenée dans le plan de l'équateur par une manoeuvre effectuée le 13 août 1986. Le lancement du prochain satellite Météosat P2 a été reporté à juin 1987. Il faudra donc mettre en oeuvre une nouvelle stratégie de maintien à poste pour prolonger la durée du service du satellite F2. Deux solutions possibles sont actuellement à l'étude:
- *cessation de la tenue de poste nord-sud, en maintenant le plus longtemps possible l'axe de rotation du satellite perpendiculaire au plan de l'équateur*
- *orientation de l'axe de rotation du satellite perpendiculairement au plan de l'orbite à une époque plus rapprochée.*

Dans les deux cas on sera limité par la précision du processus de rectification des images au fur et à mesure que l'inclinaison augmente.

Plusieurs améliorations ont été apportées au logiciel de traitement des données météorologiques. Des études ont ainsi montré qu'on pouvait réduire l'erreur systématique sur les vents à haute altitude en recourant à l'emploi de fenêtres dans le calcul informatique des vecteurs mouvement de nuages. Par ailleurs un nouveau paramètre, l'indice de précipitation, a été introduit de manière expérimentale. Des mesures sur site témoin effectuées dans cinq pays africains ont montré qu'il existait une étroite corrélation entre les zones où les précipitations provenaient essentiellement de nuages convectifs.

En raison du retard de lancement mentionné plus haut, il a fallu replanifier toutes les activités de réaménagement. Il faudra surtout s'attacher à terminer les parties essentielles de la station d'Odenwald et de son électronique avant le lancement du satellite P2. Le renouvellement de la plate-forme de collecte des données et des dispositifs de mesure de distance sera effectué par la suite, dès le début de l'année 1988.

Spacelab et IPS

Les travaux se poursuivent sur les tâches restantes de Spacelab et du Système de Pointage d'Instruments (IPS).

En ce qui concerne Spacelab, des modifications contractuelles ont été conclues avec MBB/ERNO en vue d'effectuer des essais de qualification supplémentaires sur l'Unité d'acquisition décentralisée (RAU) et d'améliorer l'Adaptateur d'interface de charge utile launch failure until June 1987. A new station-keeping strategy will therefore have to be implemented, aimed at extending the lifetime of the F2 satellite. Two alternatives currently under study are:

- cessation of north-south station-keeping, keeping the satellite's spin axis perpendicular to the equatorial plane for as long as possible, or
- orienting the satellite's spin-axis perpendicular to the orbital plane at an earlier time.

The limiting parameter for both alternatives will be the accuracy of the image-rectification process as a function of increasing inclination.

Several improvements have been introduced into the meteorological data processing software. In particular, studies have shown that the bias in the high-level winds can be reduced by the introduction of a windowing technique in the software-controlled cloud-motion-vector calculation.

Moreover, a new product, namely the precipitation index, has been introduced on an experimental basis. Ground-truth measurements taken in five different African countries have shown good correlation for areas where rainfall is mainly from convective clouds.

Because of the launch delay mentioned earlier, replanning of all ground-refurbishment activities became necessary. The main emphasis will be put on completing the essential parts of the Odenwald station, and associated electronics, before the Meteosat P2 satellite is launched. Renewal of the DCP and ranging systems will then follow by the beginning of 1988.

Spacelab and IPS

Work is continuing on the tasks remaining open for both Spacelab and the Instrument Pointing System (IPS).

For Spacelab, contractual changes have been negotiated with MBB/ERNO to cover additional qualification tests on the Remote Acquisition Unit (RAU) and for upgrading the Payload Interface Adaptor (PIA). All residual work on the RAU has now been completed and the required changes to the PIA, as determined by the Qualification Review, have been implemented. Flight hardware production is in progress. One Data Display Unit (DDU) is still at the supplier for repair and continues to be delayed due to consecutive failures experienced in acceptance testing.

On IPS, two sets of retrofit hardware to be installed in gimbal latch mechanisms of both the C/D and FOP IPS flight units, have been produced and are ready for installation following completion of related documentation.

The IPS Optical Sensor Package, still to be delivered by the contractor, is further delayed and work on the failed star tracker assembly continues. A spare star tracker is now ready for final acceptance.

Follow-On Production
The FOP contract between ESA and MBB/ERNO has finally been closed. Support services tasks for NASA's Marshall Space Flight Center are being performed by ESA as requested by NASA. The last IPS spares items (actuators) under the FOP contract are still undergoing failure investigation and repair action, which is delaying their delivery to NASA.

Microgravity

The overall programme of work is presently under review in view of the serious situation regarding microgravity flight opportunities following the Shuttle accident at the beginning of the year. Work is continuing in all areas pending the availability of better schedule information on the revised Shuttle manifest. In the meantime, detailed in-house studies are being conducted to find alternative flight opportunities particularly related to sounding rockets.

Phase-1
The results of the German D1 mission were presented at a Symposium organised by BMFT/DFVLR at the end of August. The principal investigations of Biorack (14 experiments), Fluid Physics Module (seven experiments) and Sled (two sets of experiments with many co-investigators) were covered and great interest was shown in the findings which are considered to be of considerable practical importance.

Phase-2
The German authorities responsible for the D2 mission have informed the Agency that due to the shortage of technical resources (mass, crew time, etc.) it will not be possible to fly both the Anthrorack and the Vestibular Sled together on the D2 mission as originally planned. The decision has been taken to give priority to Anthrorack and therefore the Sled reflight will be delayed.

On the Fluid Physics Facilities the development phase of the Autonomous Fluid Physics Module began in June. The presentation of the Phase-B studies for the Bubble, Drop and Particle Unit will be held shortly, whilst the proposal for the hardware phase from industry on the Critical Point Facility is under consideration. The Phase C/D offer for Anthrorack has been received and certain adjustments will be required before the offer can be considered acceptable. Concerning the Advanced Gradient Heating Facility, negotiations with industry have been successfully completed and Phase-B is proceeding according to plan.

Phase-3
Several preparatory studies are in progress on Phase-3 of the Microgravity Programme – the pre-Columbus Phase and pre-Phase A of the Columbus utilisation studies.

Microgravity Core Payloads on Eureca
Work is progressing on the five core payloads

- Automatic Mirror Furnace
- Solution Growth Facility
- Protein Crystallisation Facility
- Multi-Furnace Assembly
- Exo-biological Radiation Assembly

Pending the re-establishment of a new launch date the previously agreed contractual launch date of March 1988 has been shifted by four months.

Eureca

The Eureca Design Review (EDR) was provisionally concluded by the final EDR

(PIA). Tous les travaux qui restaient sur l'Unité d'acquisition sont à présent achevés et l'Adaptateur d'interface a été modifié comme convenu lors de la revue de qualification. La production du matériel de vol est en bonne voie. Une unité d'affichage de données (DDU) est encore chez le fournisseur pour réparation. Ce contretemps est dû aux pannes qui se sont succédé lors des essais de recette.

En ce qui concerne le système de pointage d'instruments (IPS), deux ensembles de matériel à montrer après coup dans les mécanismes de verrouillage des cardans des unités lors de la phase C/D et de la production ultérieure ont été fabriqués et n'attendent plus pour être montés que la documentation qui s'y rapporte soit achevée.

La livraison du bloc capteur optique de l'IPS a encore été reportée, le maître d'oeuvre n'ayant pas terminé ses travaux sur les suiveurs stellaires tombés en panne au cours de la mission SL2. Un suiveur stellaire de rechange est prêt pour la recette finale.

Production ultérieure
Le contrat de production ultérieure entre l'ESA et MBB/ERNO a finalement été conclu. Sur la demande de la NASA, l'ESA s'est engagée à fournir des services d'assistance au Centre de Vols Spatiaux Marshall de la NASA. Les derniers éléments du système de pointage d'instruments (dispositifs d'actionnement) doivent encore subir des examens en vue de rechercher les causes de la panne et d'y remédier, ce qui contribue à retarder leur livraison à la NASA.

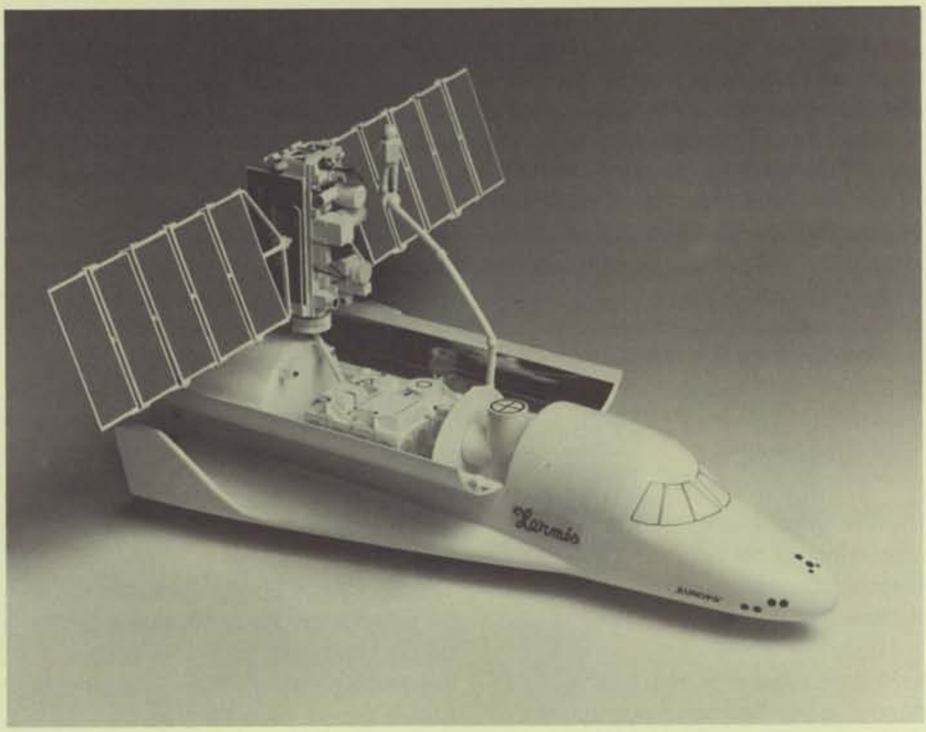
Microgravité

Le programme d'ensemble des activités est actuellement à l'étude, les occasions de vol étant par suite de l'accident survenu à la Navette Spatiale au début de l'année sérieusement remises en question. Les travaux se poursuivent dans tous les domaines en attendant que l'on dispose de plus de renseignements sur le calendrier du nouveau programme de lancement de la Navette. Dans l'intervalle, des études internes détaillées sont menées en vue de trouver des occasions de vol de remplacement, en particulier grâce aux fusées-sondes.

Phase-1
Les résultats de la mission allemande DI ont été présentés lors d'un colloque organisé par BMFT/DFVLR fin août. On a rendu compte des principales recherches effectuées sur Biorack (14 expériences), sur le module de physique des fluides (7 expériences) et sur le traîneau vestibulaire (deux ensembles d'expériences); les résultats obtenus ont suscité un vif intérêt en raison de leur grande portée pratique.

Phase-2
Les autorités allemandes responsables de la mission D2 ont informé l'Agence qu'en raison du manque de ressources techniques (masse, emploi du temps de l'équipage, etc.), il ne serait pas possible de faire voler à la fois Anthrorack et le traîneau vestibulaire dans le cadre de la mission D2, contrairement à ce qui avait été prévu initialement. La décision a été prise de donner la priorité à Anthrorack et donc de retarder le nouveau vol du traîneau vestibulaire.

Sur les installations de physique des fluides, la phase de développement du module autonome a débuté en juin. Les études de phase B de l'Unité Bulles, Gouttes et Particules seront présentées incessamment, les propositions industrielles pour la phase de réalisation matérielle de l'Installation de Point Critique étant à l'étude. L'offre que l'on a reçue pour la phase C/D d'Anthorack ne pourra convenir qu'après certaines modifications. Des négociations avec l'industrie ont été menées avec succès en de qui concerne le four à gradient de conception évoluée et la phase B se poursuit comme prévu.



Model of Eureca on board the Hermes vehicle

Modèle d'Eureca à bord de la navette Hermès

Phase-3
Plusieurs études préparatoires sont en cours, portant sur la phase 3 du programme de microgravité, la phase préalable au projet Columbus et la pré-phase A des études d'utilisation de Columbus.

Charges utiles principales de microgravité sur Eureca
Les travaux avancent sur les cinq charges utiles principales (Four à miroir automatique, Installation de croissance en solution, Installation de cristallisation des protéines, Ensemble multi-four, Ensemble de rayonnement pour l'exobiologie) et en attendant qu'une nouvelle date de lancement soit établie, la date précédemment fixée par contrat à mars 1988 a été décalée de quatre mois.

Board session on 24 July. The Board identified as points of continuing concern:

- the Eureca mass projection (considerably exceeding the specification value of 4000 kg)
- excessive temperatures on two instruments
- storage of a large amount of operational data in Programmable Read Only Memories (PROMS)
- doubts about a proper test approach for solar array retraction.

The Board requested the project office to report back once satisfactory solutions have been obtained.

At the Interface Meeting with NASA in July, agreement was reached on the proposed modifications, for safety reasons, of the hydrazine latch valve. The problem of qualification of the hydrazine tanks was also discussed between NASA, ESA and the US tank supplier PSI. While NASA has flown these tanks several times as part of Shuttle payloads, this was done on a waiver basis rather than with full design qualification. This is unlikely to be possible in the future in view of the reinforcement of Shuttle safety standards after the Challenger accident. ESA has therefore instructed MBB/ERNO to define, together with PSI, a procedure for full qualification of the tanks.

The Overall Check Out Equipment (OCOE), to be delivered to MBB/ERNO as ESA-furnished equipment, has been put into operational status at ESTEC and is planned to be shipped to MBB/ERNO in September. To accelerate software development for the new packet telemetry and telecommand standards, ESA has installed Laben and Gawazzi personnel at ESTEC with priority access to all supporting computer facilities.

In preparation for a second microgravity mission of Eureca-A, MBB/ERNO has been requested to evaluate the refurbishment needs of both the microgravity core facilities and the Carrier.

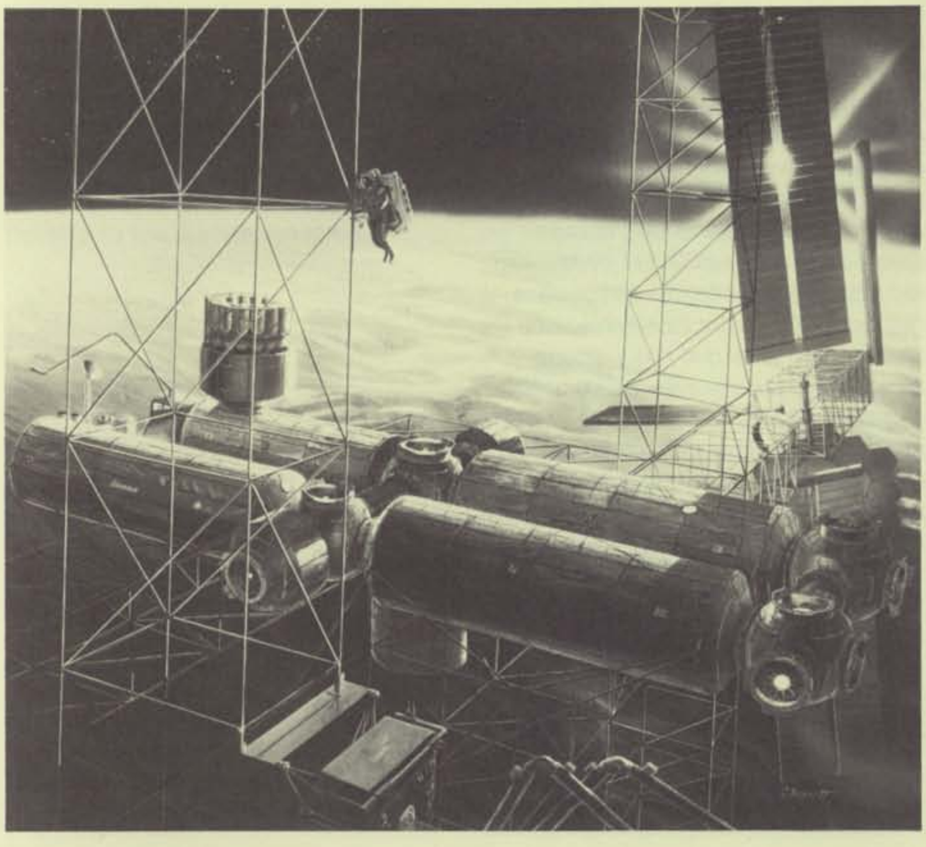
The current contractual launch date for Eureca is July 1988, but recent NASA projections indicate a launch date of November 1990. The Programme Board has been requested to provide financial coverage for this programme extension.

Space Station/ Columbus

Phase B1 of the Columbus system-definition studies was finalised in mid-July with the delivery of the final reports from industry. The technical content of the final reports responded well to the major redirections given to industry following the programme re-alignment approved by the Programme Board in April.

Preparation for the initiation of Phase B2 was completed at the end of June with a formal request to MBB/ERNO for an industrial proposal on continuation of the system definition studies. Unlike Phase B1, where the studies were performed under five parallel contracts. Phase B2 will be under the leadership of a single prime contractor. Their proposal was received on 25 August and is being evaluated.

The NASA Space Station programme has been undergoing considerable re-assessment as a result of the Challenger accident. A Configuration Critical Evaluation Task Force has been established to re-evaluate the current Space Station baseline against a reduced NASA Space Transportation System (NSTS) availability and a reduction in the number of crew Extra Vehicular Assembly (EVA) hours during the assembly phase. The use of expendable launch vehicles as well as the NSTS is being considered in this re-evaluation. The recommendations of the task force are expected to be reviewed by NASA management during the latter part of September for presentation to the US Congress at the beginning of October.



Vue imaginaire du complexe Station spatiale/Columbus

Space Station/Columbus (Artist's impression)

Eureca

La Revue de conception d'Eureca s'est provisiorement conclue le 24 juillet par la dernière réunion du Comité de revue qui a recensé les points encore préoccupants, à savoir la masse d'Eureca qui dépasse de beaucoup les 4 tonnes spécifiées, les températures excessives sur deux instruments, les stockage d'une grande quantité de données relatives aux opérations dans des mémoires mortes programmables (PROMS), l'incertitude au sujet de la méthodologie à adopter pour les essais de rétraction des panneaux solaires. Il a donc demandé au bureau du projet de faire son rapport une fois ces sujets de préoccupation résolus de façon satisfaisante.

Lors de la réunion de liaison avec la NASA en juillet, les responsables du projet sont arrivés à un accord sur la proposition de modification de la vanne de verrouillage de l'hydrazine, dans l'intérêt de la sécurité. Le problème de la qualification des réservoirs d'hydrazine a également fait l'objet d'une discussion entre la NASA, l'ESA et le fournisseur américain PSI. Si jusqu'ici la NASA a fait voler à plusieurs reprises ces réservoirs à bord de la Navette, elle l'a fait par dérogation et non au terme d'une qualification en bonne et due forme. La chose ne sera sans doute plus possible en raison du renforcement des normes de sécurité de la Navette après l'accident de Challenger. L'Agence a donc chargé MBB/ERNO de définir avec PSI une procédure de qualification complète des réservoirs.

L'équipement de vérification générale qui doit être livré en septembre à MBB/ERNO par les soins de l'ESA a été mis en état de marche à l'ESTEC. Afin d'accélérer le développement du logiciel aux nouvelles normes de télémesure et de télécommande par paquets, l'Agence a fait venir à l'ESTEC du personnel des firmes Laben et Gavazzi, avec priorité d'accès à tous les moyens informatiques correspondants.

En vue d'une seconde mission de recherche en microgravité d'Eureca-A, MBB/ERNO a été chargé d'évaluer les besoins de réaménagement des installations de microgravité ainsi que de la plate-forme porteuse.

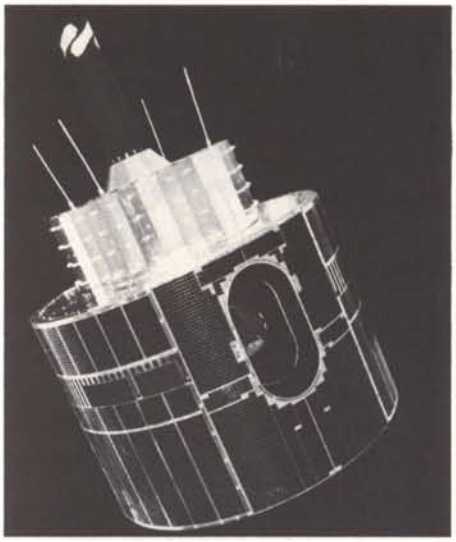
Jusqu'ici la date de lancement d'Eureca était fixée par contrat à juillet 1988 mais les dernières prévisions situent celle-ci en novembre 1990. On a demandé au bureau du programme d'assurer la prise en charge financière de cette prolongation de programme.

Station spatiale/Columbus

La phase BI des études de définition du système Columbus s'est achevée à la mi-juillet avec la remise des rapports finals de l'industrie, dont le contenu technique reflète de manière satisfaisante les nouvelles orientations fixées à l'industrie après le recadrage du programme et son approbation par le Conseil directeur au mois d'avril.

Les préparatifs de mise en route de la phase B se sont achevés fin juin avec la demande officielle à MBB/ERNO de soumettre une offre industrielle sur la poursuite des études de définition du système. A la différence de la phase BI dont les études ont été menées parallèlement par cinq contractants, la phase B2 sera placée sous la direction d'un seul maître d'oeuvre. L'offre a été reçue le 25 août et elle est en cours d'évaluation.

Le programme de Station spatiale de la NASA a été considérablement revue après l'accident de Challenger. Un groupe de travail chargé de procéder à l'analyse critique de la configuration a été constitué en vue de réévaluer la base de travail actuelle en fonction de la moindre disponibilité du système de transport spatial de la NASA (NSTS) et de la réduction de la durée des sorties dans l'espace (EVA) durant l'assemblage de la Station. C'est ainsi que l'on envisage l'emploi de véhicules non récupérables en plus du NSTS. Les recommandations du groupe de travail doivent être revues fin septembre par l'état-major de la NASA pour être présentées au Congrès américain début octobre.



A Curious Sea-Surface-Temperature Phenomenon Observed by Meteosat

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One of the five meteorological products derived from Meteosat-2 data on a routine basis at ESOC is Sea-Surface Temperatures (SSTs). These are produced twice daily, nominally for 1200 and 2400 GMT, from radiance data received by the satellite. Each SST result can be thought of as an estimate of the sea skin temperature averaged over an area of about 200 x 200 km².

After automatic processing and quality control, the SSTs are displayed on the Meteorological Information Extraction Centre (MIEC) display subsystem for manual quality control by the shift meteorologist on duty. During the manual quality control of the Meteosat data for the period 15—26 August 1985, a curious SST phenomenon was observed to develop in the Mediterranean Sea.

SST automatic processing and quality control

Segment processing

In common with the derivation of other meteorological products, SST results are obtained from the analysis of Meteosat radiometric data [in the Visible (VIS) 0.5–0.9 μm, Infrared (IR) 10.5–12.5 μm and Water Vapour (WV) 5.7–7.1 μm wavelength bands]. For SST extraction, however, mainly IR radiance data are used. Analysis takes place on a segment by segment basis using the results from segment processing, which forms the basis for all meteorological product extraction.

A segment comprises an array of 32×32 IR pixels, cut from an image such that each segment centre is always at a fixed geographical location. An array of 80×80 segments then adequately covers the Meteosat field of view, although analysis is currently restricted to complete segments within a 55° great-circle arc of the subsatellite point.

For each Meteosat segment (i.e. an approximate 200 km × 200 km square), two-dimensional IR/VIS histograms are constructed. The radiances forming these histograms tend to be grouped into clusters corresponding to the physical bodies located within the satellite's field of view. Most bodies can then be well discriminated by using these IR/VIS histograms, e.g. sea-surface source bodies. All sea-radiance clusters extracted and identified by the automatic system are then subjected to a quality screening, designed principally to detect and remove cloud contamination from within the cluster (sub-pixel clouds or overlying semi-transparent Cirrus cloud) and to detect and remove low-cloud radiance clusters mis-identified as sea.

After correcting for atmospheric absorption between the segment and satellite (principally by water vapour), the mean IR radiance for sea clusters is then finally used to estimate SST, using the Planck relationship.

Automatic quality control

In most geographical regions within the Meteosat field of view, SST is a relatively slowly changing parameter, particularly bearing in mind the area over which an individual SST is calculated. The SST product is therefore based on a composite of several sea-surface-temperature derivations to minimise the effect of errors in the individual determinations and so form an estimate of the most probable temperature field. This technique also helps to remove from the product diurnal variations in sea-surface skin temperatures. The segment processing task as described above is run every 3 h, and sea radiance data accumulated over a 36 h period are used to form a statistical estimate of the sea radiance. For each segment, therefore, a composite of 12 absorption-corrected sea-surface-temperature fields exists.

The first step in the automatic quality control is to quality check each individual temperature estimate in each of the 12 images against a similarly updated background or reference SST field. All

Figure 1 — Segment mean Sea-Surface Temperature (SST) field for 26 March 1986 (1100 GMT, Julian day 085). In this low-resolution image, the two-degree colour-table option is shown. Only units figure of temperature is displayed for each segment square

Figure 2 — New background SST field for 26 March 1985 (1100 GMT, Julian day 085). Other details as per Figure 1

SST estimates differing by more than preset quality thresholds are rejected as unacceptable. The quality thresholds vary across the field (from segment to segment) with an estimate of the quality of the background field at that point; this is dependent upon local temperature gradient and local background age (i.e. the length of time since the background field at that segment was last updated).

A second quality-control step is built into the scheme to prevent all sea radiances being continuously rejected at a particular segment as a result of an unrepresentative or erroneous local background value. This consists of performing the quality check again with somewhat relaxed thresholds at those segments where all available sea radiances have been rejected, and where the local background age is beyond a set limit.

After the above quality checks have taken place for all segments of each available image, the remaining sea radiances of acceptable quality are combined to form a single sea-radiance estimate at each segment. The result is called the segment mean sea radiance and is the basic product of the automatic quality-control scheme. A weighted mean of the individual acceptable radiances is formed for a given segment, where the weights vary with the estimates of the quality of the radiances.

Factors assumed to affect the quality of a radiance value are:
(a) the spread of the clusters
(b) the timeliness of the forecast data used in the water-vapour absorption correction
(c) the availability of the VIS channel in the cluster extraction and identification scheme.

Next, the segment mean sea radiances so derived are used to perform an update on the background field used in the quality-control scheme so that the evolution of the true sea-surface temperature field is followed.

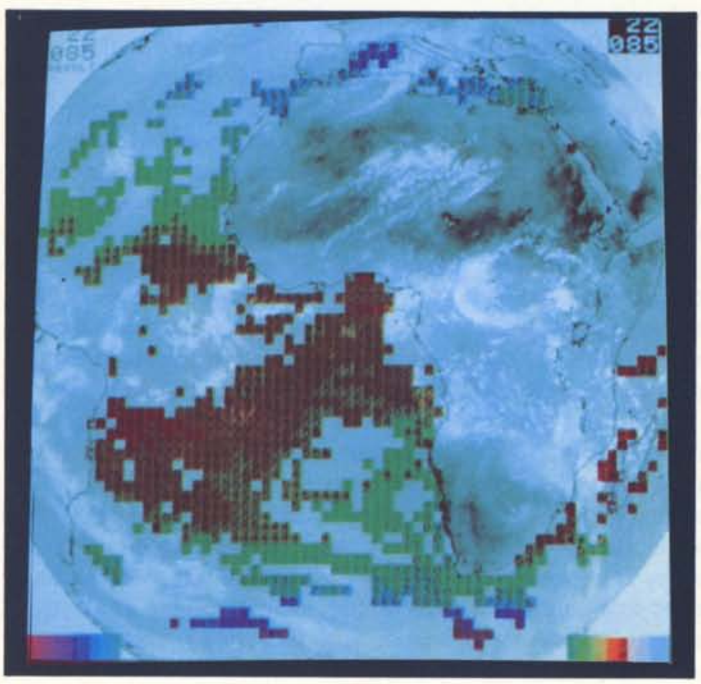
Finally, when all of the radiance computations have been completed, segment mean sea radiances for the results field and the background field are converted into SSTs using the Planck relationship, in preparation for manual quality control.

Manual quality control and dissemination

Up to now, all processing and quality control of the SST product has been fully automatic. It is essential that a manual control step be included at this point to ensure that any remaining spurious SSTs are rejected in both the results and new background fields.

The meteorologist performing this quality control is provided with various sources of information on his interactive display monitor:

(a) a low-resolution IR image covering the full Meteosat area, superimposed with
(b) two of the following image format foreground data masks in animated sequence:
— segment mean SST field; only values where at least one component of SST is within 12 h of the extraction time are considered (Fig. 1)
— new background SST field (Fig. 2)



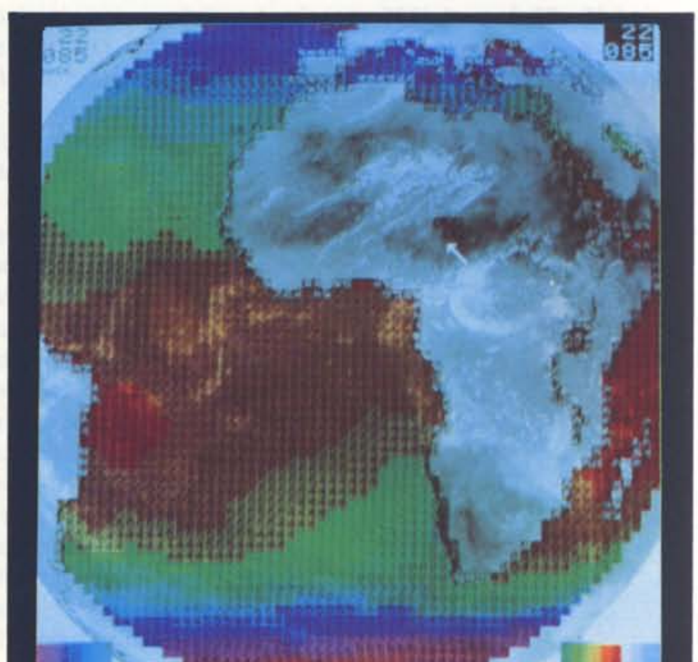


Figure 3a — Ship sea-temperature field for data up to 0600 GMT on 26 March 1985. Other details as per Figure 1

Figure 3b — Zoom from Figure 3a to view only the North Atlantic quadrant

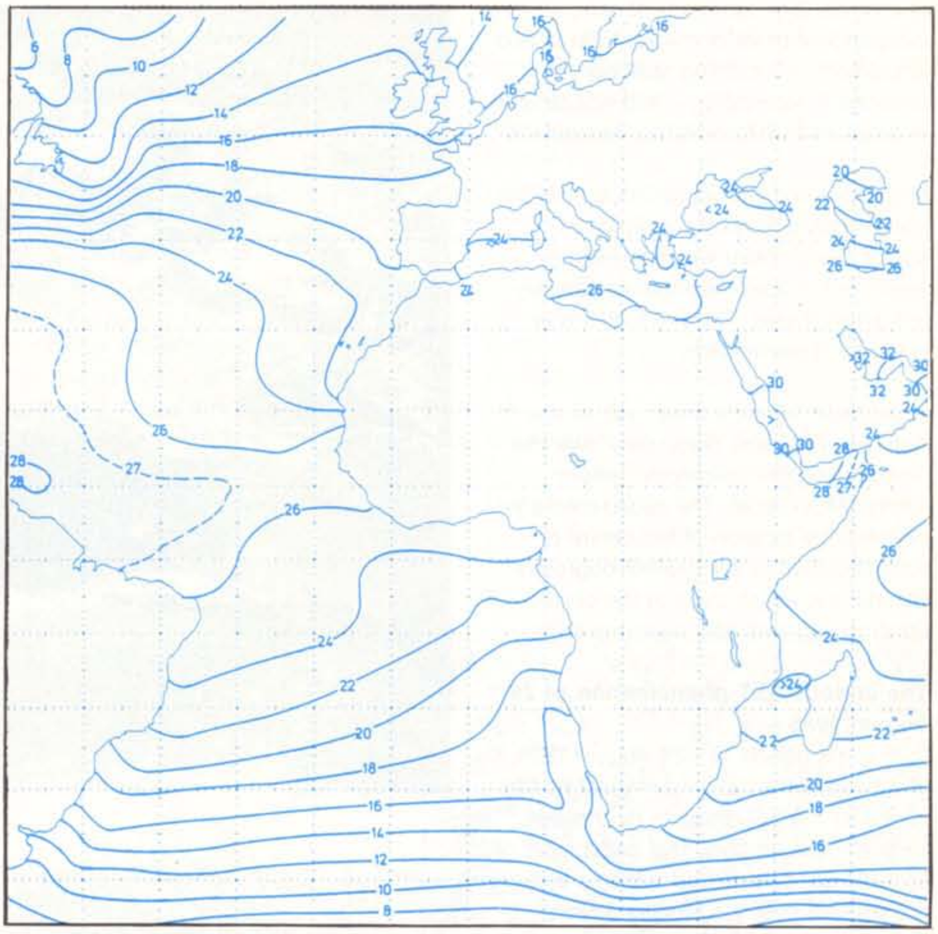
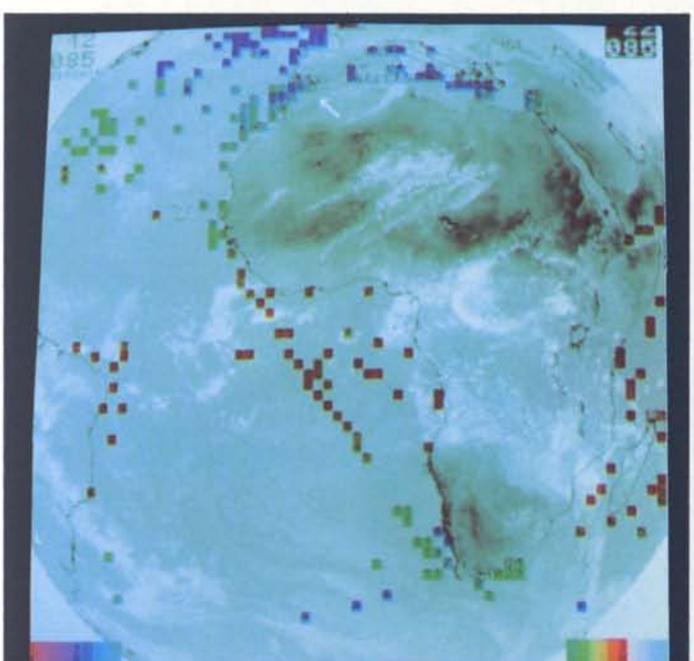


Figure 4 — Climatological chart of ten-year mean of sea-surface temperature (°C) for the month of August

- observed sea temperature field from ground-based measurements (Figs. 3a and 3b). This field is constructed from all ship and buoy data received at ESOC with a validity time within the previous 96 h. Only data within 4°C of climatology are accepted in order to screen false data, which often occur as an result of telecommunication transmission errors. Where more than one ship temperature is found within a given segment, a mean ship temperature is derived.

The meteorologist also has at his disposal mean monthly sea-surface-temperature climatological charts for cross-reference where necessary (Fig. 4).

With this information, the shift meteorologist can then compare both the segment mean SST field and the new background SST field, firstly against the ship temperature field, and secondly against each other. To help with this task, all sea-temperature data fields are colour coded in 2°C or 10°C steps. The display monitors also allow a flexible, large range



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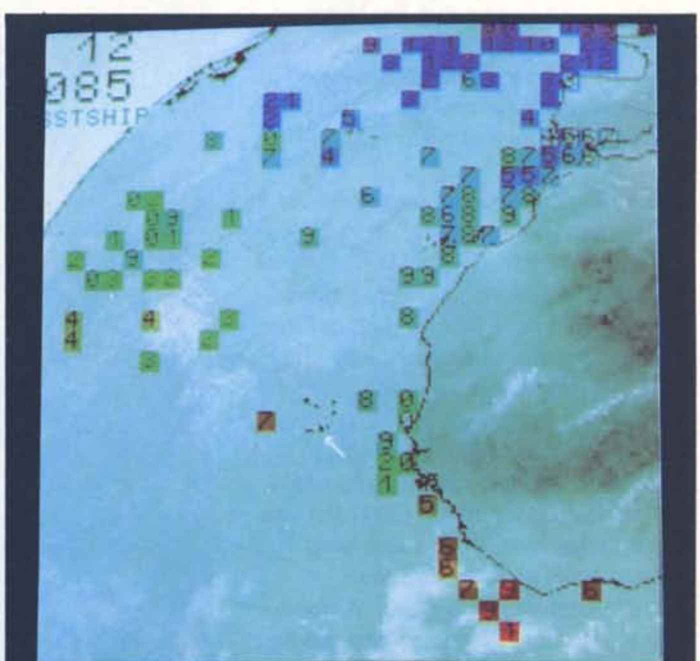


3b

Figure 5 — Meteosat visible image of Europe taken on 26 August 1985 at 1055 GMT

Figure 6 — Meteosat infrared image of Europe taken on 26 August 1985 at 1055 GMT

of controls (e.g. zoom adjustment, independent offset of masks, loop speed adjustment — including stationary positions if necessary — and adjustment of black and white or colour saturation).

After close scrutiny, all spurious SSTs are rejected, usually on the grounds of spatial discontinuity within the same mask, or by direct segment comparison with other masks. The product is now ready for dissemination.

Acceptable segment mean values are distributed to users twice daily over the Global Telecommunications System (using SATOB code). The coded message includes the location of the centre of each segment to the nearest degree of latitude and longitude, and the corresponding segment SST coded to 0.2°C.

The curious SST phenomenon of 26 August 1985

During the period 15—26 August 1985, it had been noticed during manual quality control of the SST product by the shift meteorologist on duty, that acceptable or sensible SST results had become virtually non-existent over the Mediterranean. From inspection of these computed results, it was evident that the Meteosat-produced temperatures were much too high (of the order 5—10°C) compared to the background climatology or reliable ship SST data for that area.

With reference to the relevant Meteosat-2 images and meteorological charts (Figs. 5—8), it can be seen that at 1200 GMT on 26 August 1985 a rather complex cold front was lying across the northern Adriatic, to southern Italy and western Sicily (with a weak link westwards to southeast Spain), and was moving erratically southeastwards. In association with the surface feature, a well-marked upper trough (500 hPa) was moving eastwards, with its axis lying north to south at about 8°E from northern Germany to Sardinia. A good deal of post-frontal cloud, giving rise to rain and thunderstorms, lay over

southeastern Germany and Austria in association with a triple point which had formed near Venice. A marked surface ridge was now pushing into western France from the west and a much cooler, fresher maritime airstream had become established over France and northern and western Germany, with some moderate convection embedded.

It was this airstream that had pushed into most of the western Mediteranean, west of Sicily and east of Alicante. Mean surface wind speeds over this area had increased generally to about 15 knots, with stronger winds reported off the coast of southern France. A moderate sea-state was therefore to be expected in this area.

Meanwhile, the pressure gradient over the eastern Mediterranean remained very slack, enabling the quiet, calm and hot weather to continue unabated.

During routine manual quality control of the SST product for 1100 GMT on 26 August 1985, an interesting feature was recognised: a very noticeable division of the Mediterranean Sea was apparent in the SST results. To the west and northwest of Sicily, a cluster of segments containing 'sensible' SST data was observed for the first time in about 10 d. To the east and southeast of Sicily still no SST results were displayed (SST results rejected by the automatic quality-control scheme are not presented on the MIEC display).

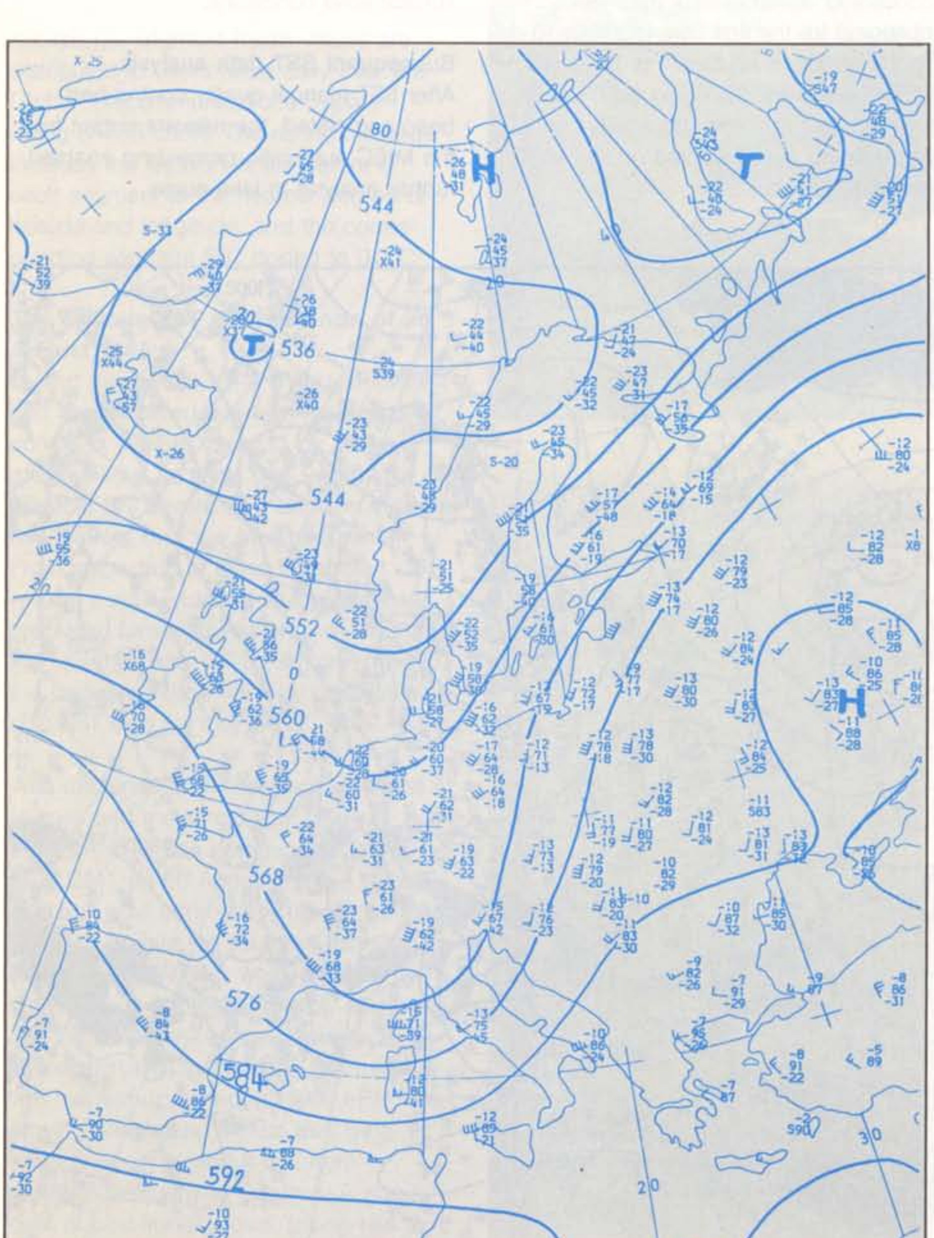
Although the latest meteorological information (Figs. 7 and 8) was not yet available, continuity from earlier synoptic weather charts and inspection of the near-real-time dissemination of Meteosat-2 image data for 1100 GMT revealed an interesting preliminary correlation: namely, between the sea-surface area north and west of Sicily containing realistic SST results, and the sea-surface area behind the surface cold front now experiencing the stronger surface-wind conditions.

Subsequent SST data analysis

After SST manual quality control had been completed, the relevant output from the MIEC automatic processing enabled further analysis to take place.

Figure 7 — Surface weather chart for 1200 GMT on 26 August 1985

Figure 8 — 500 hPa contour chart for 1200 GMT on 26 August 1985



Figures 9 and 10 show the rejected and acceptable SST segment data and Figure 11 the disseminated SST data, all for the Mediterranean area for 1100 GMT on 26 August 1985. Each two-digit value shown represents the SST of one segment in degrees Centigrade.

It could now be confirmed that the only acceptable results found by Meteosat at that time were in the northwestern Mediterranean. Meanwhile the rejected SST data indicated considerably higher temperatures than expected, particularly east of Sicily, where temperature differences of 5—10°C (from climatology) were observed.

Note that Figures 9 and 10 are for rejected and acceptable data produced from the 1100 GMT segment processing task run only — 12 three-hourly runs of this task are needed to accumulate data over the last 36 h in order to extract a final segment mean sea radiance, or SST. This explains the slight differences in SST results seen in Figures 10 and 11.

From the above, it appears that the passage of the cold front, and the (relatively) strong surface winds behind it over the western Mediterranean to the west and northwest of Sicily, had mixed the sea-surface layer both vertically and, to a lesser degree, horizontally, to the extent that the skin surface temperature as 'seen' by Meteosat-2 was now realistic (compared to both climatology and SST as measured by ships). Consequently, for the first time in about 10 d, a sensible group of SSTs was available for manual quality control by the shift meteorologist and for subsequent dissemination.

This can be contrasted with the situation in the eastern Mediterranean. Here again over the previous days the surface sea-state had become very calm as a result of an almost entire lack of wind stress over a large area. It was assumed, therefore, that a particularly stable, non-mixed layer of approximately 1 m depth had developed in the presence of the strong daytime insolation. The temperature of this layer would be considerably warmer (by at least 5°C, and perhaps as much as 10°C) than the waters 1—2 m below; this latter depth is probably where the 'acceptable' SST measurements by Mediterranean ships would be made (nominally at 2 m depth). An apparent warm bias as given by Meteosat SST data would then result. Consequently, no sensible SST results could be displayed on the MIEC consoles for manual quality control, since the automatic quality control had already removed them by comparison with the background field. As long as the sea surface remained undisturbed and the strong solar heating continued, these anomalous temperatures would be present.

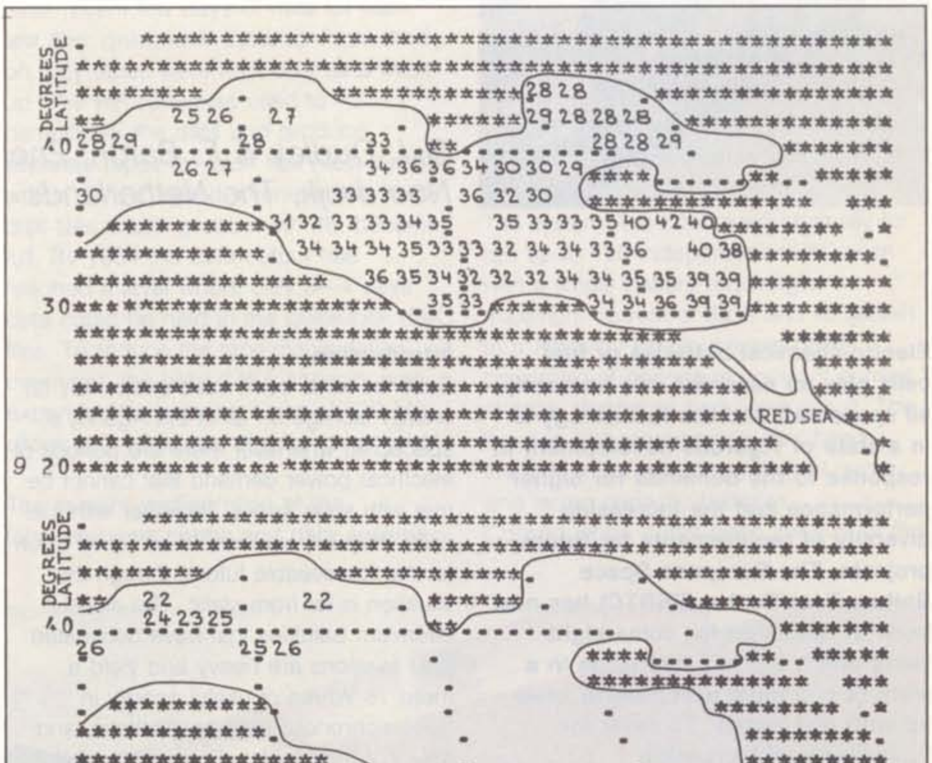
Conclusion

Although this lack of wind-stress effect is considered to play the dominant part in

Figure 9 — Rejected SST data for 1100 GMT on 26 August 1985 (day 238)

Figure 10 — Acceptable SST data for 1100 GMT on 26 August 1985 (day 238)

Figure 11 — Disseminated SST data for 1100 GMT on 26 August 1985 (day 238)

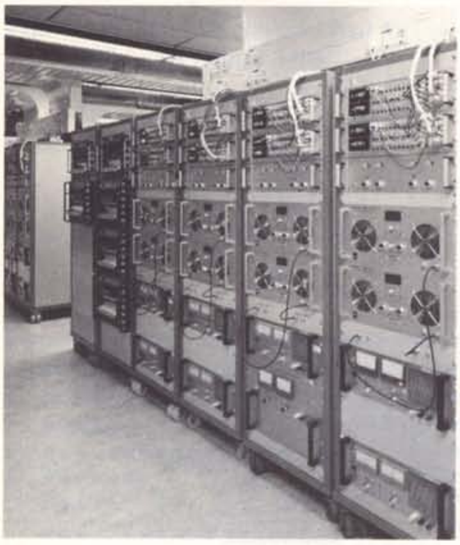


the production of abnormally high SST results, other factors may also play a role, alone or in combination. One possibility is that atmospheric conditions as represented by the relevant European Centre for Medium-range Weather Forecasts (ECMWF) model atmospheres (used to correct SSTs for atmospheric absorption) over the Mediterranean area were not sufficiently accurate, especially at lower levels, to account for the water-vapour absorption. An in-depth study would be needed to confirm such a theory.

A similar phenomenon has been observed previously by another research group, where satellite observations were used to study the SST temperature structure around the British Isles. Using satellite imagery combining Tiros-N and Meteosat-1 data on 12 July 1979, an anomalously warm patch of water appeared at about local noon in the eastern part of the North Sea, about 200 km west of the Danish coast. The position of this warm patch of water was also found to be well correlated with an area of low surface wind stress, i.e. surface winds were again weak, inhibiting surface mixing. By calculation from simple energy-balance equations, the surface mixing layer was found to be reduced in depth to about 0.6 m at the centre of this temperature anomaly. The lifetime of this warm patch, however, is presumed to have been much shorter than the phenomenon described in this article, and therefore the assumed non-mixed depth of about 1 m for the latter is likely to be a reasonable estimate.

This SST anomaly is an inherent problem associated with the remote sensing of the sea surface by Meteosat, where the irradiated energy from the sea surface skin is detected by the radiometer. In calm conditions, the very strong temperature gradient present in the top 2—3 m of the water is such as to provoke an abnormally hot and non-mixed surface layer.

Acknowledgements
The author would like to thank Mr. B. Mason, Dr. J. Schmetz and Dr. M. Fea for their constructive comments and ideas, and Miss A. Troitsch for her painstaking typing of several draft copies before the final article was completed.



Space Battery Testing at ESTEC

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Electro-chemical batteries or fuel cells play an essential role on nearly all spacecraft and the technology is in a state of vigorous development in response to the demands for higher performance and the increasing diversity of requirements for future projects. The European Space Battery Test Centre (ESBTC) has now been in operation for some eight years and it too has had to be in a state of continual evolution to keep up with test needs. To cater for future tests of increasing sophistication and power, major developments are planned to take place over the next few years.

Introduction

Batteries have been used exclusively for energy storage on all of the Agency's spacecraft whenever there are periods of electrical power demand that cannot be met with solar arrays. Together with fuel cells, they will continue to be relied upon for the foreseeable future, though the situation is far from static. The nickel-cadmium batteries that have dominated past missions are heavy and yield a mere 18 Wh/kg of useful energy in geosynchronous-orbit applications, and only 7 Wh/kg for low-Earth-orbit missions. With the trend towards higher powers, the mass of batteries is an ever-increasing concern, and substantial efforts are being devoted to the development of other chemical couples that could offer better energy densities. Consequently, nickel-cadmium batteries are gradually being replaced by nickel-hydrogen with about twice the gravimetric energy density, and these in turn may eventually be replaced by others such as sodium-sulphur or regenerative-fuel-cell or other such systems offering yet higher energy densities.

Because battery failure could result in many cases in loss of the spacecraft, it is essential to demonstrate beforehand the ability of a particular battery to operate throughout a mission's lifetime. In the early years of the European space programme, battery testing was carried out under contract at a number of scattered industrial laboratories. It was soon realised, however, that substantial advantage could be gained by having a single centre equipped for these somewhat specialised tests, adaptable to changing test demands, and with a standardised system for acquiring and processing the test data. This led to the decision in 1975 to set up the European Space Battery Test Centre at ESTEC.

Commissioned in 1978, the Centre has now completed more than 200 test programmes. During this time, it has been subject to a process of continuous development. Today the centralised computer test system is stretched almost to its limit, and the next five years will see the introduction of completely new test systems and a gradual phasing out of the centralised system.

Just before operations at the ESBTC began, an article in the August 1977 ESA Bulletin described the new laboratory. Now, nine years on, we highlight some of the work that has been carried out, the developments that have occurred since the Centre's inception, and plans for the future.

Evolution of the ESBTC (1978—1986)

The centralised computer system

The test equipment, described in detail in the August 1977 ESA Bulletin, is based upon a dual PDP 11/45 computer system in which at any given moment one computer is controlling the tests and the other is on hot standby ready to take over in the event of a malfunction in the other computer or its peripherals. The capacity of the system as designed is 100 simultaneous tests, with a maximum of 2000 measurement channels. All measurements are logged automatically and raw data stored in chronological

Figure 1 — The PDP and HP 1000 (right) computer facilities, the former for test control and data-acquisition, the latter for data-processing

order on magnetic tape ('day tapes').

As originally conceived and operated, the data analysis was performed offline using these tapes as input. The turn-around time for such batch-analysis proved, however, to be unacceptably long for many tests and did not allow convenient real-time monitoring of test progress. This deficiency was rectified in June 1982 with the installation of an HP 1000F computer dedicated to data processing (Fig. 1).

Towards the end of 1982, a direct data link was established between the PDP and HP systems, enabling the HP terminals to be used to examine the most recent few days of data for each test (the 'quick-look' system). From then on, day tapes were kept only as a back-up. The HP 1000 was used to demultiplex the data and produce separate tapes for each test ('test tapes'), which were updated whenever the hard-disk files, totalling about 80 Mb, became full. By 1984 the data output had reached a level where only 3—4 days data could be held in the quick-look disk files. To reduce the tape-manipulation overhead, the hard-disk's capacity was expanded to its present size of 520 Mb, allowing 2—3 weeks of data to be held.

The current configuration of the laboratory test centre and data analysis systems is outlined in Figure 2. Graphics terminals allow up to five test managers to examine and process the data from their tests simultaneously.

Battery-test requirements and equipment

The system was conceived originally to run up to 100 independent tests, each with a single battery requiring a maximum current of 30 A and subjected to a relatively simple cycling profile consisting of periods of constant current charge, discharge and open circuit. The trend in test requirements has been towards more realistic cycling of larger and larger capacity batteries. Consequently, it has been the size of the

Figure 2 — Schematic of the European Space Battery Test Centre (ESBTC) system

existing power supplies and the limits in the complexity of test definitions that have become limiting, rather than the number of tests or measurement channels required.

The first limitation has been largely overcome by the use of the existing computer-controlled power supplies and relays to control 'external' equipment dedicated to the particular test, consisting for example of a high-current power supply for battery charging, an electronic load capable of constant-current or constant-power operation for discharging, and suitable electronics to provide for temperature-dependent taper charging. On the other hand, the test complexity problem is fundamental to the test definition concepts used in the PDP system software and could only be solved by a major redesign. At the time of writing there are about 35 tests running, using a total of 711 channels, but the test-definition memory is 85% full and the data-acquisition rate is close to 80% of maximum.

The temperature of operation and the presence of temperature gradients have a strong effect on the performance and lifetime of batteries. Since in practice a spacecraft battery rejects its waste heat via a radiator plate or fluid-cooled plate whilst the remaining battery surfaces are well insulated, the trend in testing has been away from the use of temperature-controlled chambers that produce essentially isothermal conditions towards the use of temperature-controlled plates. An example of the latter can be seen in Figure 3.

Operation of the ESBTC

In the years following its establishment, the ESBTC was run by an average of five full-time staff with a further three engineers spending 30% of their time initiating, following and analysing tests. In 1984, preparations for a large test programme ('ELAN', described later) required an increase in this effort and a stepping up of the out-of-hours surveillance of the tests. As a result,

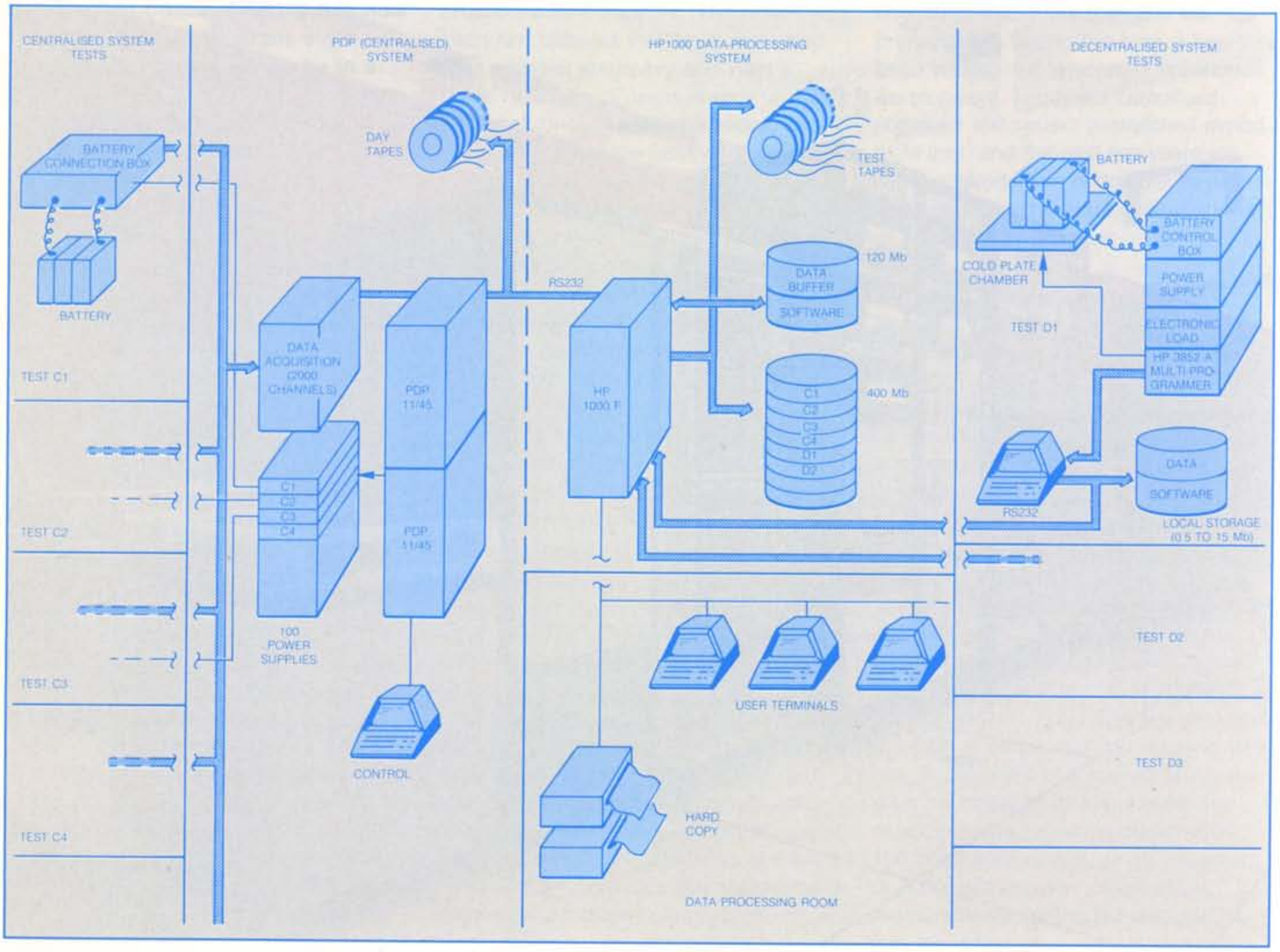
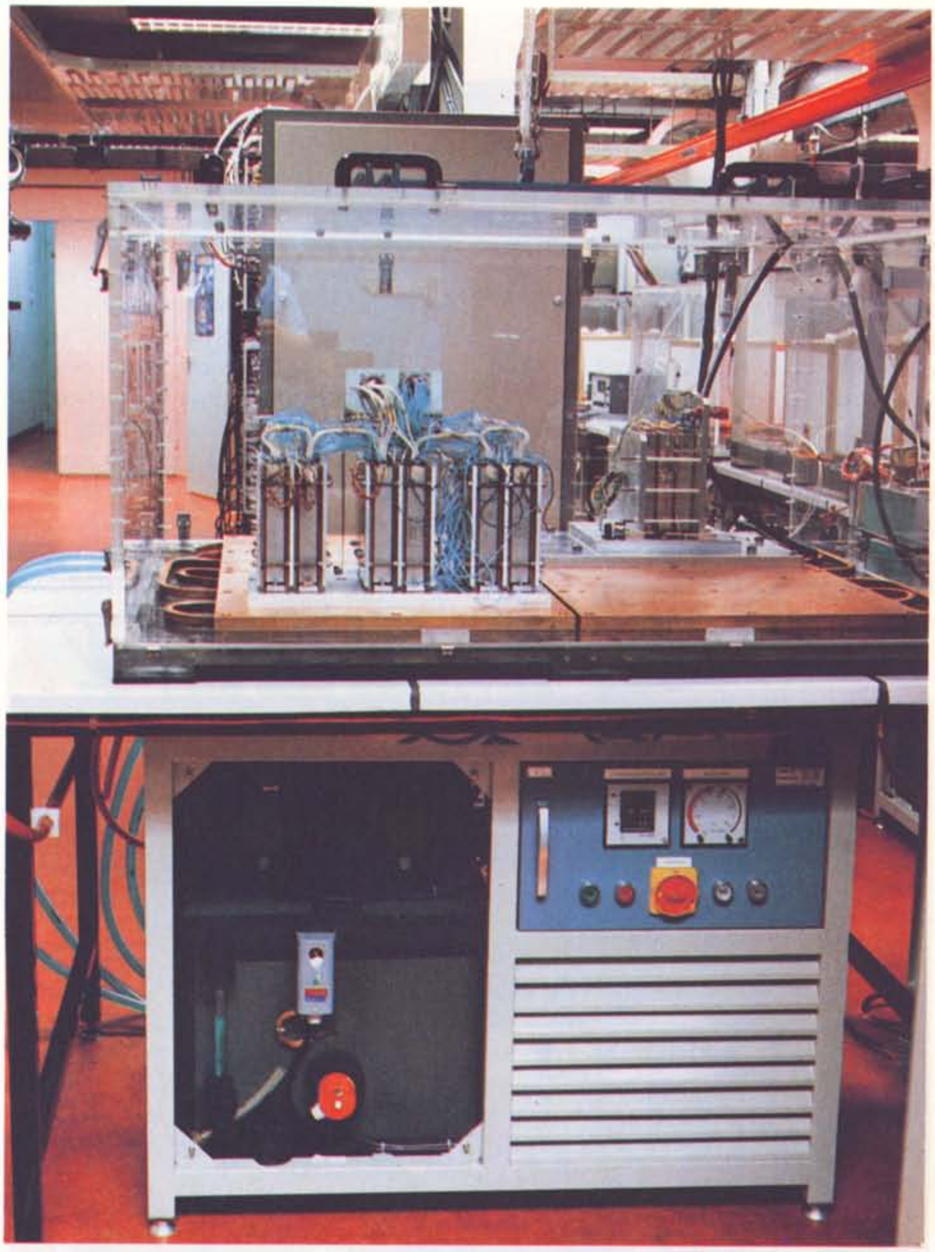


Figure 3 — An 'ELAN' test in progress with batteries in a cold-plate chamber



organisational changes were made for the running of the laboratory and a competitive tender issued for a contractor team to be given the task of carrying out the routine test operations, including production of results in the form of graphs and listings. RCA Ltd. were selected and are currently supplying a team of seven engineers and technicians.

On the other hand, initiation of new tests, liaison with the test customer, preparation of test batteries, and analysis and reporting of the results remain in the hands of ESA engineers and technicians, each of whom is responsible for certain tests. Organisation and procedures within the laboratory have been documented in the ESBTC Quality Assurance manual, to be issued shortly.

In a battery life-test lasting several years, the chances of test-equipment failure are high. In the interests of personnel safety and to prevent expensive damage to cells and batteries, considerable efforts have to be undertaken to minimise the chances of batteries being subjected to dangerous and damaging conditions. If the PDP computer function responsible for checking that the battery parameters remain within safe limits should fail, all tests are put into open circuit within a maximum of 2 min by a 'watchdog' timer. Should test hardware such as a power supply fail, then the same function will put the relevant battery into open circuit. Failures in environmental chambers and plates that could cause dangerous temperature excursions are prevented by the use of redundant temperature sensors that switch off the relevant chamber or plate.

Tests on metal-hydrogen batteries also involve a risk of explosion due to hydrogen leakage (Fig. 4). Chambers used for these tests are equipped with hydrogen detectors which, on activation, cause the chamber to be flushed with nitrogen, signal an alarm to security staff, and signal the computer to stop all tests in the affected chamber.

During working hours the computer triggers audible and visual alarms whenever human intervention is required. The Centre is not staffed on a 24 h basis, however. In the event of a failure outside normal working hours, the PDP computer makes a telephone call to activate a radio-pager carried on a rota basis by the test-laboratory contractor staff.

An uninterruptable power supply provides emergency power to the PDP and HP 1000 computers and essential peripherals, allowing a controlled shutdown in the event of a mains power failure.

Types of test conducted

The tests fall into one of three broad categories:

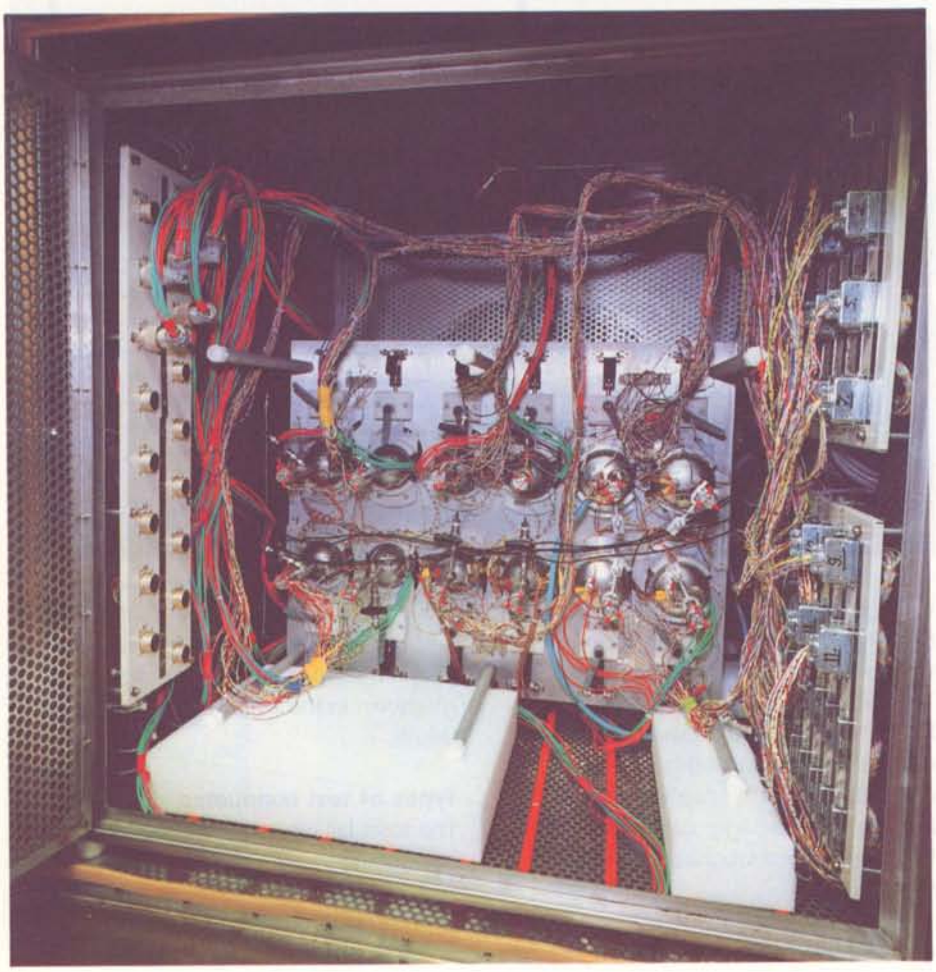
— evaluation of new cell types or battery-management schemes

Figure 4 — Metal-hydrogen cell tests

- tests to support ESA projects
- tests carried out under contract for outside organisations.

The first category are usually fairly small tests originated by members of the ESTEC Energy Storage Section to evaluate new commercial products or prototype cells produced under contract within ESA R&D programmes. Examples are the evaluations of nickel-hydrogen cells made by SAFT and DAUG, and that of silver-hydrogen cells made by SAFT.

There is currently increasing interest in comparative evaluation of different battery charge/discharge management schemes and the influence they may have on battery lifetime. One such test, originally carried out in support of the ERS-1 project and now being continued internally, is an evaluation of a new charge-control technique developed at ESTEC and recently awarded a patent. The charging of a nickel-cadmium battery is terminated when the temperature of specially positioned thermistors passes through a minimum (the so-called 'Temperature Derivative Technique'). This makes use of the thermal properties fundamental to the cell reactions and reduces, in general, the amount of overcharge experienced by the cells compared to the more common charge-control methods relying on battery voltage limits or fixed charge return factors. The end-of-discharge voltage behaviour of three batteries cycled in parallel after a 2.8 y life, shows very good stability from cycle to cycle.



The longest-running life test at ESTEC, of SAFT nickel-cadmium cells under low-Earth-orbit conditions, uses a conventional battery-charge-control method which relies upon a battery voltage limit which is a function of the battery temperature. More than 22 500 cycles (corresponding to 4.2 y of life) at 23% depth of discharge have already been performed and the test is still continuing. Although voltage degradation is visible, the end-of-discharge battery voltage is still more than 1 V per cell, which should be sufficient to support most spacecraft power-bus requirements.

The majority of the tests conducted fall into the second category, being in support of ESA projects. The emphasis in the early tests was on batteries for geosynchronous communications spacecraft. At about the same time that ESA's first communications satellite, OTS, was launched in 1978, a test was started in the ESBTC on an identical nickel-cadmium battery to that carried by the spacecraft. This battery has since been subjected to the same average charge/discharge and reconditioning procedures as that on the spacecraft. Now, eight years later, no loss of capacity compared to the value measured for the new battery has occurred either on the spacecraft or in the laboratory.

Olympus will be the first ESA spacecraft to employ a nickel-hydrogen battery and at an early stage in the spacecraft's development the ESBTC carried out extensive life testing of suitable cells manufactured in the USA by Eagle-Picher.

The emphasis has turned in recent years towards low-Earth-orbit spacecraft, with project starts such as ERS-1, Eureca and more recently Columbus. ERS-1 was the first ESA project needing to know how the charging of a group of batteries to be discharged in parallel should be managed. Seven batteries were tested in two groups of three plus a separate

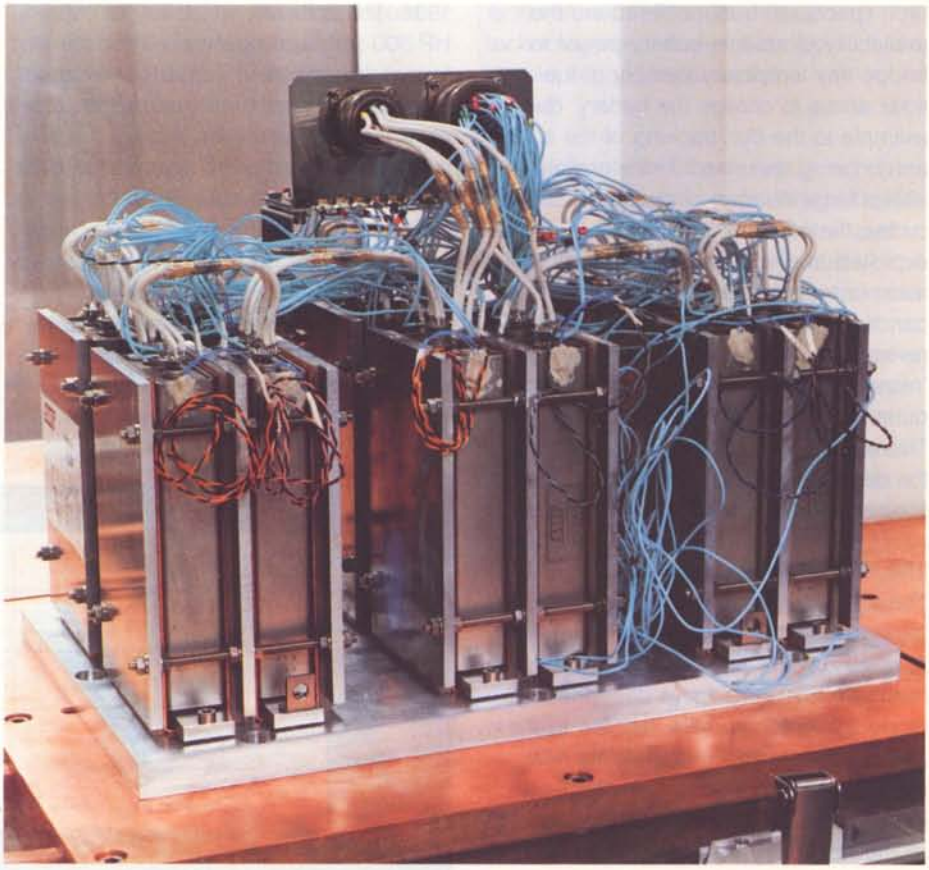


Figure 5 — Detail of an ELAN-test nickel-cadmium battery

single battery for comparison. Of the two groups of three, one was permanently hard-wired in parallel, whilst the other was discharged in parallel, but individual batteries charged separately. The results showed that the former arrangement, which is the simpler, exhibited no significant disadvantages in behaviour compared with the latter.

The third category of tests, those carried out under contract for outside organisations, have included tests for the French Spot and Telecom-1 projects. Three life-cycle tests have also been carried out on SAFT nickel-hydrogen cells under CNES contract. Three different types of nickel electrode were compared and all shown to operate for 2000 cycles (geostationary Earth-orbit conditions) at 85 to 90% depth of discharge without failure.

In 1984, an agreement was made between ESA and CNES to carry out a jointly funded five-year test programme on nickel-cadmium batteries under low-Earth-orbit conditions. Called 'ELAN' (Etude Longévité Accumulateurs Nickel-cadmium), the programme resulted from a concern on the part of the two agencies about the lack of lifetime data on such batteries in low Earth orbit as a function of depth of discharge and temperature. The ESA participation includes contributions from the ERS-1 and Eureca projects and the test programme, which is easily the largest ever carried out in the ESBTC, involves tests on 20 12-cell batteries (Fig. 5) specially designed to be thermally representative of real spacecraft batteries, but with the possibility to remove individual failed cells for destructive analysis. This important feature of the programme should enable the predominant wear-out mechanisms of the cells to be identified and provide the input needed for possible future improvements in cell design. At the time of writing, the ELAN tests have been running for one year without failure. Typical routine graphical output used to monitor these tests is shown in Figure 6.

Future plans

Future test requirements

A number of current technological research programmes will yield prototype hardware to be life-tested in the ESBTC. This hardware will include battery couples that are relatively new to space use, such as lithium-sulphur dioxide and sodium-sulphur. The former, together with the lithium-thionyl chloride system, will become an important primary power source for scientific deep-space probes, and tests will largely be concentrated on demonstrating their ability to function satisfactorily after several years of storage in open circuit, representing the time between launch and arrival of the probe at its destination. Sodium-sulphur on the other hand is a reversible system with potentially at least twice the gravimetric energy density of nickel-hydrogen.

ESA project support is expected to focus on two major developments, a 3 kW advanced nickel-hydrogen battery module for Columbus and a 4 kW fuel-cell module for Hermes. Both are currently under development and hardware delivery is expected in 1987/8 for ESBTC testing. In addition, for future communications satellites a complete battery containing European nickel-hydrogen cells is under development and will be delivered for test at about the same time. Testing of these large systems involving hydrogen will in fact require a new facility, a 'hydrogen systems laboratory', with the necessary gas supplies and safety measures.

As is evident from the ELAN programme, nickel-cadmium cells will continue to play an important role in space projects. One area requiring more test data is the so-called 'memory effect' characteristic of this system. Low-Earth-

Figure 6 — Typical graphical output from an 'ELAN' test
(a) for a single orbit
(b) for 400 orbits ('repetitions')

orbit spacecraft frequently require the availability of reserve battery power to bridge any temporary inability of the solar arrays to charge the battery, due for example to the Sun-tracking of the solar arrays being disturbed. Unfortunately, after a large number of charge/discharge cycles, the 'unused' capacity can only be exploited at a voltage below the minimum needed by the power-conditioning electronics. This effect is reversible by a process known as 'reconditioning', but it takes a long time, during which the battery is unavailable. This effect has important implications for the design, cost and reliability of spacecraft power subsystems.

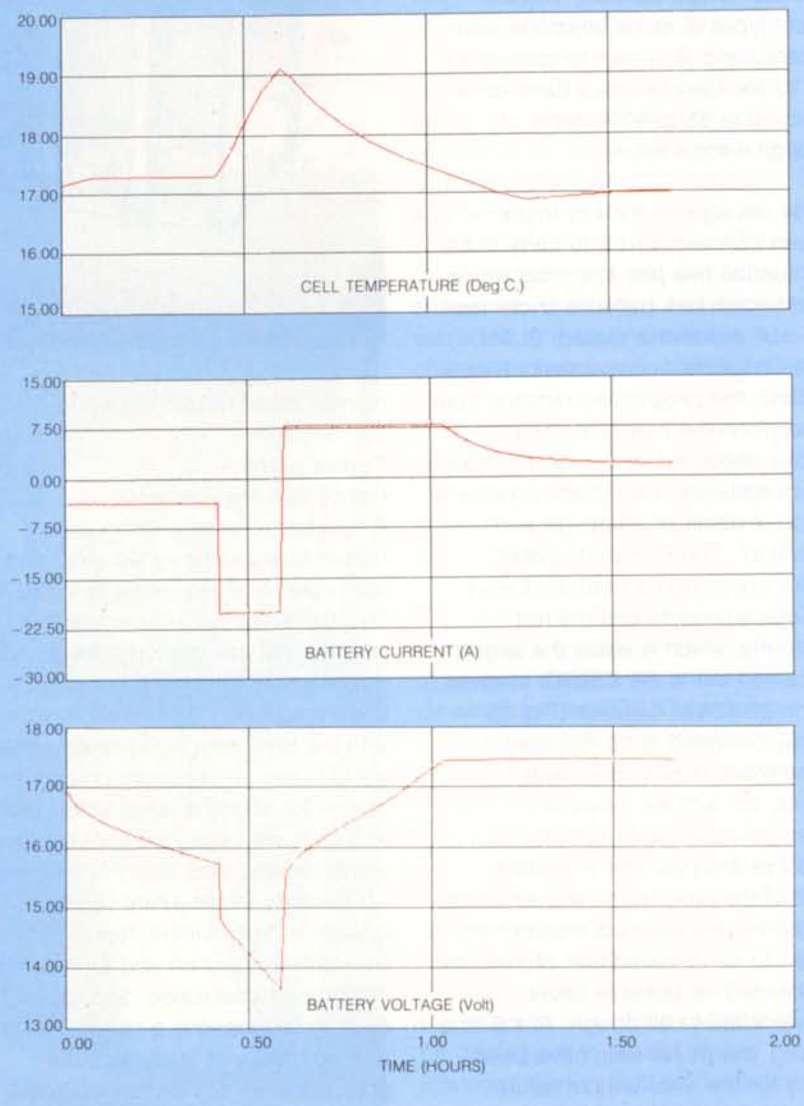
The ESBTC facilities

The test complexity shortcomings discussed earlier, coupled with the obsolescence of the existing PDP system hardware and the relative cheapness of modern microcomputers, has led to the decision to develop a completely new suite of test equipment in which an independent local test station containing all the necessary test hardware and controlled by a microcomputer will be associated with each test. This concept has many advantages, not the least of which are:

- Tests are independent of each other and no equipment failure (apart from mains power failure) can affect more than one test.
- Much greater test flexibility is possible both through more sophisticated hardware control capabilities and because new software can be developed for a particular test without affecting the software used by other tests.
- The length of wires used to connect the battery to the test station is much reduced, resulting in fewer noise pickup problems and reduced power losses.

This 'decentralised system' is currently under development, with the first validation tests planned for November 1986. The software, which will run on HP 300-series computers, is modular in format. It consists of a 'master program', which is common to all test stations and provides general utilities such as event scheduling and the management of data files, and 'user subroutines', which are test-specific. In this way a library of user subroutines will be built up. Existing user subroutines will be reused as much as possible whenever a new test has to be programmed, but any completely new requirements can be catered for by writing new routines that will subsequently be added to the library.

The decentralised test stations will include local storage for several days of data and will also send data to the existing HP 1000 computer, which is more suited to manipulation and archiving of very large files and represents a large investment in existing data-processing software. The local storage will serve as a backup to the HP 1000 'quick-look' files (since there is no 'day tape' associated with the decentralised system), as well as



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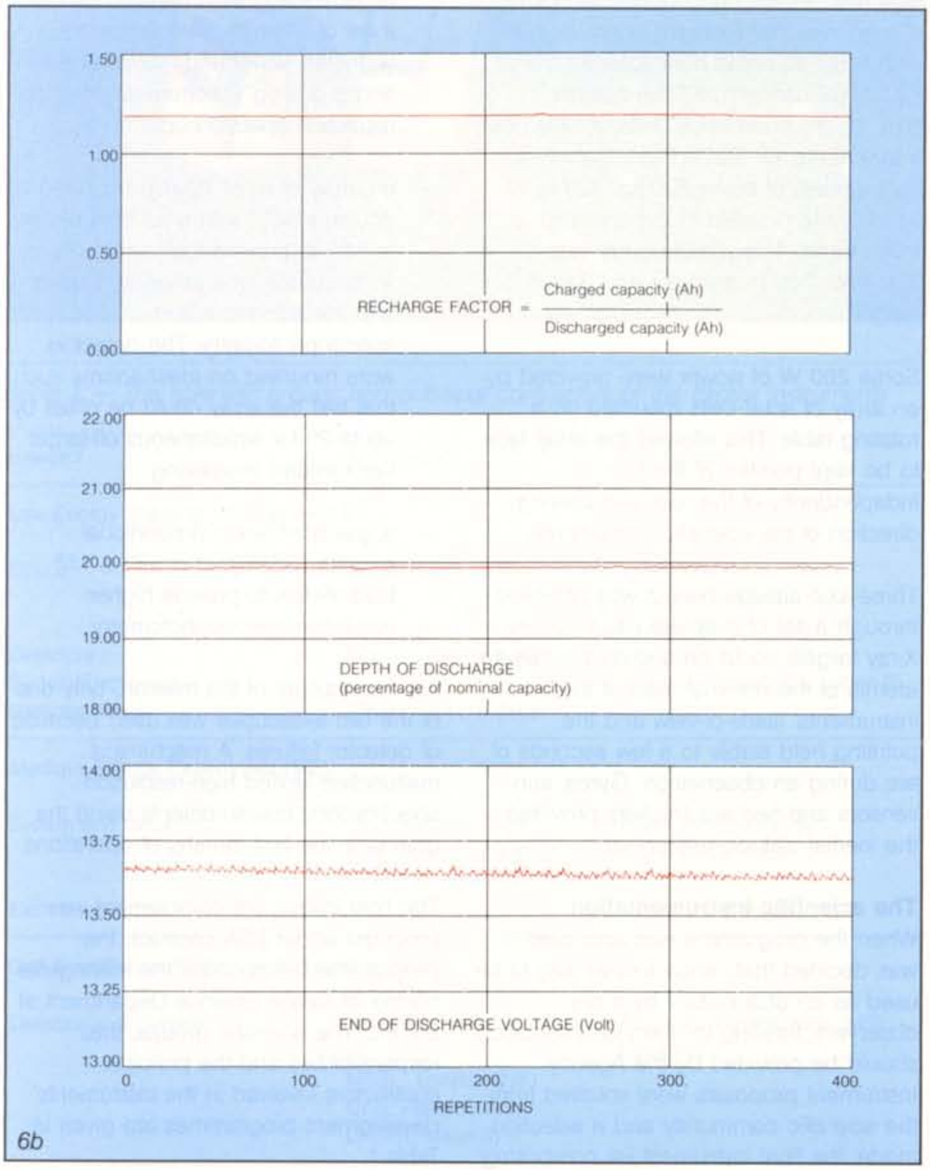
allowing limited local data-processing.

The essential elements of a decentralised test station are shown on the right-hand side of Figure 2. The RS232 data links to the HP 1000 computer allow the test stations to be located remotely. The data format used by the decentralised system to communicate with the HP 1000 will be identical to that currently in use by the PDP system, so that once in the HP 1000, test results will be treated in the same way whichever system they originate from. Within this format it is possible to define the new data record types that will be necessary for decentralised system tests. Once proven, the number of decentralised test stations will grow steadily and the PDP system will be used only for the more simple tests, probably being phased out completely by 1992.

Use of magnetic tapes for test-data archiving involves considerable manipulation both during updating and when reading is required for later data analysis. A switch to optical-disk storage is therefore foreseen when this technology becomes sufficiently developed and reasonably priced.

Future tests will not only require a more sophisticated control capability, but also new battery environmental control and safety measures. A relatively small advance will be the development of cold-plates capable of simulating the behaviour of a spacecraft radiator and of measuring the heat output of a battery during cycling. More significant will be the need to test large nickel-hydrogen battery modules and fuel-cell modules rated up to at least 10 kW. A hydrogen systems laboratory, dedicated to such work and incorporating the necessary gas supplies and safety equipment, is currently under consideration. It will need to be operational by early 1988.



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Exosat — End of Orbital Operations

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Exosat, the European X-ray astronomy observatory, re-entered the Earth's atmosphere on 6 May 1986. Launched on 26 May 1983, the satellite, originally planned and funded for a two-year operational life, successfully completed the better part of three years of detailed studies of cosmic X-ray sources including normal stars, binary systems containing a 'compact' object, supernova remnants within our galaxy and quasars far out in the Universe. From the analysis of observations so far, many new and exciting discoveries have already been made.

All Exosat data will shortly be available, not only to the observer whose observation was performed, but to the scientific community at large. The Agency has made a commitment to support the scientific community in this post-operational phase over the next four years.

The orbiting observatory

Studies of an X-ray astronomy mission within ESA (then ESRO) were initiated in the late 1960s. The Exosat mission was approved in 1973 and began its main design and development phase in 1977 with MBB as prime contractor for the COSMOS consortium. The satellite (Fig. 1), launched on a Delta vehicle from Vandenberg Air Force Base, California, had a mass of some 500 kg, 120 kg of which were devoted to the scientific instruments. The satellite body was a little over 2 m in diameter and 3 m in height.

Some 260 W of power were provided by an array of solar cells mounted on a rotating table. This allowed the array face to be kept pointed at the Sun independently of the required viewing direction of the scientific instruments.

Three-axis attitude control was achieved through a set of propane gas thrusters. X-ray targets could be acquired within an arcmin of the nominal axes of the instruments' fields-of-view and the pointing held stable to a few seconds of arc during an observation. Gyros, sun sensors and two star trackers provided the inertial attitude references.

The scientific instrumentation

When the programme was approved, it was decided that, since Exosat was to be used as an observatory by many observers, funding for the instrumentation should be provided by the Agency. Instrument proposals were solicited from the scientific community and a selection made, the final instrument list comprising:

- the grazing incidence telescopes (LE) of 1 m focal length to provide X-ray images within a one degree field-of-view. Each telescope was provided with two imaging detectors, a set of filters for selecting more restrictive wavebands for photometry and a grating spectrometer for high-resolution spectroscopy

- an array of eight double proportional counters (ME) with a full field-of-view of 1.5° to provide high sensitivity for X-ray source time-variability studies and medium-resolution spectrophotometry. The detectors were mounted on mechanisms such that half the array could be offset by up to 2° for simultaneous off-target background monitoring

- a gas scintillation proportional counter (GSPC), also with a 1.5° field-of-view to provide higher resolution spectrophotometry.

For the majority of the mission, only one of the two telescopes was used because of detector failures. A mechanical malfunction limited high-resolution spectroscopy measurements using the grating to the first months of operations.

The final instrument complement was procured under ESA contract, the programme being under the managerial control of Space Science Department at ESTEC. The scientific groups, their responsibilities and the principal contractors involved in the instruments' development programmes are given in Table 1.

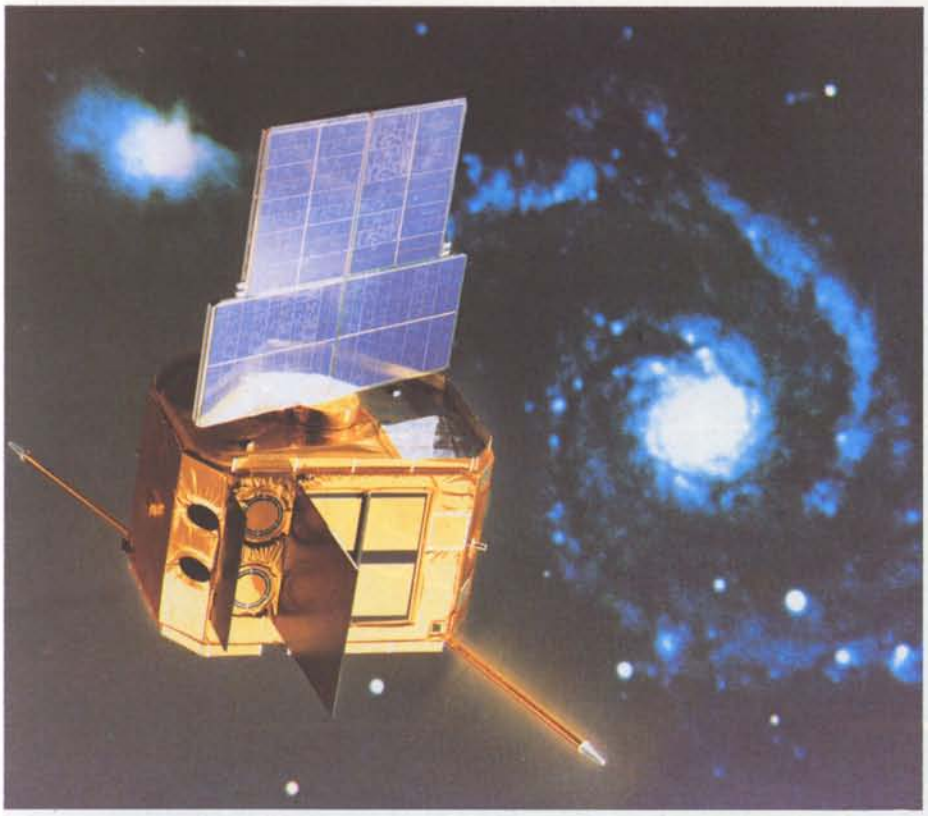


Figure 1 – The Exosat observatory projected against the Whirlpool galaxy in 'Canes Venatici'. The scientific payload is visible on the front of the spacecraft. The two black holes on the left are the apertures for the star trackers, the two circles between the flaps are the low-energy telescopes (LEs), the large square behind the largest flap is the medium-energy counters (MEs) and the small square with a white border on the right is the gas-scintillation proportional counter (GSPC)

Table 1 — The scientific groups and principal contractors of the Exosat instruments

Element	Institutes	Contractors
Low-Energy Imaging Telescopes (LE)		
Optics	SRON, Leiden (NL)	CIT-Alcatel (F), Instruments SA (F), Fichou (F)
Detectors	MSSL, London (UK)	Sira (UK)
System/Electronics		Matra (F), SNIAS (F), Laben (I)
Gratings, Filters	SRON, Utrecht (NL)	
Medium Energy Experiment (ME)		
System and detectors	Univ. Leicester (UK) MPE Garching and Univ. Tubingen (D)	BAe (UK), LND (US) Galileo EOC (US)
Electronics		Laben (I), Matra (F)
Gas Scintillation Proportional Counter (GSPC)		
Detector and System	SSD, ESTEC	AEG (D), Electrofusion (US) Laben (I)
	MSSL, London (UK) Univ. Palermo and LFCTR, Milan (I)	

Science operations

Exosat was placed in a highly eccentric orbit with an apogee of some 190 000 km at high northern latitude and a 90 h orbital period. From the operational viewpoint this orbit meant that the satellite was in continuous real-time contact with the ESA ground station at Villafranca, Spain, for the scientifically significant part of the orbit, i.e. those 76 hours when it was outside the disturbing influence of the Earth's radiation belts.

This continuous real-time link at 8 kbps proved invaluable in simplifying operational procedures, e.g. when resolving spacecraft anomalies, changing attitude to observe new targets, changing instrument or on-board computer mode etc.

Spacecraft control and science operations were conducted from ESOC, Darmstadt, the satellite's telemetry data being routed directly from the Villafranca station. Spacecraft control was exercised by ESOC personnel while science operations were conducted 24 hours a day, seven days a week by the Observatory Team (20 scientists, engineers, systems analysts, operators and data handlers) affiliated to Space Science Department, ESTEC.

Exosat's primary mission was to study X-ray sources already detected by earlier satellites or celestial objects expected to be X-ray emitters on the basis of similarity with known sources. It was not intended to make an all-sky, unbiased survey — although many new sources have been discovered serendipitously in the pointed telescope exposures, or by the medium-energy instrument when the spacecraft was slewed from one target to the next. Figure 2 shows a sky map in galactic coordinates with the position of many of the new sources detected by the telescopes. A programme is currently underway to identify and catalogue these objects.

The observing programme

Four Announcements of Opportunity (AO)

Figure 2 – A sky map in galactic coordinates showing the new X-ray sources serendipitously detected by the low-energy telescopes (LEs) in the first two years of operations. The intensities of the sources are colour coded according to the scale given below

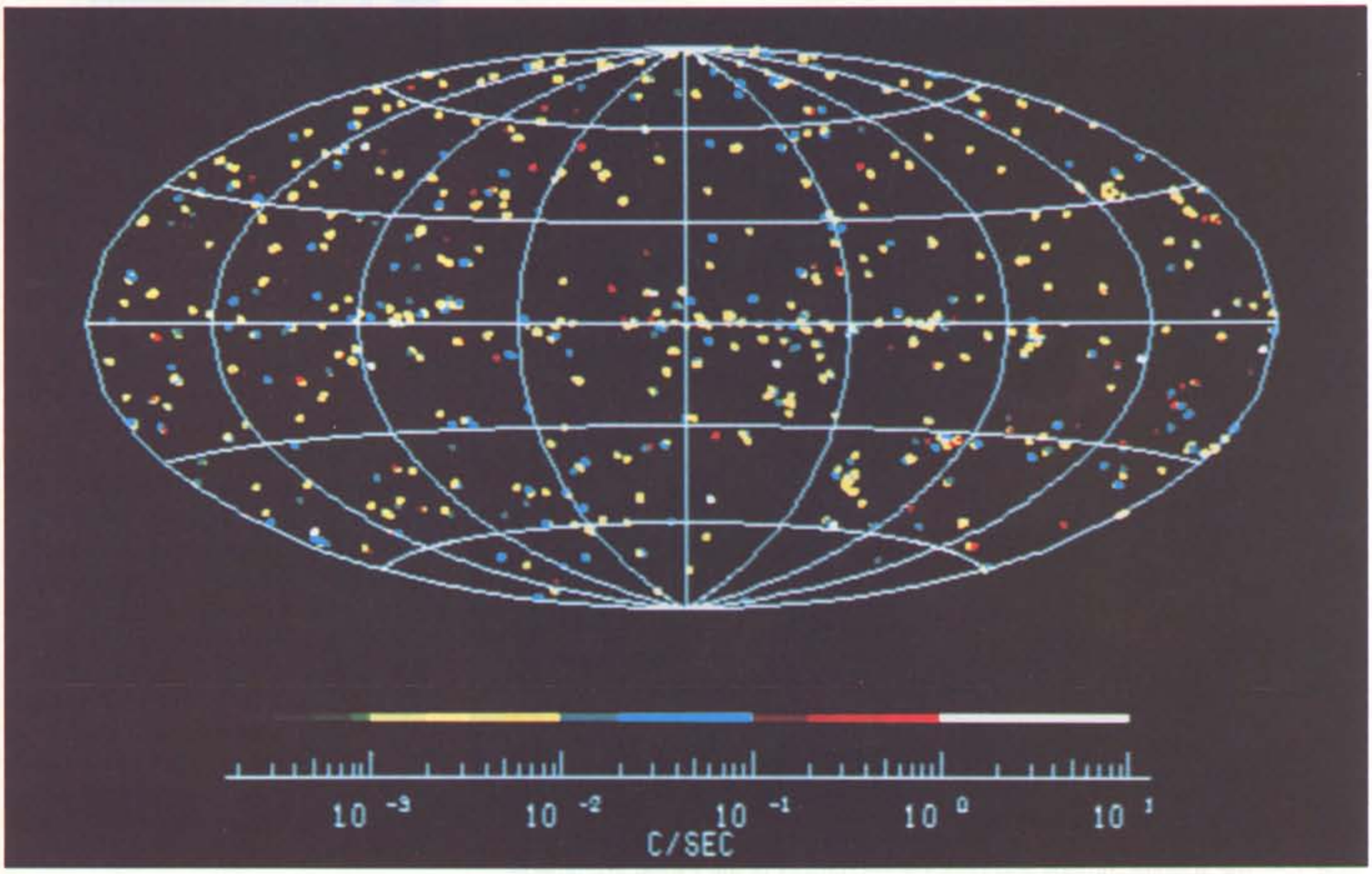


Table 2 — Allocation of Exosat observing time

Country	Number of Principal Investigators	Successful proposals*	% of total time approved	% of approved time undertaken	% of pointings completed
United Kingdom	66	224	35	75	83
Germany	44	128	22	73	84
Netherlands	32	129	18	72	80
Italy	35	81	8	79	88
France	12	32	4	65	77
Denmark	1	6	1	100	100
Spain	3	5	0.5	67	50
Eire	1	1	—	100	100
Sweden	2	2	—	100	100
USA	42	83	11	58	71
Australia	5	7	0.5	86	91
Turkey	1	1	—	100	100
Finland	1	1	—	100	100
Czechoslovakia	1	1	—	0	0
Japan	1	1	—	0	0

* Distribution according to the nationality of the Principal Investigator

were issued to the scientific community inviting participation in Exosat's observational programme. The first, in 1981, circulated only in the ESA Member States, solicited responses from which the observing programme for the first year was selected. Three further AOs (September 1983, August 1984 and August 1985) were issued world-wide. The responses to all were overwhelming with the available observing time some five times over-subscribed. To assist in the selection of the observing programme proposals, a peer review group of leading European astronomers was established. Table 2 gives an indication of the numbers and geographical origins of successful proposals.

An overview of the Exosat observing programme as a function of time allocated to categories of celestial object is given in Figure 3.

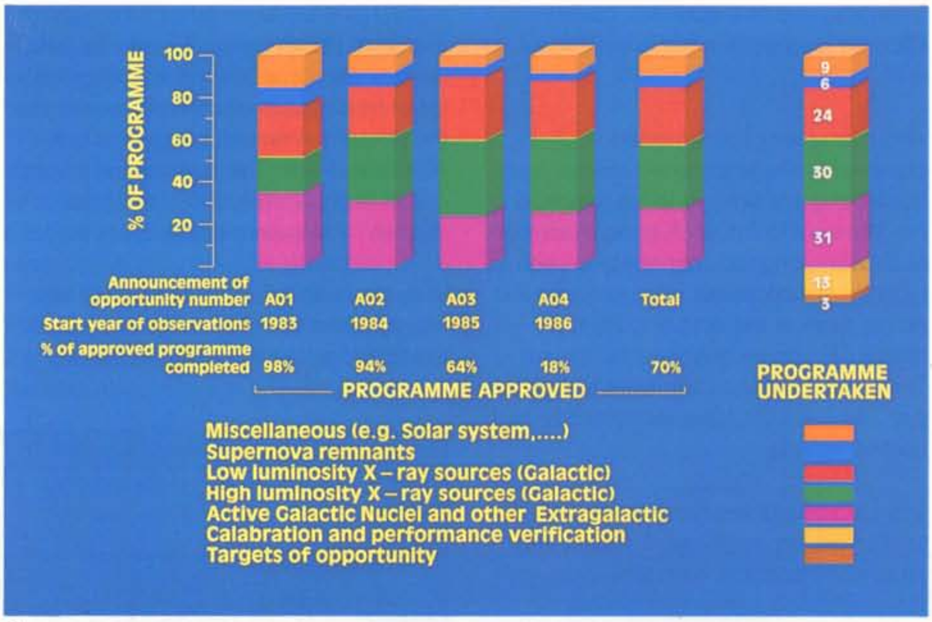
Figure 3 – An overview of the Exosat observing programme

Figure 4 – The X-ray light curve of one orbital cycle from the two-day orbital period binary star AR Lac. This is an eclipsing system and the arrows indicate the times of primary (P) and secondary (S) eclipse. The X-rays are generated in a hot corona contained in magnetic loops (star spots) attached to the two stars. The lower plot from the low energy telescope (LEIT) shows a broad minimum centred on primary minimum. This is caused by magnetic loops containing plasma with a temperature of 5 million degrees rotating in and out of view. The lack of any modulation in the ME indicates the presence of a much hotter (25 million degrees) coronal component that has a height much larger than the radius of the underlying stars

During Exosat's lifetime 25% of the observations were coordinated with ground-based observatories (radio, optical and infrared), and with other satellites, IUE (ultraviolet), with IRAS (infrared) and with the Japanese X-ray satellite, TENMA. These simultaneous observations required considerable planning. In addition, the observation scheduling system was flexible enough to allow observations of targets of opportunity at only a few hours' notice. Alerts for such observations would come from other observatories when it was anticipated that X-ray observations would prove crucial or helpful in understanding the phenomenon. Some 60 targets of opportunity were observed during Exosat's lifetime.

The observatory team at ESOC provided support to the user community in the detailed planning and monitoring of observations (usually in the absence of the observer), providing instrument calibrations, a first analysis of the data and the final observation tape (FOT). In addition an interactive data analysis facility has been provided for those observers without Exosat analysis facilities at their home institutes.
In the post-operational phase the observatory team, relocated with Space Science Department at ESTEC, will continue to provide analysis and calibration support to the user community, not only the original observers, but to any scientist interested in Exosat data. The observational data are the property of the observer for one year after the observation; at the end of that time the data are deemed to be in the public domain.

Results
Exosat made 1996 independent pointed observations during its lifetime. The early observations tended to be of relatively short duration (~6 hr). As the mission progressed the value of Exosat's long uninterrupted viewing capability and the relative strengths of the instrumentation became more apparent, the observation



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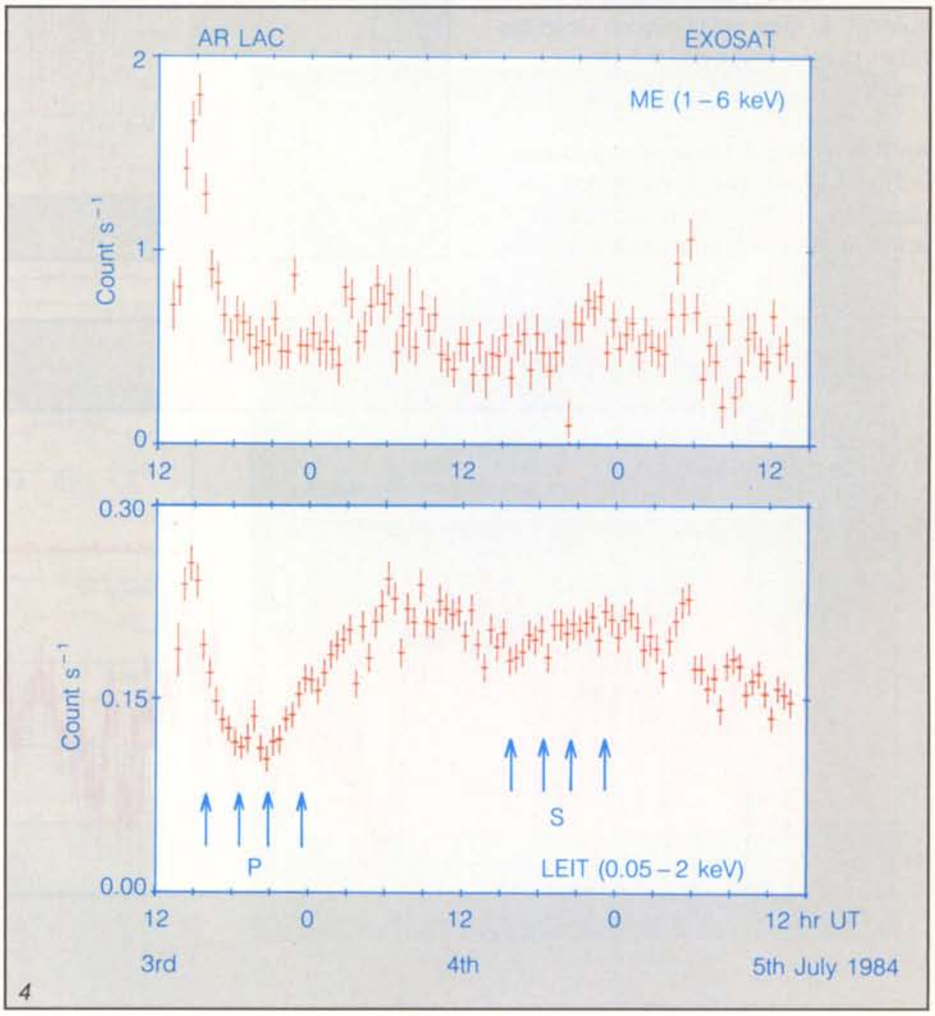

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Figure 5 – The X-ray light curve of the X-ray emission from the Seyfert 1 galaxy Markarian 766. The flickering activity on a timescale of a few hours reflects the chaotic process of accretion onto a massive black hole in the nucleus of this galaxy (29–31 Dec. 1985)

Figure 6 – Exosat discovered from SS433 an iron emission line whose energy moves by up to 30% from its rest value, in phase with the famous moving optical lines from this source. These lines are thought to originate from relativistic jets that precess towards and away from the Earth with a 176 day period. The X-ray iron line comes from the very innermost regions of the jet, much closer to the compact object than the origin of the optical emission lines. This allows models for the jet acceleration to be tested for the first time

times on average increased, sometimes to be as long as one complete Exosat orbit.

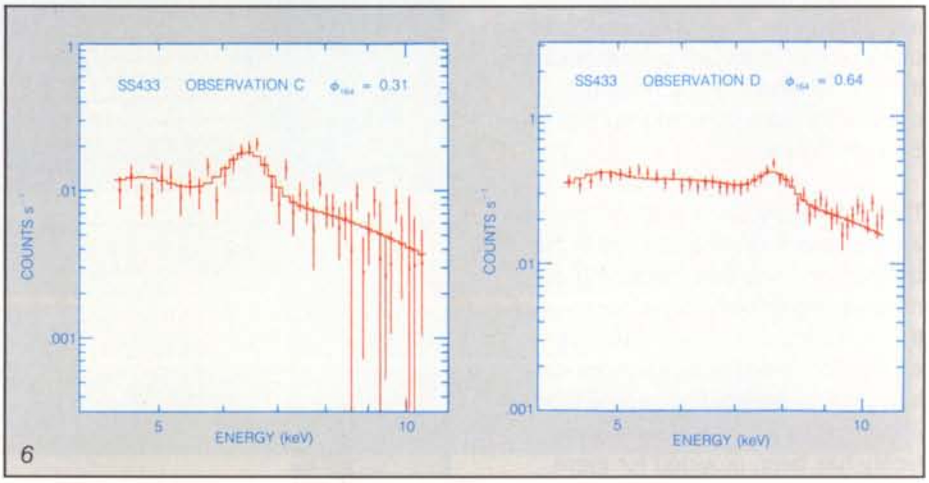
These long and uninterrupted observations have provided unique light curves that are unlikely to be repeated in the foreseeable future. A good illustration of Exosat's long-look capability is seen in Figure 4, which shows one complete 2 d orbital cycle of the eclipsing RS CVn binary AR Lac as observed by Exosat. This system contains two stars similar to the Sun that both have exceptionally high coronal activity.

The LE and ME instruments are sensitive to different temperatures (5 million and 25 million degrees). The differences in the modulation of the light curves indicate that the cooler plasma is confined to quite small regions while the hotter plasma envelopes the binary system.

Another long-look observation is shown in Figure 5, this time of the Seyfert galaxy MKN 766. This galaxy has an active nucleus with a luminosity of 10^{43} erg/s (10 000 millions times more than the Sun). Flickering activity can be seen on a timescale of 3 h which, using light travel time arguments, directly shows that the size of the emission region is only 1000 solar radii. The mass of the central object is in the range 10^4–10^9 solar masses — a supermassive black hole.

With the GSPC, Exosat discovered iron line emission from the relativistic jets in the SS433 system (Fig. 6). As the jets precessed around their 176 d cycle the iron line was blue- and red-shifted in the same sense as the moving emission lines observed at optical wavelengths. The iron X-ray line originates from much closer to the central source and provides a better probe into the acceleration mechanism of the jets and the nature of the compact object.

Another suprising Exosat discovery was of an 11 min orbital period in the X-ray



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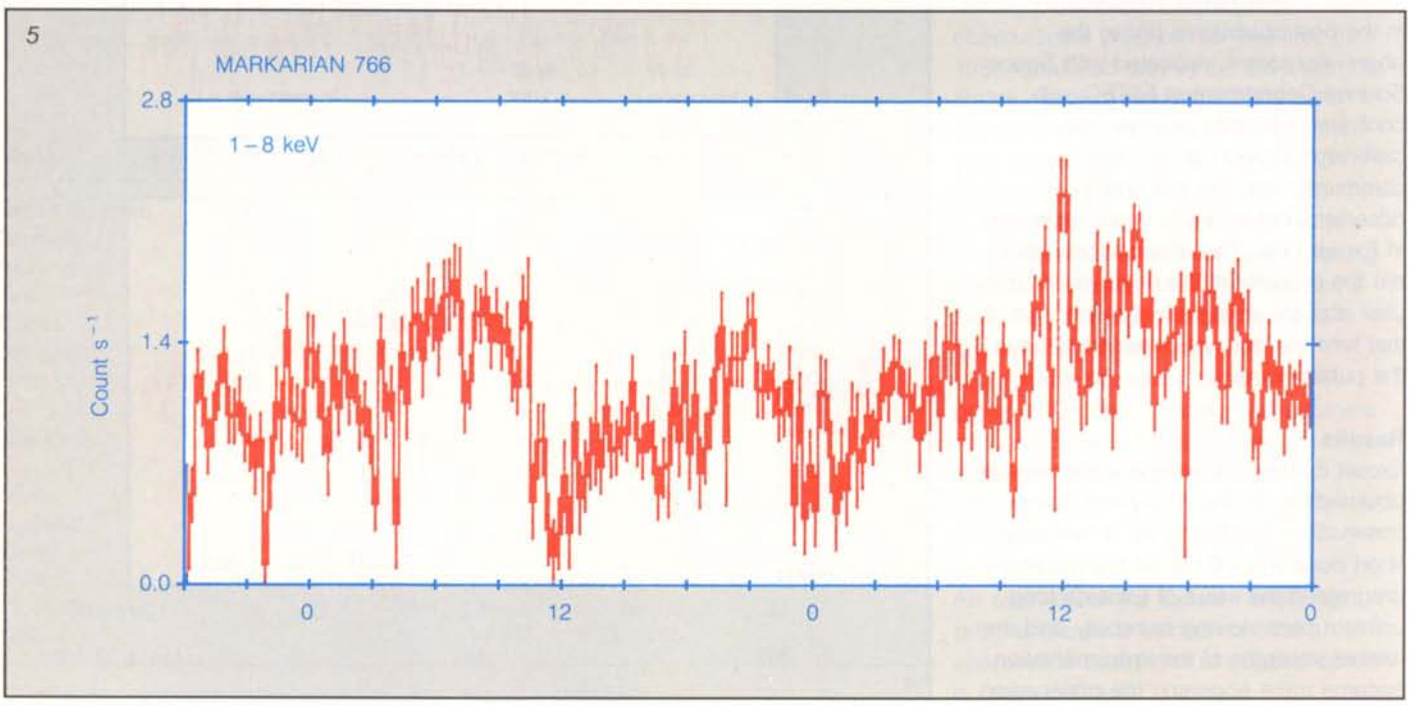

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source in the globular cluster NGC 6624. These observations showed the X-ray flux to modulate at a level of 3% (Fig. 7). This is the first binary period to be established in a globular cluster and by far the shortest known. This system probably consists of a neutron star accreting material from a white dwarf companion that is made of pure helium. The most likely origin for this binary is the result of a direct collision between a red giant and a neutron star in the dense core of the globular cluster.

The study of quasi-periodic oscillations (QPO), first discovered by Exosat, intensified through the summer of 1985. A total of seven sources, mainly from the bright galactic centre sources, have now been found to show this phenomenon. These observations have shown a large variety of behaviour, not only from source to source, but also from individual sources. An example of this, from an observation of Sco X-1, is shown in Figure 8. The bottom panel shows the intensity profile, the top panel a colour 2-d projection of the Fourier transform of the data.

The discovery of QPOs may hold the key to understanding how binary millisecond radio pulsars (neutron stars spinning at up to 1000 rev/s) were formed.

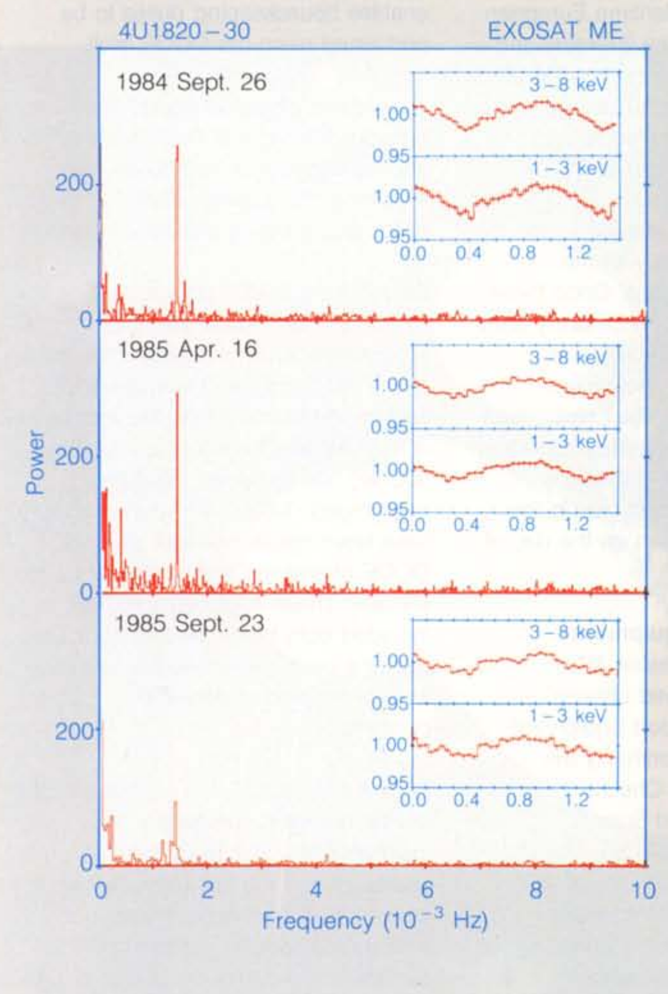

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Figure 7 – Fast fourier transforms of three observations of the X-ray source 4U1820-30 in the globular cluster NGC6624. The spikes in each reveal the presence of an 11 min sinusoidal modulation that reflects the orbital period of the system. This is the shortest known orbital period. The system was most probably formed by the collision of a neutron star with a red giant star. The inset panels show the modulation light curve in each case

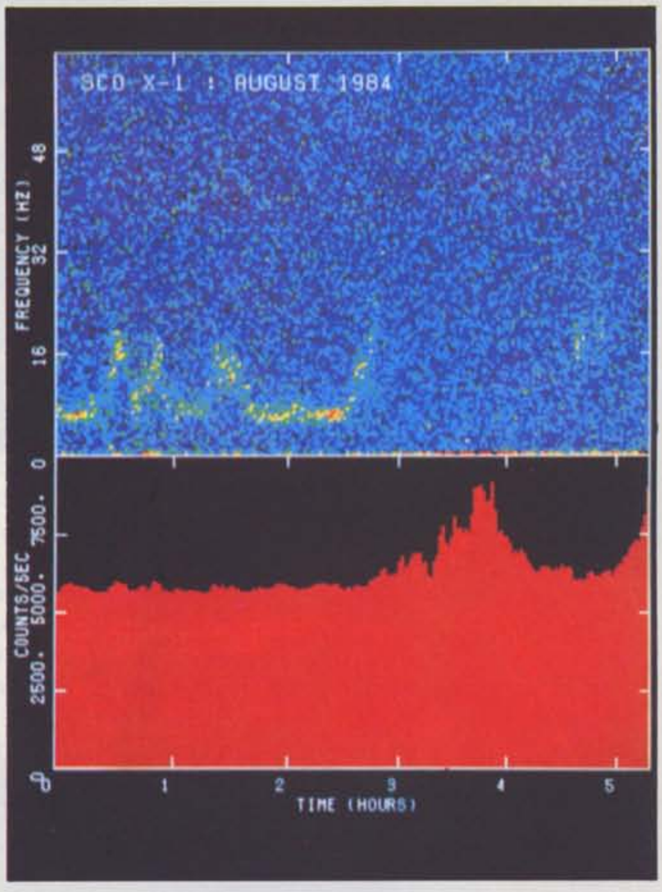

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Figure 8 – The lower panel shows the intensity profile of Sco X-1, the brightest X-ray source in the sky. The red 'islands' apparent in the top panel show how the QPO changes frequency and strength as the source intensity changes

An Application of the Agency's Satellite Checkout Policy

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The ESA communications satellite programmes have been following the Agency's industrial policy for satellite checkout formalised in June 1979 by the ESA Industrial Policy Committee [ref. ESA/IPC(79)65]. The implementation of this policy has provided European industry with the possibility of utilising common facilities for the construction and testing of communications satellites. Moreover, its application has stimulated increasing acceptance of ESA's satellite checkout standards by the European industrial community.

ESA's involvement in the development of communications satellite technologies commenced in the early 1970s with the birth of the Orbital Test Satellite (OTS) programme. This resulted subsequently in the parallel development of the maritime OTS (Marots) programme. These two programmes were followed progressively by the Maritime European Communications Satellite (Marecs) and European Communications Satellite (ECS) programmes in the late 1970s and early 1980s, respectively. This led to the current Olympus programme (Fig.1).

The earliest phases of satellite construction commence with the production of satellite units. Once these units have been tested successfully, they are integrated to form subsystems. Subsequently they are assembled together during the satellite construction phase, termed Assembly Integration and Test (AIT). The final AIT operations include satellite verification during the launch-vehicle countdown on the day of the launch.

Satellite checkout equipment

The most important satellite AIT operations are performed utilising Electrical Ground Support Equipment (EGSE). The EGSE is primarily the combination of Overall Checkout Equipment (OCOE) and Special Checkout Equipment (SCOE). The OCOE is the central control point for all AIT operations. The SCOE is normally satellite subsystem specific, providing specialised facilities applicable to subsystem testing. The OCOE provides the satellite integration engineers with their prime control interfaces to the satellite and to their SCOE. This basic EGSE architecture is shown in Figure 2. The Test Conductor Console of the OCOE provides executive control over AIT operations, and the Observer Consoles are employed for monitoring roles. The OCOE Operators Console enables housekeeping duties to be performed upon the OCOE itself.

The satellite checkout equipment provides the facilities that enable engineering judgements to be made regarding the satellite's compliance with ESA's requirements and specifications.

Establishing EGSE standards

Since the ESA Orbital Test Satellite (OTS) programme which resulted in the launch of the first European communications satellite in the mid-1970s, the architecture of the Overall Checkout Equipment (OCOE) has remained basically unchanged. Technical improvements have been made, however, to make OCOE operations and maintenance more efficient. These improvements have included both hardware and computer software modifications to improve user-friendliness and system-level performance.

On the OTS OCOE, the consoles could not be operated completely independently. The man/machine interfaces and the test language were derived from past experiences, but without any specific attempt to follow standards. Following the launch of OTS in the mid-1970s, a concerted effort was made to standardise the testing

Figure 1 — The Agency's Olympus satellite during antenna coupling tests at the Selenia Spazio Integration Centre (Italy)

techniques. At the same time the Agency's provisioning methods were rationalised before embarking on the follow-on communications satellite programmes (ECS, Marecs, Olympus, etc.). This rationalisation exercise, influenced by additional inputs from the other ESA satellite programmes such as Meteosat and Geos, resulted in the birth of the EGSE standards and the European Test Operations Language (ETOL).

Checkout equipment provisions
OTS/Marecs scenario — The start of changes

For the OTS and Marots programmes, an Agency EGSE task included the provision of some SCOE items. The other necessary SCOE was provided by the satellite contractors. The important OCOE provisions encompassing electronic hardware, computer software, together with associated operational and maintenance services, were the prime ESA EGSE tasks. The provision of these services, although an ESA responsibility, was effected via industrial contracts.

The OCOE and its associated services were provided to satisfy the Agency requirements of ensuring that test results were decisive and readily available for review. This enabled engineering judgements to be made concerning the quality of the satellite and its adherence to ESA standards. A partnership for OCOE supplies was established between ESA and various industrial companies to provide a service which gave the Agency a close and supportive relationship with industry. This partnership evolved into an efficient checkout team composed of both ESA and industrial staff.

Until the mid-1970s all OCOE provisions were normally made entirely by ESA, with an absolute minimum of industrial participation. Thus the OCOE provisions for the OTS and Marots programmes in the mid-1970s were a significant change from the established satellite checkout policies existing at that time.

ECS/Marecs scenario — Policy changes

The advent of the Marecs and ECS programmes signalled the birth of the

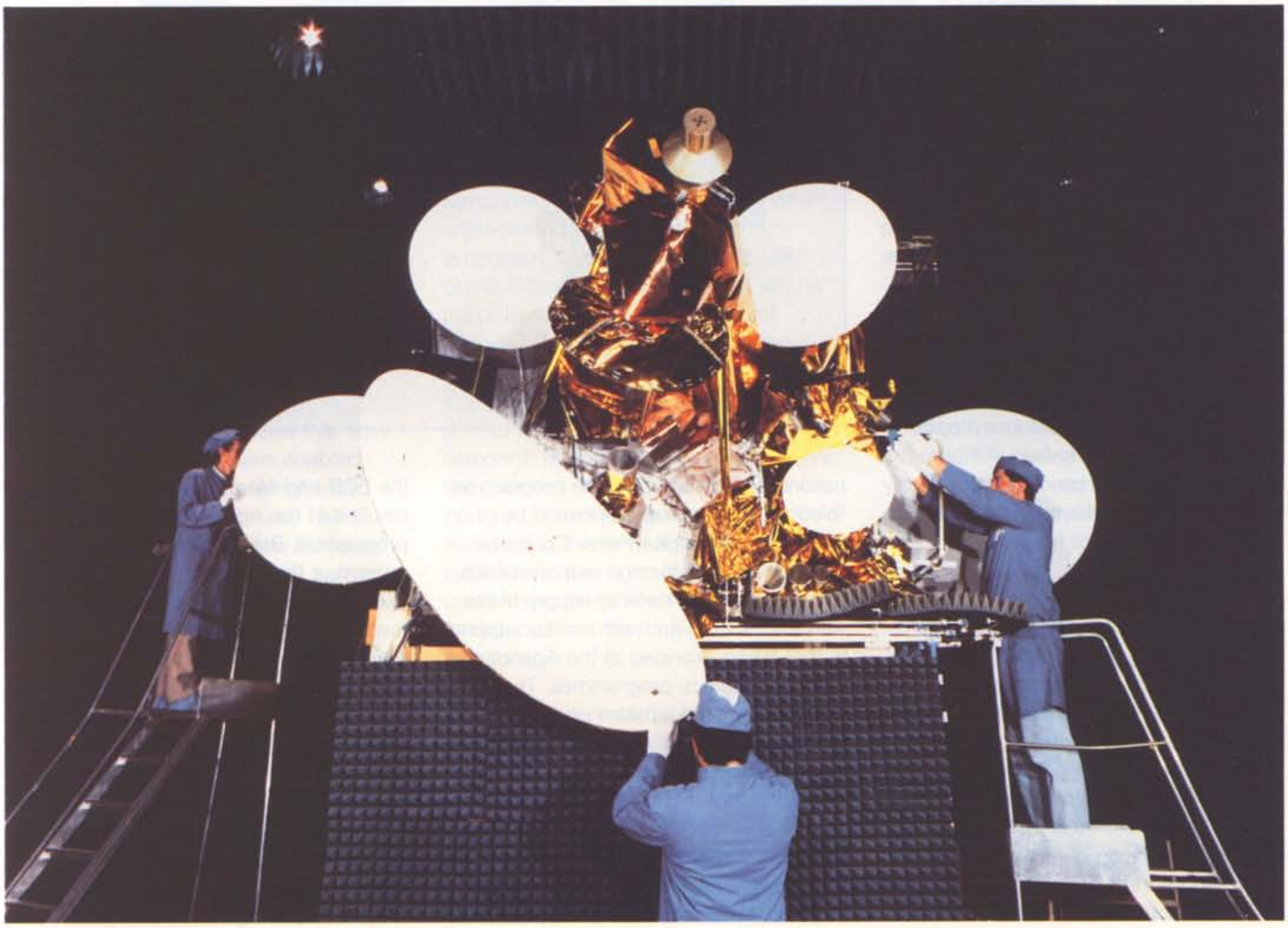
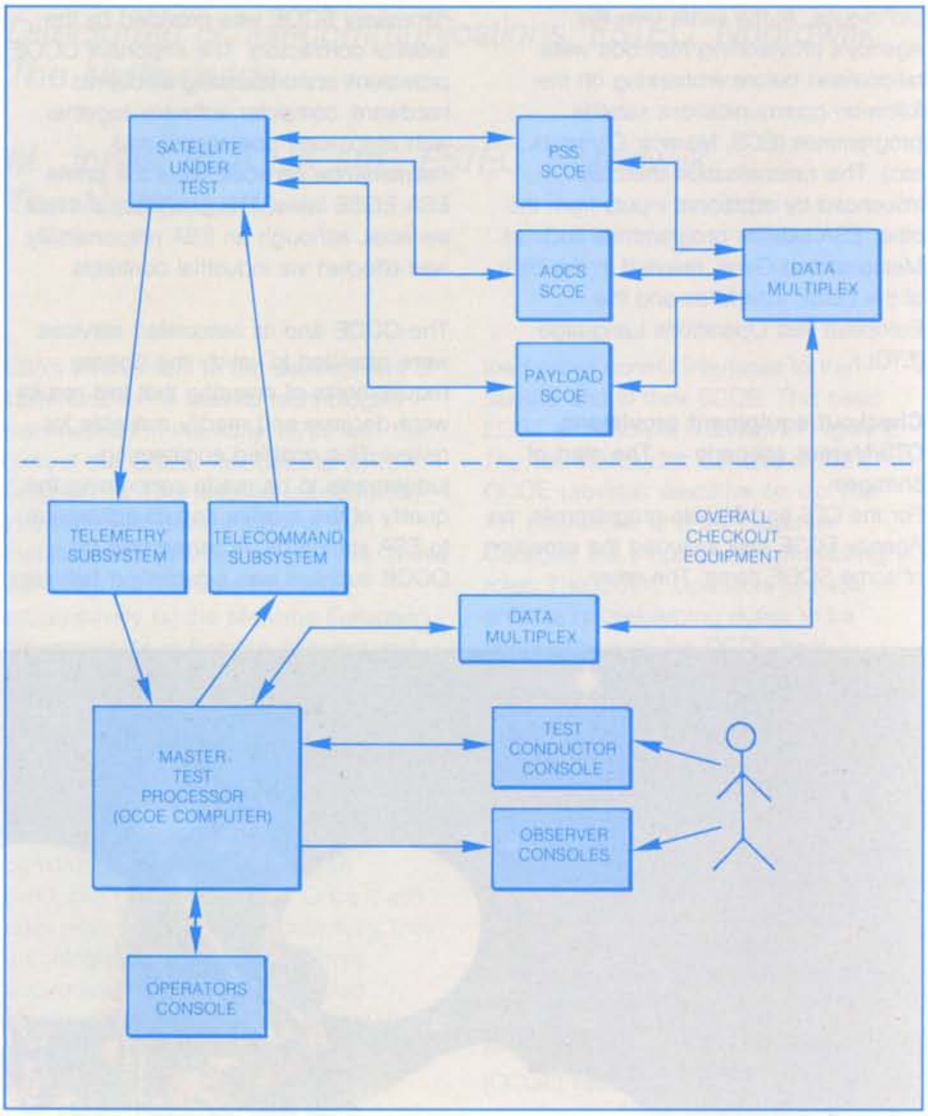


Figure 2 — Basic architecture of the Agency's Electrical Ground-Support Equipment (EGSE)



European communications satellite industry. As a result, the Agency's industrial policy for satellite checkout was updated, formally presented, and approved in 1979. OCOE supplies were thereby made the responsibility of the communications satellite's constructor, giving industry the major responsibility for EGSE procurement. However, ESA continued to play a significant role in defining the standards and quality of the EGSE. As the Agency retained the responsibility for computer-software standardisation, research and development continued in both the EGSE hardware and software fields.

The ECS and Marecs checkout environment was established by industry purchasing three OCOEs from the Agency to support these two programmes. British Aerospace (BAe) was appointed by the Agency as Prime Contractor for both programmes, with the Marecs satellite being constructed by BAe in Stevenage (UK), and ECS by Matra-Espace in Toulouse (F).

These two companies took responsibility for the respective OCOE operations. The facilities provided by the Marecs/ECS OCOE software gave the industrial satellite assembly and test engineers the ability to utilise the OCOE without this task being onerus to their prime activities. For example, colour-synoptic diagrams of the type shown in Figure 3 were produced and used by these engineers to assist them with the satellite assembly task without recourse to software specialists.

Responsibility for ensuring that the OCOE met programme requirements, primarily related to technical and schedule aspects, remained with ESA. The Agency and its industrial partners performed a supporting role for OCOE development and maintenance services.

The implementation of this scenario prompted Matra to request the Agency to make similar provisions for the French national telecommunications programme Telecom-1. Matra was appointed by CNES as the satellite Prime Contractor with satellite-construction responsibilities. The Agency undertook to supply Matra with the OCOEs and with similar support to that being provided to the Agency's ECS and Marecs programmes. These services were undertaken on an external-customer basis, with Matra purchasing one OCOE and leasing another for a sufficient period to meet their needs.

Olympus scenario — Further policy adoption

The successful launch and utilisation of the ECS and Marecs series of satellites resulted in the Agency's Olympus programme, British Aerospace being appointed Prime Contractor for this large telecommunications satellite, with overall responsibility for all EGSE provisions. In the discharging of the responsibilities associated with OCOE, BAe contracted Fokker to assemble and commission the hardware, with the Agency being employed in a consultative capacity. The Agency provided BAe with the latest versions of their OCOE software which included the European Test and Operations Language (ETOL) and diagnostic packages. A training

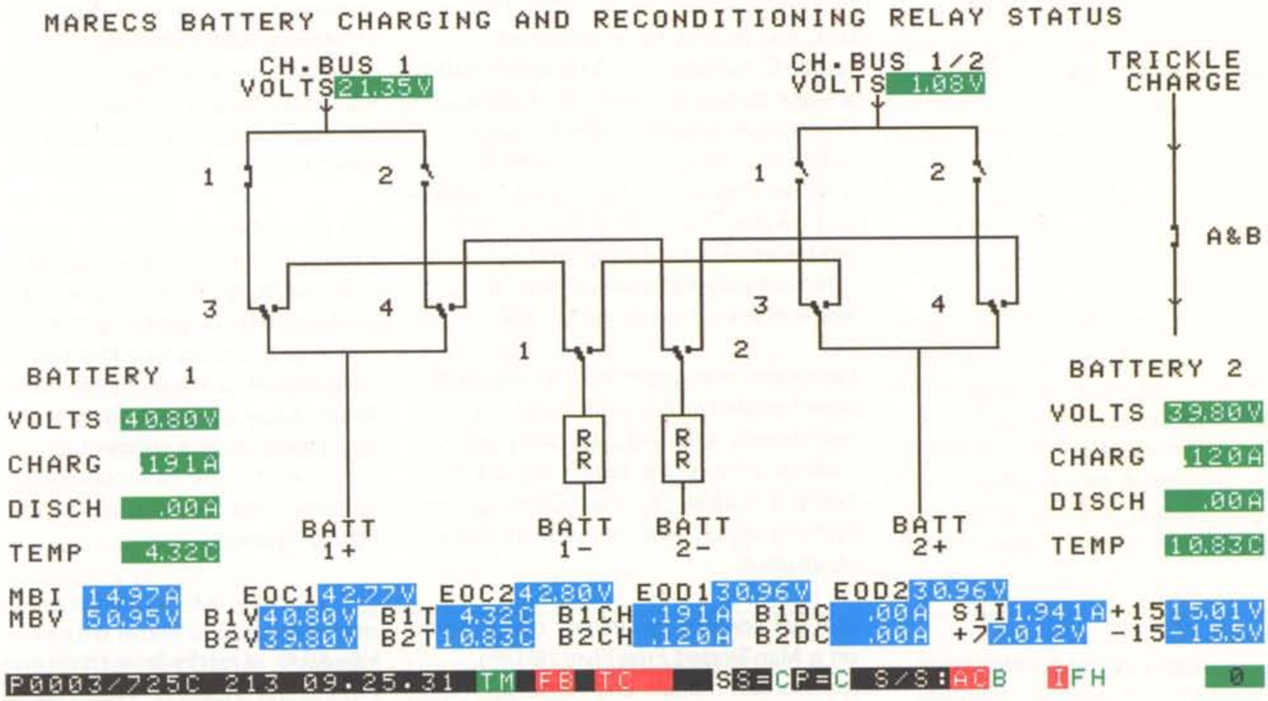


Figure 3 — OCOE colour synoptic display showing the status of the relays associated with battery charging/reconditioning for the Marecs satellite's power-supply subsystem

programme was given to BAe under the auspices of the Agency for these software handovers, so that BAe could themselves implement any software developments which they might require. These software handovers have been made the subject of agreed licensing arrangements.

Policy results

The satellite checkout policies that have been pursued by ESA have enabled industry to become increasingly self-sufficient for EGSE provisions. This capability has enabled some European satellite contractors to produce and test commercial communications satellites. The industrial companies that participated in the past in the provision of OCOE supplies and services to ESA are now dealing directly with the satellite construction industry. ESA is therefore able to fulfil its primary role of developing new designs adapted to future user requirements.

The successful application of the policy in the communication satellite environment has given the stimulus to a broader acceptance of the ESA EGSE standards. These standards have been implemented on other satellite programmes, culminating in the 1983 EGSE Round Table Conference. All the major European space companies attended this Conference where there was unanimous agreement that the European Test and Operations Language (ETOL) should be adopted as a standard. In addition, it was agreed that the user community would continue to perform an advisory role in guiding the evolution of the language. The conference also agreed that the EGSE could have an architecture of distributed intelligence, but conforming to a standard.

After the conference ESA undertook the task of defining and formalising these EGSE standards. The ESA EGSE Communications Standard has been developed to cope with the EGSE architecture. ETOL has been embraced in the 'ESA EGSE User Interface Standard'.

The EGSE Standards complement the ESA Telemetry, Tracking, Command (TTC) and On-Board Data Handling (OBDH) standards. The Agency's role in the activities of the International Consultative Committee for Space Data Standards (CCSDS) has enabled the ESA TTC and OBDH standards to be adopted.

Thus, if industry adheres to all these standards, satellite customers, with and without ESA involvement, have the visibility and comprehension of test procedures and results needed to ensure that a highly qualified satellite product is placed in orbit.

Acknowledgments

The authors wish to acknowledge the support provided by the ESTEC Data Handling Division and their industrial partners in preparing this article. This ESTEC Division can also provide more detailed information concerning the Agency's overall satellite-checkout activities.

In Brief

ESA and NASA Reach Space-Station Programme-Level Agreement

ESA and NASA announced on 1 August 1986 that they had reached agreement on the hardware elements of the International Space Station that ESA will carry into preliminary design. As ratified by ESA's Director General, Prof. Reimar Lüst, and NASA's Administrator, Dr. James C. Fletcher, this Agreement marks a major milestone in the Space-Station Programme. It calls for ESA to conduct preliminary design of a permanently attached Pressurised Laboratory Module and a Polar-Orbiting Platform for the remainder of the definition and preliminary design study (Phase-B), which extends through early 1987.

Discussion and negotiation on technical details related to the outfitting of the permanently attached Laboratory will continue through the remainder of the Phase-B studies. The Polar-Orbiting Platform will be used primarily for earth observation.

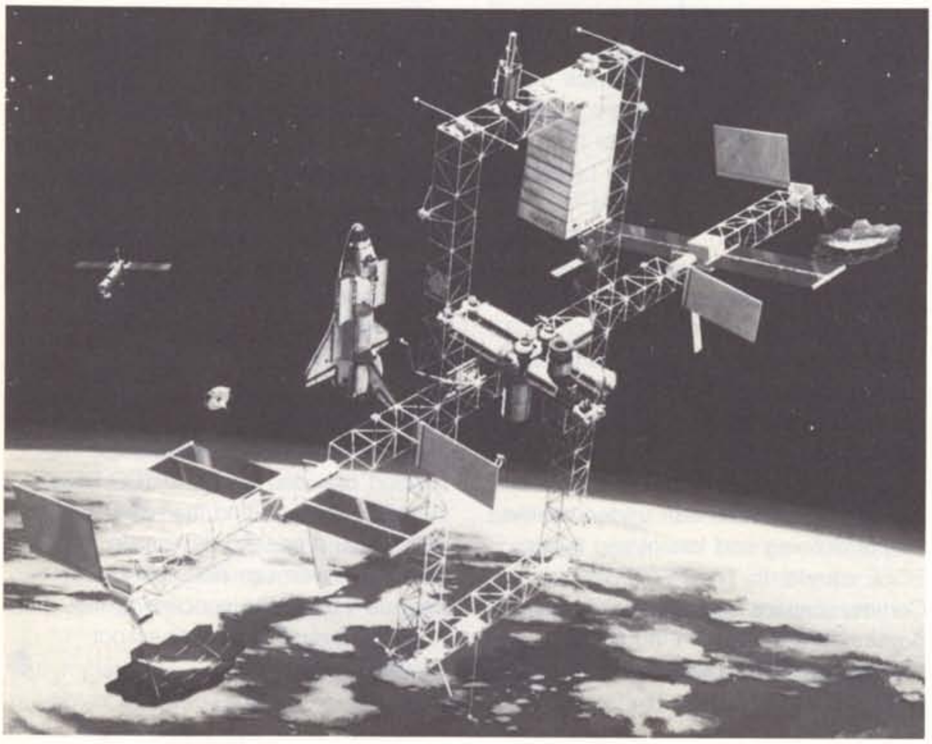
ESA will conduct preliminary design work on a Man-Tended Free-Flyer (MTFF) (pressurised module and resource module) for international utilisation, primarily for research in the fields of material- and life-sciences and fluid-physics requiring a long duration, undisturbed microgravity environment. In addition, ESA and NASA will jointly study the MTFF. This joint study, to be completed by January 1987, will concentrate on user requirements and development and operational impacts on the Space Station as a whole, and will provide a basis for determining the utility of the MTFF to the Space-Station system.

ESA will also study a Co-orbiting Platform, based on an enhanced version of the European Retrievable Carrier (Eureca). The servicing of this platform will initially be ground-based, but when the Space Station is operational it will be serviced at the Space Station.

The present Agreement only covers the remainder of the Phase-B period, and does not oblige ESA to develop this hardware. The undertaking of a cooperative programme to cover development of the hardware elements will be subject to the satisfactory negotiation of an agreement for cooperation in the development, operation and utilisation of the Space-Station System.

ESA will carry out the preliminary design studies referred to above within the framework of its Columbus Preparatory Programme, in which twelve ESA Member and Associate Member States participate. This programme, which formally got underway in February 1985, covers the definition of the specific elements for preparing a European in-orbit infrastructure as recommended by the ESA Council at Ministerial Level in Rome in January 1985 and having regard to the US invitation to participate in its Space-Station Programme. It also covers technological research work in the area of manned and unmanned systems.

Artist's impression of an early Space-Station concept



Corrigendum, Bulletin 46, May 1986
It was omitted to point out that the photograph of Comet Halley on 9 January 1986, shown on page 12 of the above Bulletin, was obtained by K. Birkle, Max-Planck-Institut für Astronomie, Heidelberg, W. Germany, using the Schmidt-Telescope of the Calar Alto Observatory in Spain.

Finland New Associate Member of ESA

On 19 September 1986, Prof. Reimar Lüst, ESA's Director General, and representatives of the Government of Finland, Mr. Seppo Lindblom, Minister of Trade and Industry, and Mr. Juhani Kuusi, Director General of the Technology Development Centre, signed three Agreements concerning:

- Finland's status as Associate Member of ESA
- Finland's participation in the ESA Science Programme, and
- Finland's participation in the ESA Earth-Observation Preparatory Programme (EOPP).

As an Associate Member of the Agency, Finland will benefit from most of the activities executed under the General Budget, attend Council meetings, and have access to ESA facilities. It may also participate in other Agency activities and programmes under the terms of separate agreements.

For its part, Finland, by becoming an Associate Member of ESA, agrees, first and foremost, to act in conformity with the purpose to which the Agency is dedicated, in particular the exploration and utilisation of space for exclusively peaceful purposes. It also agrees that, in developing its national space potential and in planning for national space missions, it will make primary reference to the use of European space transportation systems, and of facilities, products and services belonging to, or developed or operated under the auspices of, the Agency or its Member States. The association Agreement, which comes into force on 1 January 1987 at the earliest, will be valid for five years.

The second Agreement, which also comes into force on 1 January 1987 at the earliest, concerns Finland's participation in the ESA Science Programme. It entitles Finland to participate in the agency's Science Programme under the usual rules of scientific competition applied to the selection of experiments and instrumentation and the allowance of observation time. It also provides that Finland may participate in handling experiment data generated by scientific projects already in the operational phase and that it have access to observation time made available via these projects.

The third Agreement, which concerns Finland's participation in the Earth-Observation Preparatory Programme (EOPP), will enter into force on the date of signature. The EOPP, a five-year programme that got underway in March 1986 following the recommendations made by the Ministers of ESA Member States at the Council meeting in January 1985, is designed to prepare Europe's activities in this field until the end of this century. The main fields covered are polar-orbit earth-observation programmes (for land, ocean, ice and atmosphere), a second-generation Meteosat programme, and solid-earth programmes.

Finland, which already participates in the Meteosat Operational Programme, has already indicated that it also intends, at a later date, to participate in other ESA programmes, for instance in the communications field. It has also expressed its intention of becoming a full Member State of the Agency in due course.

Programme Ariane 2/3-4: Situation des mesures correctives post-V18

Alors que l'origine exacte de la défaillance de l'allumage du moteur n'a pu être établie, les conclusions ont conduit à remettre en cause les conditions d'allumage de la chambre, l'accent étant mis sur les aspects essentiels suivants:

- maîtrise du phénomène de propagation et d'accrochage de la flamme de combustion;
- énergie de l'allumeur et distribution de cette énergie (nombre et orientation des jets de gaz);
- conditions d'injection des ergols et définition de la séquence d'allumage correspondante.

Un plan d'action a été engagé pour résoudre ce problème d'allumage du moteur à partir des quatorze recommandations émises par la Commission d'Enquête. Ce plan pourra évoluer en fonction de l'avancement des travaux et des recommandations complémentaires qui seront faites par la Commission d'Enquête dont le mandat a été prolongé jusqu'au 30 novembre.

Le plan d'action comporte deux phases principales:

- un plan à court terme destiné à autoriser le prochain vol V19;
- un plan à moyen terme mené en parallèle mais se prolongeant au-delà des prochains vols pour consolider définitivement la fiabilité du fonctionnement du moteur.

Le plan à court terme porte sur la nouvelle définition du dispositif d'allumage; il incorpore également d'autres mesures correctives résultant d'anomalies de fonctionnement constatées lors de vols précédents dont la résolution a été jugée indispensable pour le prochain vol. Ces améliorations complémentaires concernent principalement les conditions d'allumage du générateur de gaz (modification de sa séquence d'allumage LOX/LH_2 et les conditions de refroidissement des roulements de l'arbre grande vitesse de la turbopompe.

La recherche de la nouvelle configuration du dispositif d'allumage de la chambre porte essentiellement sur la combinaison des principales modifications suivantes:

- augmentation de la puissance (rapport 3 environ) de l'allumeur pyrotechnique;
- localisation de l'énergie de l'allumeur dans la chambre par répartition du débit de gaz (jets déviés);
- réduction éventuelle de la durée de pré-refroidissement de la chambre par l'hydrogène avant l'injection LOX.

Le programme d'essais d'allumage du moteur comporte les principales phases suivantes:

(a) Une première série d'une vingtaine d'essais de développement effectués en condition de simulation d'altitude (banc SEP/PF41), devra conduire au gel de la configuration d'allumage à qualifier.

(b) En parallèle, une série complémentaire de 10 essais effectués à la pression atmosphérique (banc SEP de Melun-Villaroche), permettra de mettre au point la nouvelle séquence d'allumage du générateur de gaz et de vérifier la séquence complète d'allumage et de démarrage du moteur. Les modifications concernant les roulements de la turbopompe seront également mises au point séparément puis qualifiées en endurance sur turbopompes et moteur.

(c) L'ensemble de ces modifications sera intégré sur deux moteurs ainsi équipés au nouveau standard de vol, le premier de ces moteurs étant effecté au vol V19. Ces moteurs subiront un total de 5 essais d'allumage en condition d'altitude simulée en plus des essais habituels de réglage et de recette à la pression atmosphérique. Cette recette 'renforcée' aura pour but de confirmer l'adéquation de la nouvelle configuration de vol.

(d) La qualification proprement dite avec démonstration des marges fonctionnelles fera l'objet d'une phase ultérieure d'essais dont les résultats contribueront à prononcer l'aptitude au vol du moteur V19 et suivants.

Ce plan à court terme correspond à une approche essentiellement expérimentale. Cependant, la conduite de ce programme prend en compte, au fur et à mesure de leur disponibilité, les résultats des modélisations et des essais partiels entrepris en parallèle dans le cadre des travaux à moyen terme (visualisation des écoulements d'ergols et des interactions jets ergols/jets allumeur, essais d'injecteurs mono-éléments, essais de sensibilité à la cavitation de la pompe LH_2 . . .).

Le plan à moyen terme a pour objectif de maîtriser définitivement la phase d'allumage et de démarrage du moteur grâce à une connaissance théorique suffisante des phénomènes transitoires mis en jeu. Ceci nécessite l'établissement de modèles de calculs détaillés et complexes permettant de caractériser en particulier:

- le comportement dynamique et thermodynamique du moteur en prenant en compte l'influence de modifications ou de dispersions;
- l'allumage de la chambre, la propagation de la flamme et l'influence des interactions des jets ergols/allumeur;
- les paramètres auxquels l'allumage est le plus sensible.

Cette approche reçoit un support expérimental à l'aide d'un programme d'essais partiels mentionné précédemment dont les résultats permettant de vérifier et recaler les modèles de calcul.

Sur la base des connaissances théoriques ainsi acquises, le programme à moyen terme pourra déboucher sur d'éventuelles améliorations qui permettront d'augmenter et/ou de maîtriser définitivement les marges fonctionnelles.

Par ailleurs, l'objectif du plan à moyen terme a été étendu à la fiabilisation définitive du fonctionnement complet de l'ensemble propulsif grâce à un programme de revue des principaux équipements. La définition de ce programme est en cours de préparation. Les travaux devront porter en premier lieu sur les améliorations nécessaires des dossiers (spécifications de besoin – dossiers de définition . . .) et pourraient être suivis par les essais de validation et de qualification des modifications qui s'avèreraient indispensables.

En ce qui concerne le **calendrier,** l'avancement des essais de développement devrait permettre de confirmer, fin novembre, que les mesures correctives actuellement engagées pourront aboutir à une configuration apte au vol V19; ceci permettra également de préciser la date de lancement V19 (début 87).

Le programme à moyen terme couvre une période d'environ 2,5 ans jusqu'en fin 1988.

Irish President Visits ESTEC

Within the framework of a State Visit to the Netherlands, the President of Ireland, Dr. Patrick J. Hillery, visited the Agency's European Space Research and Technology Centre in Noordwijk on the afternoon of 5 November. The President was accompanied by His Royal Highness Prince Claus of the Netherlands.

During his visit, Dr. Hillery was given a

Prince Claus (left) and Dr. Patrick Hillery (centre) being shown models of some early ESRO/ESA satellites by Mr. Marius Le Fèvre, Director of ESTEC

ESA Participates in XXXVIIth International Astronautical Congress in Innsbruck

The International Astronautical Federation is a non-governmental association of national societies and other organisations, formed with the objective of encouraging the development of astronautics for peaceful purposes and ensuring widespread dissemination of scientific and technical information related to space. As part of the IAF's XXXVIIth Congress, held in Innsbruck, Austria between 6 and 10 October, a large number of Symposia were held devoted to space systems, earth observation, energy in and from space, power and propulsion, microgravity sciences, life sciences, satellite communications, space safety and rescue, etc.

In addition, reinforcing the themes of the Congress, ESA, the national space organisations and European space industry were represented at an exhibition organised in parallel with the Congress. The ESA stand, occupying approximately 100 m², presented both existing and future European space programmes. Models of Giotto, ECS-2, Ariane-4, the Space Station and Eureca were on display. On 6 October, the first day of the Congress, Prof. Reimar Lüst, ESA's Director General, welcomed Dr. Heinz Fischer, Austrian Minister of Science and Research, to the ESA stand, where together they hosted a Press Conference.

Prof. Reimar Lüst (left) and Dr. Heinz Fischer during the ESA Press Conference at the IAF

New IACG Project Selected

At the Sixth Meeting of the Inter-Agency Consultative Group for Space Science (IACG), held in Padua, Italy on 4 November 1986, 'Solar-Terrestrial Science' was chosen as the next focus for the IACG, now that the Group's initial role of informally co-ordinating all matters related to the space missions to Halley's Comet is drawing to a highly successful conclusion.

From its formation in 1981, the IACG demonstrated an ever-increasing usefulness for the various Halley flight projects as a focal point for exchange of information, discussion on common problems, and mutual support to enhance the overall scientific return of the various missions.

Other contenders to be the next focus for the IACG were international projects in 'Radio Astronomy' and the study of 'Planetary and Primitive Bodies'. The former was deemed by the selection committee to be not yet at the level for approval, but could be adopted as an IACG discipline area in a few years' time, while the latter may become an IACG project further into the future.

A Working Group appointed in March 1986 to summarise the position of the Solar-Terrestrial Science discipline as a candidate for IACG selection identifed twelve international space missions already in the planning stage that could contribute significantly to our understanding of solar-terrestrial relationships. Each member of the IACG

short introduction to the roles of ESA and of ESTEC by ESTEC's Director Mr. Marius Le Fèvre. He subsequently made a tour of the Centre's Environmental Test Facilities, where the presence of the Giotto structural model served as a reminder of Ireland's scientific involvement in the payload of the spacecraft and its historic rendezvous with Comet Halley on the night of 13/14 March this year.

Dr. Patrick Hillery's party being shown the Giotto structural model by Dr. Brian Taylor of ESA's Space Science Department

has one or more solar-terrestrial science missions approved or near approval for launch and operation in the 1989—1996 period. The scientific output of these missions will be significantly enhanced by the coordinated operations provided by the IACG and through the data-sharing and the joint data analysis by the science communities associated with the IACG members.

The Heads of the Delegations from Intercosmos, from ESA, from NASA and from Japan's ISAS — the four member agencies of the IACG — strongly endorse the continuation of the IACG and the adoption of Solar-Terrestrial Science as the Group's next project.

IACG
Inter-Agency Consultative Group for Space Science

Halley's Comet Investigators Meet in Heidelberg

Scientists from around the World involved in the various international space missions to Halley's Comet, as well as those involved with the theory and ground-based, airborne and near-Earth space observations of Halley, all met together in Heidelberg in October (27—31) for the first time since the spacecraft encounters with the Comet in March this year. While the main emphasis of this, the 20th ESLAB Symposium, was on Halley, discussions and papers on other comets, particularly Giacobini-Zinner, were very much in evidence.

The Symposium, which attracted a total of 500 participants from 30 countries, was held in the Kongresshaus Stadthalle in the centre of the old town of Heidelberg. It was organised jointly by ESA Space Science Department and the Max-Planck-Institut für Kernphysik (Heidelberg). It was sponsored by the Inter-Agency Consultative Group (IACG) and the International Halley Watch (IHW), and co-sponsored by the Committee on Space Research (COSPAR) and the International Astronomical Union (IAU).

The Symposium was opened by Prof. Reimar Lüst, ESA's Director General, and welcoming addresses were given by: Prof.H. Engler, Minister for Science and Art, Baden-Württemberg; Prof.G. zu Putlitz, Rector of the University of Heidelberg; Dr.D. Klette, Mayor of Heidelberg; and Dr.H. Römer, Ministerialrat, Federal Ministry of Research and Technology, Bonn.

Twenty-six formal sessions were held in the course of the week, during which a total of 250 papers were presented. Seven of these sessions were devoted to 'plasma', eight to 'gas', seven to 'dust' and four to the 'nucleus' of Halley. In addition, there were two Poster Sessions running during the Symposium, at which a total of 120 posters were shown.

A summary of the main scientific results presented and discussed in Heidelberg will be included in the next issue of the ESA Bulletin (No. 49, February 1987).

The initial camera-ready Proceedings of this historic Symposium are already in preparation and will be published in December this year by ESA Publications Division. They will contain almost all of the formal papers and posters presented in Heidelberg and should represent a substantial contribution to the literature on the science of comets and their associated phenomena.

Advance orders for copies of these Heidelberg Proceedings (ESA Special Publication SP-250; price 175 Dutch guilders, or equivalent) can be placed using the Order Form to be found inside the back cover of this Bulletin.

1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1. Scale model (1.5:1) of Giotto outside the Kongresshaus Stadthalle in Heidelberg

2. The Heidelberg audience during the Symposium opening

3. Symposium Organiser Dr. Rüdeger Reinhard of ESA Space Science Department

4. Dr. H. Römer of the German Federal Ministry delivering his Welcoming Address

5. From left to right: Prof. H. Fechtig (Director, MPI Heidelberg), Dr. D. Klette, Prof. H. Engler, Prof. R. Lüst, and Prof. zu Putlitz, beside a full-scale engineering model of Giotto

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Photographs: Lossen Foto, Heidelberg

6

6. From left to right: Mr. D. Dale, Giotto Project Manager; Dr. R. Reinhard, Giotto Project Scientist; Prof. R. Lüst, ESA's Director General; Dr. U. Keller, Halley Multicolour Camera Principal Investigator; Dr. R. Bonnet, ESA Director of Scientific Programmes; Dr. E. Trendelenburg, Dr. Bonnet's predecessor; and Prof. F. Whipple of Harvard's Smithsonian Astrophysical Observatory

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. 10, No. 2:

COMPUTER SIMULATION OF LASER RANGING ON ERS-1: DESIGN OF THE RETROREFLECTORS
MORANÇAIS D & REYNOLDS M L

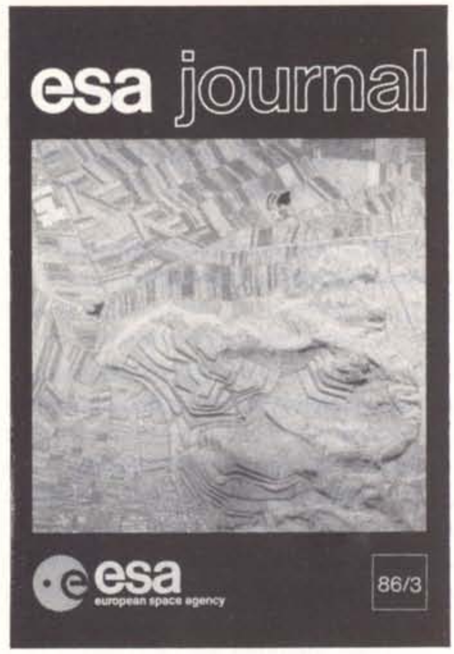
LA VALIDATION DE L'INDICE DE PRECIPITATION
TURPEINEN O M, ABIDI A & BELHAOUANE W

THE GIOTTO MISSION OPERATIONS SYSTEM
WILKINS D E B

SPREAD-SPECTRUM MULTIPLE ACCESS FOR SPACECRAFT SERVICE FUNCTIONS (TT&C)
OTTER M

RESULTS OF AN AIRBORNE SYNTHETIC-APERTURE RADAR (SAR) EXPERIMENT OVER A SIR-B (SHUTTLE IMAGING RADAR) TEST SITE IN GERMANY
SIEBER A & NOACK W

DERIVATION OF SATELLITE EQUIPMENT TEST SPECIFICATIONS FROM VIBRATION AND ACOUSTIC TEST DATA
GIRARD A & MOREAU D



Special Publications

ESA SP-251 // 580 PP
PLASMA ASTROPHISICS, PROC JOINT VARENNA – ABASTUMANI INTERNATIONAL SCHOOL AND WORKSHOP, SUKHUMI, USSR, 19–28 MAY 1986 (AUG 1986)
GUYENNE T D & ZELENY L M (EDS)

ESA SP-259 // 147 PP
LAND-MOBILE SERVICES BY SATELLITE, PROC ESA WORKSHOP, ESTEC, NOORDWIJK, THE NETHERLANDS, 3–4 JUNE 1986 (SEPT 1986)
GUYENNE T D & HUNT J (EDS)

ESA SP-263 // 724 PP
NEW INSIGHTS IN ASTROPHYSICS: EIGHT YEARS OF UV ASTRONOMY WITH IUE, PROC NASA/ESA/SERC INT SYMP, UNIVERSITY COLLEGE LONDON, 14–16 JULY 1986 (SEPT 1986)
ROLFE E J (ED)

ESA SP-265 // 194 PP
FLUID DYNAMICS & SPACE, PROC INT SYMP, VON KARMAN INST FOR FLUID DYNAMICS, RHODE-SAINT-GENESE, BELGIUM, 25 & 26 JUNE 1986 (AUG 1986)
BURKE W R (ED)

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REPORT ON THE ACTIVITIES OF THE SPACE SCIENCE DEPARTMENT IN 1984–1985 (JUNE 1986)
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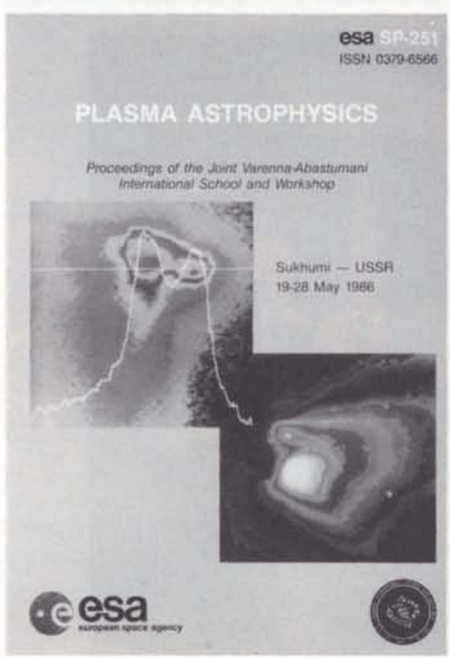

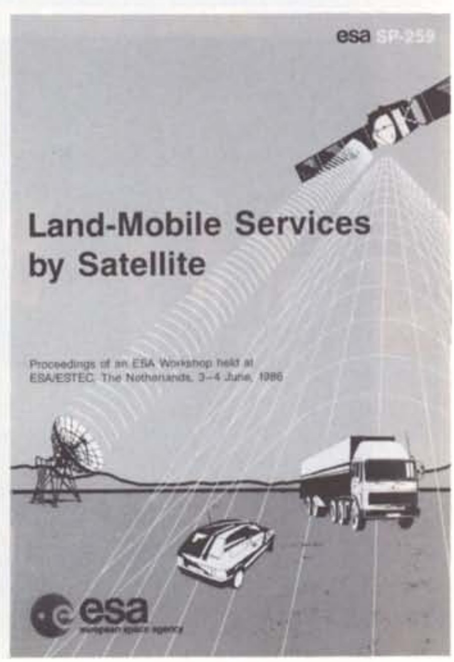

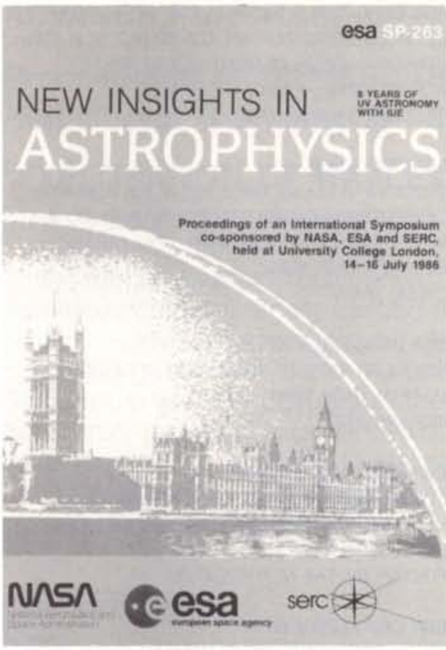

Contractor Reports

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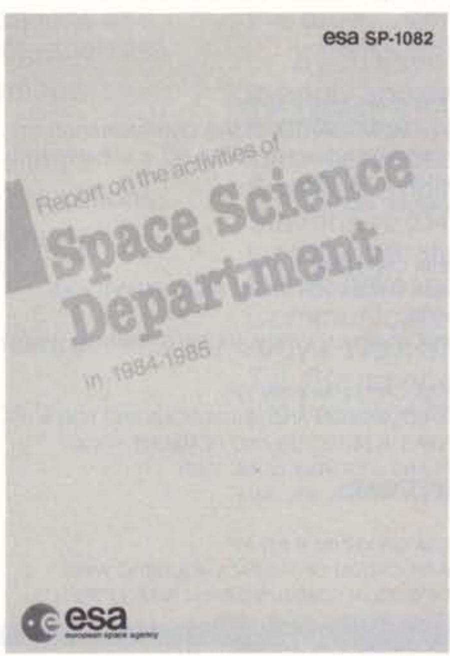

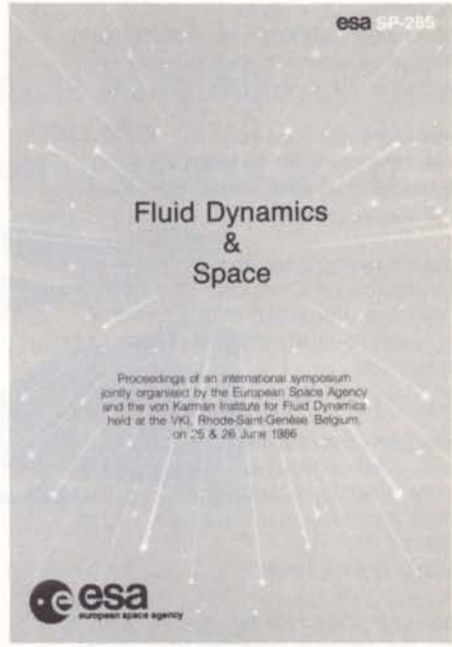

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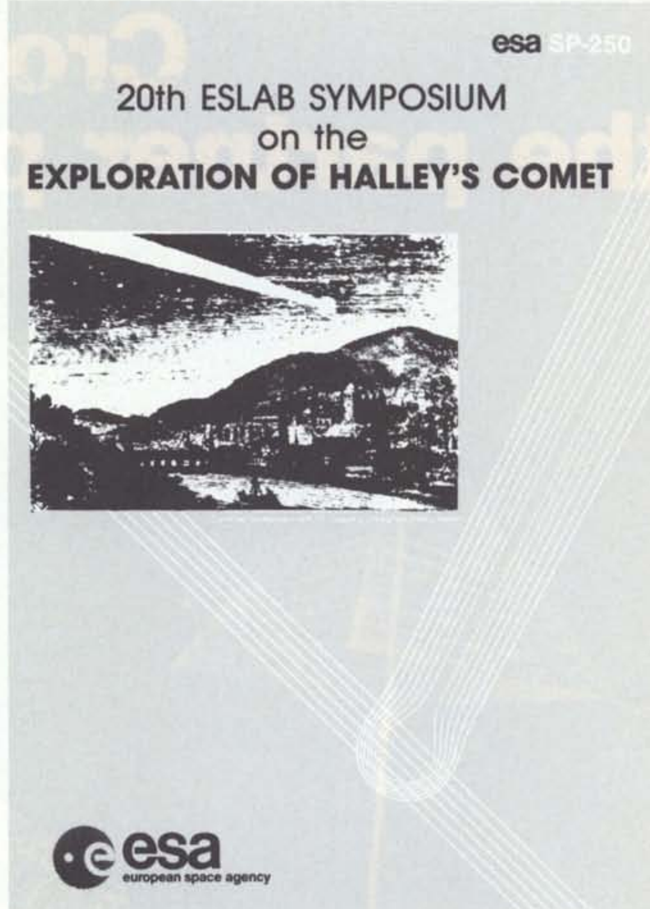

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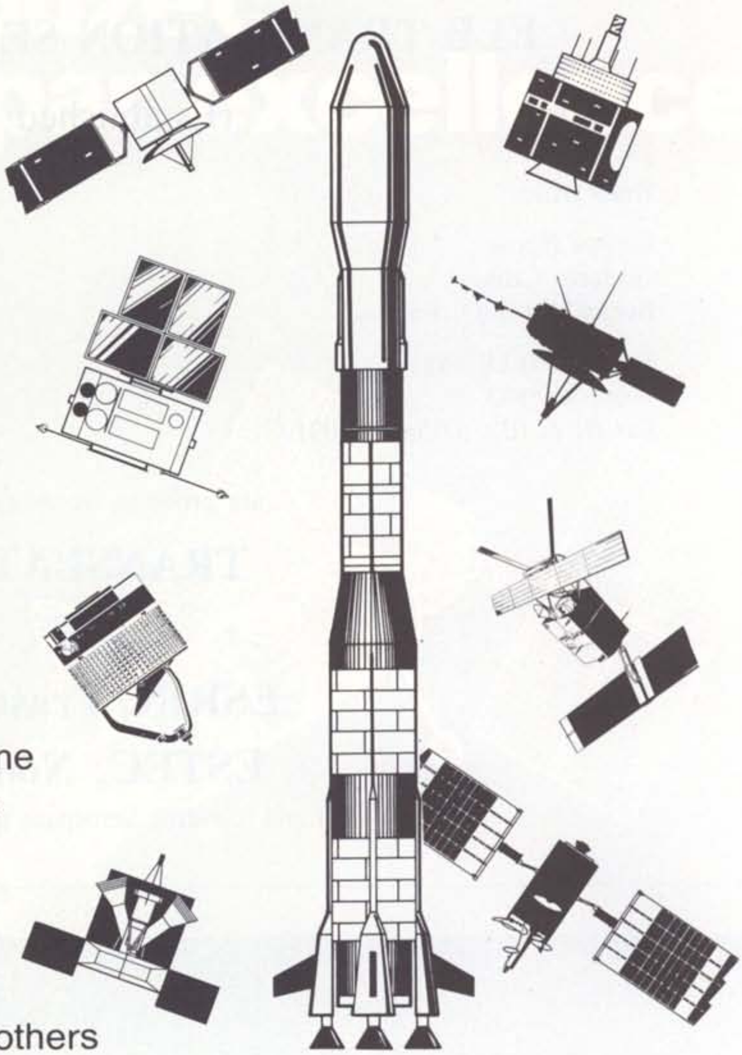

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The Bulletin is the Agency's quarterly magazine that helps to fulfil this obligation, carrying information on ESA, its activities and its programmes, on-going and future.

The ten or so articles that go to make up each issue (approximately 100 pages) are drafted by professional scientists and technologists. They are original and significant contributions on space technology, space science, space missions and space systems management and operations. The goal is to bring the results of ESA's space research and development activities to the notice of professionals concerned with the exploration and exploitation of space, many of whom are senior politicians and those responsible for government contracts.

Every Bulletin also carries some 16 pages of 'progress information' that comprehensively describe the last three months' developments in all the major European space programmes (telecommunications, meteorology, earth observation, and scientific satellites, the Spacelab/Space Shuttle programme and the Ariane launch-vehicle programme). Newsworthy events, conferences, symposia and exhibitions associated with the European space programme are also featured in every issue.

The Readership

Through the nature of its content and the role that the Agency plays in shaping Europe's space research and development activities, the Bulletin has come to have a fast-growing (currently 10 500 copies per issue) but *select* distribution among 'decision makers' in space matters not only in Europe but around the World. The Bulletin is now distributed in more than 100 countries. It is read by managers and senior staff in space-oriented organisations – both national and international – in ministries, in industry, and in research institutes. It forms a fundamental part of the continual dialogue between ESA and its national counterparts and between ESA and the industrial firms to whom the contracts and subcontracts are awarded that account for the major part of the Agency's $950 million per year budget (contract awards on a geographical-return basis linked directly to the financial contributions of the individual ESA Member States).

Advertising Potential

The Bulletin therefore offers the commercial company – large or small – which already provides space-related products and/or services or which wishes to develop its markets in that direction, a direct entrée to a very special readership with a much *higher than average* rating as far as *market potential* is concerned. This commercial market potential is growing steadily each year with a constantly increasing percentage of readers being faced with a need to apply in their own environments the technologies that ESA, the national agencies, and industry have been developing to meet European needs.

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