esa bulletin

number 39

august 1984

xx years of european cooperation in space
european space agency
1964 1984
esa
agence spatiale européenne
xx ans de coopération spatiale européenne
ELDO ESRO

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 has Observer status.

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

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

Director General: Mr. E. Quistgaard.

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée – l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) – dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, la Belgique, le Danemark, l'Espagne, la France, l'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'observateur.

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

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

Directeur général: M. E. Quistgaard.

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Back cover: A view of the Space Exhibition that formed part of the 'Twenty Years Celebrations' at ESTEC.

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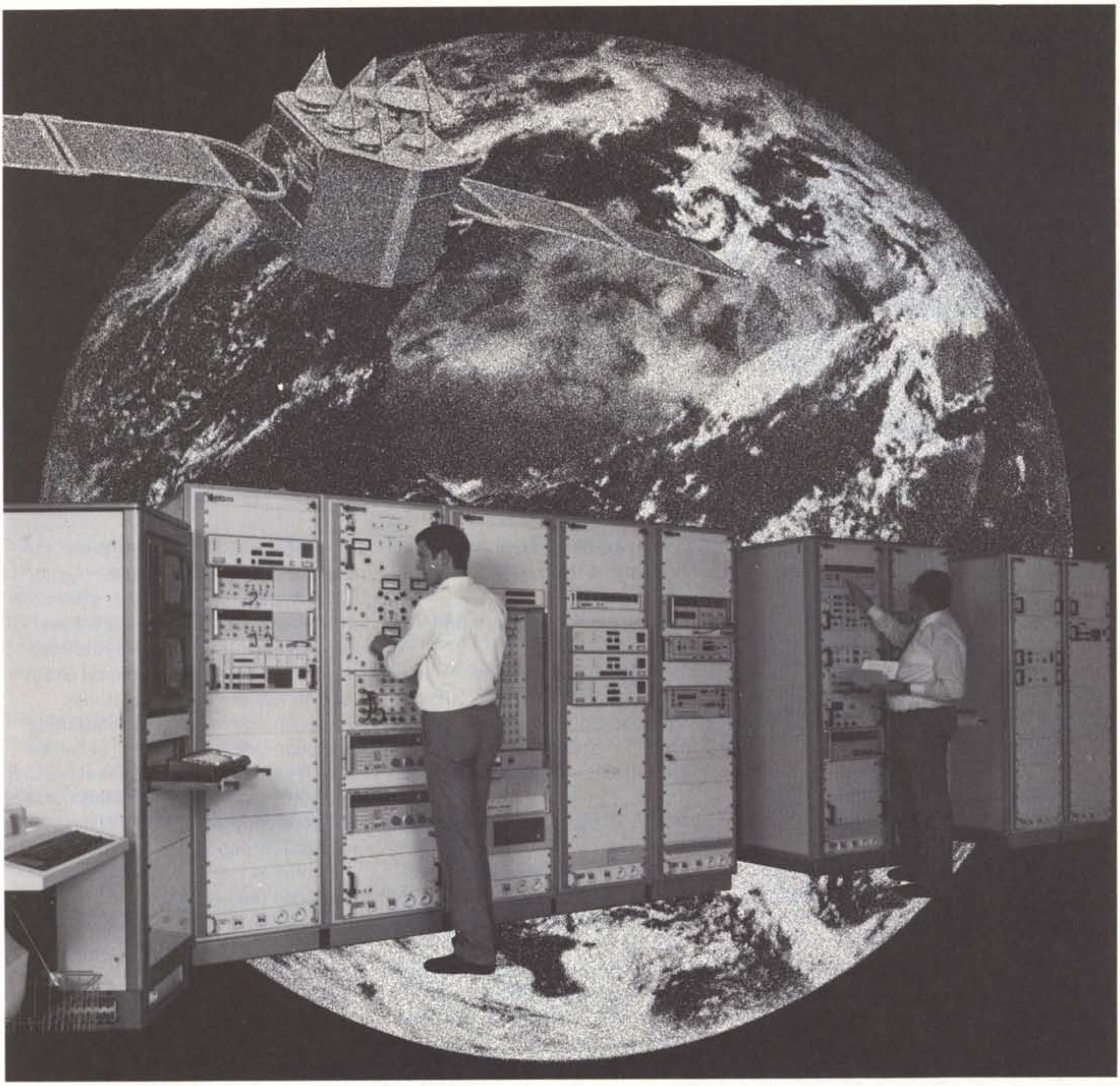


The Celebration of 20 Years of European Cooperation in Space

W. Brado, Head of Cabinet, ESA, Paris

ESA originated from the merger of the European Space Research Organisation, ESRO, and the European Launcher Development Organisation, ELDO. Both the ESRO and the ELDO Conventions entered into force in 1964 and 1984 therefore marks 20 years of European cooperation in space (see ESA Bulletin No. 38, pages 20-30 and page 105).

To commemorate this important milestone, ESA decided to hold a celebration at the Agency's European Space Research and Technology Centre (ESTEC) at Noordwijk in The Netherlands in the week of 7-12 May.

The programme of events consisted of an official day of celebration on 9 May, a space exhibition, plus staff celebrations and activities on 11 and 12 May. The Agency's Council held its 63rd Meeting at ESTEC on 10 and 11 May, and the Ministers of the Member States had an informal meeting during lunch on 9 May.

The official celebration on 9 May

This celebration was in two parts, divided between the morning and the afternoon. Both took place in ESTEC's Test Hall, which had been specially decorated for the occasion and was linked by teleconference and video transmission facilities via Eutelsat-F1 (an ECS satellite developed by ESA) to ESA Headquarters and two other Agency Establishments – ESOC in Darmstadt, and ESRIN in Frascati. This enabled a large number of guests, press representatives and ESA staff at these Centres both to follow the events at ESTEC and to play an active role in the discussions during the morning event on 9 May.

The morning panel discussion and teleconference

The panel discussion and teleconference that took place from 10.00 to 12.00 h on 9 May were devoted to the theme 'Europe in Space'. The panel participants were:

- Prof. H. Curien, Chairman of the ESA Council
- Mr. E. Quistgaard, Director General of ESA
- Dr. N. Smit-Kroes, The Netherlands Minister of Traffic and Public Works
- Dr. A. Caruso, Secretary General of Eutelsat
- Sir Peter Anson, Marconi, Portsmouth
- Prof. G. Haerendel, Director, Max-Planck-Institut für Extraterrestrische Physik, Garching
- Mr. B. Chabbert, Journalist and Panel Chairman.

During this event all of the ESA Establishments were presented and a film entitled 'Europe in Space' was shown for the first time. The ensuing panel discussion provided an opportunity for the speakers to give their views on the future of European activities in space and to reply to questions asked by the audience and by guests in the Establishments who were following the video transmission.

The afternoon ceremony

In the afternoon, the ceremony marking 20 years of cooperation was honoured by the presence of Her Majesty, Queen Beatrix of The Netherlands, and various Ministers, Secretaries, and Ambassadors of Member and non-Member States, the Commissioner of the Province of South Holland and several mayors, as well as Parliamentarians and representatives from industry. The guests also included the Secretary General of Eutelsat and representatives from Inmarsat, the European Communities, the Western European Union, the Council of Europe and other international organisations and national institutes. **The speeches made at this ceremony are reproduced in the subsequent pages.**

Two video presentations were made: an 18 min film '20 years of European Cooperation in Space', which described the achievements over the past two decades, and a Spacelab first-mission film 'Touch Down', with commentary by the European astronauts Ulf Merbold, Wubbo Ockels and Claude Nicollier.

At the end of the ceremony the first, numbered copy of the ESA Commemorative Book 'Europe, Two Decades in Space' was presented to Her Majesty the Queen by ESA's Director General, who then accompanied her on a tour of the Exhibition. A short reception concluded the ceremony.

The Gala Dinner in the Ridderzaal

The historic Ridderzaal ('Knight's Hall'), in the Hague, was chosen for the Gala Dinner, which brought together about 300 invited guests. Representing the Netherlands Minister for Economic Affairs and the Minister for Education and Science, Minister G.M.V. Aardenne, the Deputy Prime Minister and Minister for Economic Affairs, welcomed the guests and paid tribute to the success of European cooperation.

In the course of the evening, the Italian Minister for Scientific and Technological Research, L. Granelli, the current ESA Director General, Mr. E. Quistgaard, and Prof. R. Lüst, ESA's next Director General (from 1 September 1984) also addressed the assembled dignitaries.

The Dinner was an occasion for the European space 'family' to exchange reminiscences; some old friends found the atmosphere so congenial that they missed the official coaches, which left at midnight.

The Ministerial Meeting

The fact that several Ministers, Secretaries, Ambassadors and other high-ranking officials of the ESA Member States came together at ESTEC provided an excellent opportunity for an informal Ministerial Meeting and a first exchange of views on the future of European Cooperation in Space and, in particular, on President Reagan's offer to Europe to participate in the US Space Station programme. As Italy had chaired the last Council meeting at Ministerial Level in 1977, Italian Minister Granelli took the initiative in convening the meeting and leading the discussions.

As a result of these discussions, which took place in an excellent atmosphere, a wide-ranging consensus emerged with regard to future European cooperation and means of arriving at decisions. The American offer to participate in the development and construction of the Space Station was welcomed. The Ministers and senior officials of the Member States declared their willingness to explore, at an early date, the possible orientation of European participation. It was agreed that this could be done at a Council meeting at Ministerial Level, which could be held as early as Autumn 1984. This meeting would prepare for the decisions to be taken by a second Ministerial Meeting in 1985.

Staff celebrations

The staff party

The major single event was the staff party, held on Friday 11 May at Warmond's Dekker Hall. It was an attempt to bring together, on at least this one occasion, as many ESA staff and their spouses as possible. Of the 1200 present, 110 came from ESRIN, 103 from ESOC, 122 from Headquarters, 11 from Toulouse and 4 from Villafranca. The party, with a well-stocked buffet and dancing to three bands, continued well into the early hours.

The Clubs

A series of sporting and other events were organised around the staff party by the ESA, and especially the ESTEC, Clubs. The ESA inter-Establishment football cup went to ESOC, who also won the tennis tournament.

Other ESTEC Clubs joined forces to organise a large fête on Saturday 12 May. The fine arts, photography, computer, sailing, subaqua and philatelic clubs presented exhibitions, while others organised a fair with groups serving typical foods from Italy, Scandinavia, Germany and the United Kingdom. The Space Club sold ESA T-shirts, caps and other items. The day of festivities was rounded off with a party and barbecue. The ESTEC Theatrical Group put on four 'Victorian evenings', which were attended by more than 600 guests and staff members. The ESTEC Flying Club staged a flying display and provided the guests and staff with an opportunity to see ESTEC and its surroundings from the air.

The Exhibition

The Agency and European industry joined forces to mount a comprehensive 'Space Exhibition', providing a complete panorama of the past 20 years' achievements. Full-size mockups from practically all the European programmes were displayed, ranging for science from ESRO II, the first European spacecraft launched, to Giotto, which will be launched next year, for applications from the Orbital Test Satellite and Meteosat to ECS, and for space transportation from Spacelab to Ariane (a 1:8 scale model owing to the limited height of the exhibition hall). Smaller scale models from such programmes as ISO, the Space Telescope and ERS-1, as well as mockups of the Kourou Space Centre and the Fucino Telespazio ground station, were also on display to make the Exhibition as comprehensive as possible. Items such as satellite momentum wheels, heat pipes and other components, illustrated state-of-the-art technology. Industry – through its consortia, Arianespace and the Prime Contractors – made a substantial contribution to the success of the Exhibition, providing models of Giotto, a structural model of Meteosat, an Ariane half-fairing, etc.

Open to the general public from 28 April to 5 May, the Exhibition was visited by some 18 000 people from Noordwijk and the surrounding areas.

Queen Beatrix showed great interest in the displays during her tour of the Exhibition on 9 May. Other personalities, and in particular the Delegates to the ESA Council, visited the Exhibition on 10 and 11 May.

Morning ceremony

Allocution de bienvenue

Prof. H. Curien, Président du Conseil, ESA

C'est un grand honneur et un grand plaisir pour moi d'accueillir votre Majesté au nom du Conseil de l'Agence spatiale européenne dans ce bâtiment de l'ensemble de l'ESTEC, et j'espère que vous pourrez ainsi voir nos grandes réalisations spatiales européennes, en particulier celles qui sont situées ici, dans votre pays.

Vingt ans de conviction

La commémoration d'un anniversaire de vingt ans est toujours une belle cérémonie, et celle-ci est plus belle encore, puisque nous fêtons non seulement vingt ans de collaboration européenne mais aussi vingt ans de *conviction* européenne dans l'espace. Je sais bien que l'espace n'est pas le seul domaine où la collaboration européenne est une réussite; mais je peux dire, sans aucune immodestie, que cette coopération européenne dans l'espace est exemplaire. Elle est exemplaire, mais il faut aussi avouer que nous sommes favorisés. Nous le sommes parce que nous construisons des objets qui sont à la fois élégants et utiles. Favorisés parce que, plus facilement que d'autres, nous sommes toujours écoutés et assez souvent entendus, parce que nous évoluons dans le monde de la nouveauté, de l'innovation et parfois même du rêve. Mais cet accès facile que nous avons à la considération et à l'estime de nos concitoyens européens se paie par une évidente vulnérabilité. En effet, nos échecs – ils sont très rares, je vous rassure, et en tout cas ils sont toujours générateurs de progrès – nos échecs nous font mal, peut-être plus mal qu'à d'autres. En effet, aussi, les critiques que nous recevons sont à la mesure même des louanges que nous aurions pu espérer.

Les objets que nous construisons, je l'ai dit, sont élégants et utiles. Elégants donc séduisants, utiles donc gratifiants; mais la réalisation en est souvent difficile, difficile donc stimulante. Quand j'ai dit 'les objets que *nous* réalisons': qui 'nous'? Eh bien, là encore nous donnons l'exemple de cette synergie que chacun appelle de ses voeux, coopération directe et profonde entre une agence d'objectifs, l'Agence spatiale européenne, les industriels européens qui ont fait la preuve de leurs qualités, et les utilisateurs eux-mêmes, qui font usage de nos systèmes.

Ce matin, autour d'une table ronde, nous avons réuni des représentants de ces trois populations et nous avons montré combien nos points de vue étaient proches et combien nos langages sont communs. Mais nous n'avons pas à nous en glorifier outrageusement: notre langage commun c'est celui de la technologie et c'est cet Esperanto de la fin du vingtième siècle qui s'impose chaque fois que l'on conçoit et construit des objets nouveaux.

L'espace a un caractère international. L'Agence spatiale européenne en est la preuve. Mais il est également exemplaire en ce sens qu'il est interdisciplinaire, puisqu'il exige une profonde conjonction entre toutes les connaissances que nous pouvons avoir dans la mécanique, dans l'électronique, dans la thermique, mais aussi, du côté des applications, dans les communications, dans la géologie et dans l'astronomie. L'espace est un carrefour tout à fait privilégié pour l'innovation.

Ombres et lumières

Pour rehausser les quelques lumières du tableau que je brosse de l'espace, je crois qu'il est prudent, et peut-être même habile, de mettre aussi quelques ombres. Je n'en mettrai que deux. La première, en disant que l'espace c'est long. En effet, c'est le vingtième anniversaire que nous célébrons aujourd'hui. Eh bien, en vingt ans, nous n'avons guère connu que deux générations de programmes. Un programme spatial normal prend dix ans pour son développement: Ariane en est la preuve, Spacelab en est une autre. Pourrait-on aller plus vite? Peut-être, mais personne ne le fait. Nos collègues américains viennent de décider la construction d'une station spatiale, dont ils annoncent la mise en orbite en 1992, au plus tôt. L'espace c'est long, l'espace c'est cher. L'espace c'est cher, c'est ce qu'on dit, mais ce n'est pas vraiment si cher que cela. Les Européens dépensent peu pour leur espace. Permettez-moi d'en parler en tant que citoyen français puisque je paie mes impôts en France. En bien, un Français paie pour l'espace, par an, un peu moins que le prix d'un bon repas. Est-ce trop?

Si je me compare au citoyen américain, lui, il paie à peu près le prix de cinq bons repas. Nous avons encore devant nous une bonne marge!

Quittons les ombres pour revenir aux lumières, et vanter à nouveau les qualités des programmes spatiaux et de la collaboration européenne dans laquelle nous les menons, en insistant d'abord sur la très remarquable continuité de la politique spatiale européenne depuis

20 ans. Nous n'avons pas eu absolument que des succès mais nous avons eu beaucoup de succès et un faible taux d'échecs. Ces échecs n'ont jamais vraiment remis en cause la continuité de notre politique; au contraire, ils ont affermi les volontés de chacun de nos gouvernements; et une réunion que le ministre italien vient d'organiser à l'instant même nous a montré combien les représentants des Etats européens avaient le sens de cette continuité dans la politique spatiale pour l'Europe. Et puis aussi nous travaillons dans un parfait esprit de collaboration entre nous Européens, mais aussi de collaboration avec nos interlocuteurs en dehors de l'Europe, dont le principal est évidemment la NASA, et plus généralement, les Etats-Unis d'Amérique. Nous avons avec les Etats-Unis deux types au moins de relations: des relations de collaboration et des relations de concurrence, mais on peut être d'excellents collaborateurs en restant par ailleurs des concurrents, je ne dirais pas acharnés mais fermes sur leurs positions. Si bien qu'avec nos amis américains nous avons défini une manière d'opérer qui me paraît tout à fait bonne: discuter avec eux, respecter leur très grande puissance technologique, mais aussi affirmer et prouver que l'Europe est un partenaire à part entière et qu'une compréhension mutuelle n'est pas du tout l'antithèse d'une négociation et même d'une négociation assez serrée.

Nous préparons maintenant, après ces vingt ans, notre futur. Comment le préparons-nous? Je crois pouvoir résumer notre état d'esprit en une phrase: aucune des portes qui ouvrent sur l'espace ne nous est inaccessible, mais raisonnablement nous ne pouvons pas les ouvrir toutes, au moins pas toutes à la fois. A nous de choisir les meilleures et surtout de trouver les bonnes clés.

The Scientific Programme, Cornerstone of European Space Activities

Prof. C. de Jager, Chairman of ESA's Science Programme Committee

Since the early days of mankind, we humans have been looking up at the sky, in wonderment, curious about our place in the Universe, searching for our origin, our future, our destiny. All great religions express views on these fundamental questions:

- How did the cosmos originate?
- What are the driving forces in cosmic evolution?

If we look at the sky as seen through the eyes of Cos-B, one of the scientific satellites launched by ESA, the view is very different from the common picture. Instead of stars and nebulae, we see an extensive diffuse glow in which only a few discrete sources are discernible. This is because the eyes of Cos-B are very different from ours: that spacecraft was built to see emissions in which the individual photons – the 'light particles' – have energies about a thousand million times larger than the photons our eyes are able to see.

The observations of Cos-B showed us a new and until then unknown part of the Universe: to be able to emit light particles with such enormous energies, the emitting sources should have temperatures of the order of 10^{12} degrees. Should we doubt whether such high temperatures can exist in our Universe, we can formulate the implications of the findings of Cos-B in another way: the mere fact that this spacecraft discovered what we see on the screen means that these photons were emitted by cosmic structures in which the atomic particles – essentially protons and electrons – practically travel with the velocity of light, thereby interacting with the ambient medium, which consists of cosmic matter and electromagnetic fields. The velocity of light is the highest velocity possible in nature and these unknown sources must therefore contain an incredible amount of energy.

The question is, where should we imagine these powerful sources of radiation to be, and what are they like?

Only a few of the sources of these tremendous energies have been identified so far; one of them appears to be the exploding nucleus of a whole galaxy – a complex of hundreds of thousands of millions of stars. As to the remainder, we can only guess what exotic manifestations of nature's unimaginable creativeness are still hidden in the observations. Without doubt, our curiosity will eventually yield the answer.

Human curiosity is the ever-driving force and the challenging thread of research. It is that very spirit that let mankind make its first stone tools, that drove the great discoverers to explore our Earth, and that lead scientists to set up experiments for exploring the fundamentals of our existence. Human curiosity helped modern science develop in Europe with the realisation that scientific research should be based on careful and patient observation of nature, while continuously checking and rechecking the results of the observations and the consequences of the hypotheses. Nowadays, science is an important part of our cultural heritage.

Science is an on-going process. While progressing further, the ultimate bounds recede. Each new scientific exploration is another step into unknown territory. Each further step therefore has to pass beyond our previous aims and possibilities: our means have to be improved and our approaches novel, and our imagination must be more 'daring' than before. Scientific research demands superiority and forces us to go further than ever before.

This qualification applies even more strongly to space research, because of the exclusive character of this activity: a research group that wishes to launch an instrument aboard a spacecraft has to enter into severe competition with other groups and there can be only very few winners. As an example, ESA's Scientific Directorate recently requested the European scientific community to submit proposals for space missions to be flown in the period 1990–2000. Some sixty to seventy proposals were received from research groups throughout the Agency's Member States. However, the current scientific budget will allow some three to five missions at most during that decade.

It is understandable, with such competitive selection, that the quality of the few scientific space experiments that Europe is able to perform is high. It is worthy of mention that we will be the first community to send a dedicated mission to a comet. The Giotto spacecraft will meet comet Halley in 1986. Europe is presently also preparing another large scientific project, the Hipparcos mission, which will enable us to determine the positions of hundreds of thousands of stars with an accuracy a hundred to a

be or not to be, the willingness to cooperate between these seven tiny provinces was not very great – to put it mildly! Each province had its own navy, its own contribution to the army, and had to determine its own financial contribution to the common pool. How difficult it was to convince them of the need for closer unity! When looking back at the history of that struggle for independence, one cannot help thinking of the present state of European cooperation. But The Netherlands succeeded finally and arts and science bloomed in the united seven provinces as never before.

Let this be so too for Europe! Europe has great potential for scientific research and has indeed dominated in science during the last 500 years. This seems no longer to be the case and one must really ask why, since our combined Gross National Product is comparable to or even exceeds that of any other equivalent community on Earth. We have more people than the so-called 'superpowers' and we have *capable* people. There is no reason why Europe should not again be the most important cultural superpower – as it was in the past. We have an obligation, not only to our glorious past, but more importantly to the next generations. For all of these reasons, it is surprising that the budget of our scientific space programme, the national programmes included, is only one-fifth of that of the United States, while it is also smaller than that of the Soviet Union. Yet, we have done so well with so little money...

Looking back, then, at the last twenty years of European scientific cooperation in space, we may conclude that we have performed well, but we could do better. Maintaining the European cultural heritage is one of our prime obligations to the next generations. Give us the means and Europe will be lifted to the level it deserves!

thousand times better than before. This mission may allow us to discover planets near stars other than the Sun. Moreover, it will be a European spacecraft, the International Solar Polar Mission (ISPM), that will enter a so-far unpenetrated part of our solar system, crossing the poles of the heliosphere, in the coming years.

Extraordinary demands require extraordinary tools and the excessive requirements of space science have therefore contributed to industrial innovation, simply because scientific discovery demands means and methods that have never been used or tried before. A flourishing science programme is therefore a precondition for economic progress.

Clearly, this applies particularly strongly to space science because of the unusual requirements imposed by space and the absolute necessity of making the instruments function for years and years, either fully automatically or under remote ground control. The space programme therefore has implications that go far beyond the demands of science; it constitutes a technological challenge of unprecedented magnitude and is a major stimulant for technological progress in today's society.

On another front, space research has proved to be one of the means of contributing, albeit in a modest but definitely positive way, to European cooperation.

Looking back over the last twenty years, I think that it is fair to say that the nations united in the European Space Agency have succeeded, in a spirit of mutual agreement, in setting up a science programme modest in its extent but high in quality. This could only have been achieved through fair cooperation; a gratifying fact, particularly if we remember that in several other fields European cooperation is not yet proceeding as well as it should.

In that connection, I believe it is useful to look further backward, not over twenty years, but over four hundred. Today's celebration is being held in The Netherlands, a country that has some experience in setting up cooperation. Four hundred years ago it originated as a joint venture by seven small provinces which rose up against Spain, at that time the most powerful country in the World. It is curious, and amusing at the same time, – perhaps even horrifying – to note how, even under the severe conditions of that time of war, when the issue really was to

ESRO, adding Applications to Science

Prof. Sir Hermann Bondi, Chairman of the Natural Environment Research Council (NERC), UK

To understand the situation of 15 years ago or so and see how the few years that I was Director General of ESRO contributed to what Europe possesses now, it is first essential to look back before that period. In three and a half years, our predecessors, Prof. Pierre Auger, Freddie Lines as Technical Director, with his tremendous energy, and Reimar Lüst, so soon so happily to be back in European space activities, and Bert Bolin as Scientific Directors, had created an instrument of considerable power. This instrument was indeed the creation of scientists, the creation of people, many of whom were already experienced in European cooperation, through the example of CERN. For the purposes of science they had 'persuaded' – maybe the right word – the Member Countries to sign a Convention that had that essential condition of an advanced technical enterprise: a powerful, unified, centralised management. In modern technology, if a project gets into difficulties, it is rarely due to technical problems – it is generally due to management problems – and to tackle these problems in a unified manner, in a way that can deal directly and powerfully with these issues, in the industries of all our countries, requires such a management.

When my colleagues and I – and we were a new team – essentially Mr. Dinkespiler, Prof. Klein, Mr. Depasse and Mr. Montalenti, joined together, we built on superb foundations, foundations that had already brought three satellites to near fruition, through the enthusiasm for the ideals of science, for the ideals of technology, for the ideals of European cooperation, among all the staff who worked in ESRO.

Although our predecessors, but for a mishap with an American launcher, would have already enjoyed in 1967 having a satellite in orbit, it was only in 1968 that three ESRO satellites were placed in orbit by the Americans, and operated very well indeed. At the same time, the Organisation had its problems, problems partly political, but to quite some extent centred on a satellite project that was financially, and I suspect technically, bigger than we could handle. Again, with energetic negotiating, with technical mastery, with goodwill among all Member Countries, it was possible to get something splendid out of this: Europe's then biggest satellite, TD 1A.

This, then, was the situation in which we found ourselves – where ESRO, the scientists' creation, uniting the drive for European science and European technology, had shown what it could do; had shown it not only in the successes of three satellites, but in being able to resolve problems that at one stage looked virtually insuperable.

At that time the mood in Europe was beginning to change, from a universal adulation of pure science to an increasing interest in matters that were of wide social and economic benefit. Europe was becoming ready for the period when applications satellites would be of the greatest importance to its future.

That wind of change was unmistakable, and Europe's cultural unity is shown by the fact that this occurred in virtually all of our Member Countries practically simultaneously. There was then a choice as it were: a choice between broadening ESRO's task to include applications satellites as well as scientific ones, or letting Europe handle the applications side differently, in a different manner.

It was clear to me and my colleagues that this second route should be avoided. Having created one, well-functioning European organism with the requisite powers of management, with the technical capability, with the links with industry, and the degree of mutual understanding that had been fostered, it would have been most wasteful to attempt to recreate this, and possibly not feasible at all. On the other hand, there was a natural reluctance – an understandable reluctance – on the part of the scientists to let the instrument born of their experience, their understanding of how technology should be managed, to let this instrument take on a task that, as already could be foreseen, would before long outgrow in scale the purely scientific endeavour and perhaps drive it into a corner.

Neither option looked attractive: ESRO as a purely scientific back garden while everybody's interest was on a much wider park elsewhere, or ESRO as a unified organisation, looking after a large applications programme and a smaller science programme. One thing was quite clear: there was no way back to the mood of the early 1960s!

What followed, then, was a lengthy and at times difficult period of negotiation to achieve what clearly was the right solution: that ESRO's established capabilities should be in the service of European applications satellites as well as of European space science. First we had to convince the scientists, and through them their Governments, then we had to ask the Organisation to undertake tasks that were beyond what its original Convention stated – and that could only be done with good will and energy, and real interest on the part of everybody concerned.

We had a considerable number of anxious moments, and the problem was not finally resolved until well after I had left my post. But the foundations had by that time been truly laid: we knew what we were going to go in for, we knew how to do it, we were not neglecting science, and we laid the foundations of several of the satellites mentioned in the film. As well as that, we managed to exploit those satellites already in orbit.

By bringing together the disparate branches of science that use space as a platform, by bringing them together with the disparate fields of applications, by bringing all this together with the desire for European technological advancement, something had been achieved – an organism that is alive and well and something that Europe can be proud of today.

La création de l'ESA: une réalisation de la politique spatiale européenne

C. Hanin, Sénateur Honoraire, Belgique

Je voudrais d'abord dire en deux mots ma reconnaissance aux dirigeants de l'ESA de m'avoir invité à ce 20e anniversaire de la coopération européenne dans l'espace.

Rien ne pouvait m'être plus agréable. Dans la vie politique – comme dans la vie tout court – on a de temps en temps l'impression de servir à quelque chose. J'ai eu cette impression à l'issue de la conférence du 31 juillet 1973.

Que vous ayez bien voulu vous souvenir de cette date m'a réchauffé le coeur. Soyez-en remerciés.

Les leçons du passé
La date du 31 juillet 1973 ne peut d'ailleurs être considérée seule. Il faut la mettre en relation avec deux autres dates:
- celle du 20 décembre 1972, où, sous la présidence de mon prédécesseur, le Ministre d'Etat Théo Lefèvre, les orientations de principe avaient été prises;
- celle du 15 avril 1975 où, sous la présidence de mon successeur, Monsieur Geens, furent arrêtés les textes de la Convention créant l'ESA, signés à Paris le 30 mai 1975.

Mais je ne vais pas prendre votre temps à faire de l'histoire. Le passé n'a d'intérêt que dans la mesure où il éclaire le présent.

Que nous enseignent les 20 années d'efforts européens dans le domaine spatial? Tout d'abord, elles nous montrent les fruits amers de l'incohérence et du particularisme. De 1963 à 1973, l'Europe n'était pas restée inactive. Elle avait créé l'ESRO et l'ELDO. Mais, tandis que l'ESRO, se dotant d'une administration centrale forte, avait géré de façon efficace ses programmes de satellites, l'ELDO n'avait obtenu ni les moyens, ni l'autorité nécessaires pour coordonner le travail des différents pays. Tous les essais d'Europa-I furent des échecs et Europa-II fut abandonné. Les américains et les russes se partageaient la maîtrise de l'espace.

En contrepartie, nous voyons aujourd'hui les conséquences de la cohésion et de la volonté d'aboutir.

Les grands choix avaient été bien faits en 1972. Nous nous étions fixés des objectifs cohérents: un programme de satellites scientifiques, une volonté d'utiliser pratiquement l'espace, notamment dans le domaine de la météorologie et des télécommunications. Un lanceur, enfin, sans lequel, nous l'avions bien vu, nous serions ligotés dans nos réalisations pratiques. A cela s'ajoutait l'invitation des américains à participer au programme Post-Apollo.

Mais en juillet 1973, rien n'était acquis. Aucun des programmes n'avait obtenu les moyens nécessaires à sa réalisation. Certains estimaient inutile de construire un lanceur puisqu'on pouvait disposer de lanceurs américains. Plusieurs délégations se déclaraient incapables de prendre une décision à ce moment.

Il a fallu, pour réussir, que certains pays, des grands et des moins grands, veuillent obstinément aboutir pour qu'enfin la décision fût obtenue.

Les fruits de ces efforts, nous les goûtons aujourd'hui. Ce que nous avions conçu il y a onze ans, nous l'avons réalisé:
- Nous avons un lanceur, Ariane, parfaitement performant et qui, auprès des pays tiers, entre en concurrence avec les lanceurs américains.
- Notre Laboratoire spatial a été placé sur la Navette américaine.
- Nos satellites scientifiques et d'application ont rempli et remplissent leur rôle.
- La capacité technologique de l'Europe a été démontrée.

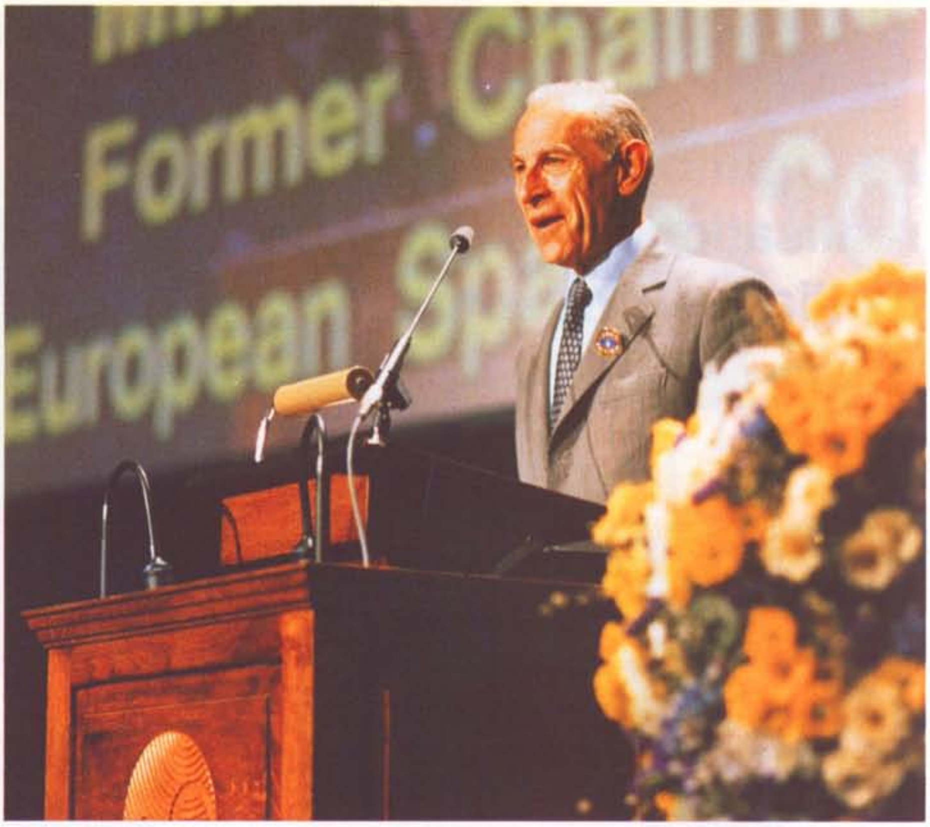
Les industries de tous les pays participants ont été capables de prendre leur part de cet effort, ce qui a maintenu, entre les pays, l'indispensable climat de coopération.

Tout cela s'est fait sous l'égide de l'Agence Spatiale Européenne, qui nous reçoit aujourd'hui.

Puis-je tirer une dernière leçon?

C'est celle de la nécessité de la collaboration de tous les pays, grands et petits. Malgré la part prépondérante que certains grands pays prennent dans la réalisation de programmes importants, la part de ce qu'on appelle les petits pays est de plus de 15% de l'ensemble. En 1973, sans ces 15 ou 16%, on n'aurait pas abouti.

Et maintenant . . . ?
Tout d'abord, sauvegarder l'acquis, et l'acquis, ce n'est pas d'abord Ariane, le Laboratoire spatial et les satellites.



L'acquis, c'est la collaboration dans le cadre de l'Agence Spatiale Européenne.

Le danger subsiste toujours de voir renaître la vieille tentation nationale ou, pire, la tentation de la collaboration bilatérale. Bien sûr, l'Agence ne peut pas et ne doit pas tout faire. Certains programmes particuliers sont à la dimension d'un Etat. D'autre part, le moment est venu où les firmes privées peuvent prendre des initiatives. Mais il est indispensable de bien délimiter le domaine de chacun, et de donner la préférence à l'Agence pour tout ce qui dépasse la dimension d'un Etat.

Cela n'est possible que si nous déterminons de nouveaux objectifs.

Pendant 10 ans, nous avons vécu des décisions des conférences de 1972 et 1973. Ces décisions sont exécutées; nous devons aller au-delà. Quels sont ces nouveaux objectifs? Il ne m'appartient pas de les définir mais peut-être puis-je risquer à leur sujet l'une ou l'autre réflexion:

- Que ferons-nous en matière de lanceurs? Certes, nous avons Ariane. Mais la mise en service de la Navette américaine soulève, à moyenne échéance, le coût de l'utilisation de lanceurs qui sont entièrement perdus après un seul service.
- Quel est notre programme en matière scientifique? Certes, nous participons aux recherches scientifiques dans l'espace. Mais lorsqu'on voit la variété des expériences européennes dans le premier vol du Spacelab, on a l'impression – peut-être erronnée – qu'elles sont choisies au gré des orientations de certains chercheurs spécialisés plutôt qu'en fonction de programmes globaux concentrant les efforts vers un objectif déterminé. Sans doute n'est-ce pas à l'Agence à faire ce choix, mais les nouvelles décisions de collaboration européenne en matière de recherche pourraient faciliter les décisions adéquates.
- C'est dans le domaine des satellites d'application que le principal effort me paraît devoir être fait. Le moment de l'utilisation concrète de l'espace est venu. A vrai dire, il a déjà commencé. Télécommunications, météorologie, pilotage des navires et des avions, télédétection: nous n'avons eu, jusqu'à présent, qu'une part réduite, découlant de nos retards techniques.

De nouveaux objectifs
Nous devons, dès à présent, examiner à la lumière des éléments scientifiques, techniques, commerciaux et financiers, la part que l'Europe peut et doit prendre dans l'exploitation de l'espace. Il appartient à l'Agence Spatiale Européenne de déterminer, sur la base de ces études, les réalisations techniques à mettre en oeuvre dans un programme de 10 ans.

En le faisant, elle ne devra pas négliger un élément important du succès de ces dix dernières années: la possibilité pour chaque partenaire de l'Agence – les plus importants mais aussi les plus petits – de coopérer aux volets du programme pour lesquels il se sent le plus motivé; seul le respect de cette règle a maintenu l'esprit de coopération sans lequel rien n'est possible.

Il est temps de renouveler notre pensée.

Nous n'avons été unis pendant 10 ans, l'Agence Spatiale Européenne n'a été forte, que parce que nous savions ce que nous voulions faire ensemble. L'enseignement le plus clair de ces dix années, c'est que nous avons besoin de nouveaux objectifs:
- à l'Agence Spatiale Européenne de les préparer et de les proposer
- à la Conférence des Ministres, qu'il faut réunir sans tarder, de prendre la décision.

Ce que nous avons pu faire en 1972 et 1973, alors que nous semblions avoir pris un retard irrémédiable, je ne vois pas pourquoi nous ne pourrions pas le réaliser en 1984.

Gala Dinner

ESA and Europe's Future in Space

E. Quistgaard, Director General, ESA

Until 1957 the World, for all mankind, was just the surface of our planet, plus or minus 10–20 km. The human race developed its civilisation and its diverse cultures within this thin shell. The thinking man, homo sapiens, had tried for a long time to understand and describe, with theories and observations, what is outside our 'shell', and also to guess at what might be gained by escaping from this shell into the new dimension that we now call 'space'.

In 1957, the first man-made satellite proved that it was possible to reach into space, and since then immense developments have proved beyond doubt that space does hold new frontiers for mankind.

In the early 1960s, a handful of Europeans with great foresight studied how and where we, in our part of the World, could participate in the exploitation of space, and what the scientific, technical, commercial and political benefits would be. This led to the start of European space activities, which began 20 years ago.

From a slow but exciting start through ESRO and ELDO, Europe's space programmes gained momentum in the early 1970s. The political will, guided by the European Space Agency, and industry's capabilities, have together led to achievements that have proved remarkable in their success. The real harvest has come during the last 12 months, punctuated by the following milestones in European space activities:

- The scientific satellite Exosat was launched on 25 May 1983.
- ECS-1, the first European operational telecommunications satellite, was launched by Ariane on 19 June 1983.
- Later in 1983, ECS-1 was turned over to Eutelsat, the European organisation for the operation of regional telecommunications satellites.
- A Convention was signed on 24 May 1983 for the setting-up of an International Organisation, Eumetsat, guaranteeing continuous Meteosat-based services for the next 10 years.
- On 12 October 1983 Ariane launched its first commercial payload, Intelsat-V.
- On 28 November 1983, the European Spacelab was launched aboard the Space Shuttle; Ulf Merbold, the first ESA astronaut, was on board this outstanding mission.
- On 4 March 1984, Ariane successfully placed the next Intelsat satellite into geostationary transfer orbit; this was the last launch of the ESA Ariane promotion series. The European commercial launch company, Arianespace, will have responsibility only a few days from now for launching a private American telecommunications satellite on Ariane.

These events demonstrate that our twenty years of space development have now matured into a commercial reality.

Politically over the last 20 years Europe has demonstrated that cooperation in space is not only an effective way, but is in fact the only way for our Continent to remain in the space race. We have cooperated with the USA and we have achieved independence in the space-transportation field with our Ariane vehicle.

In the scientific field, the European scientific community remains in the forefront of space research, and technically we have mastered the most advanced technologies. By meeting the challenging requirements of space, engineering methods and tools have been developed for managing very large, complex undertakings.

As a Continent, we must forget our national boundaries, thereby ensuring increased efficiency and fostering the chances of success within a wider industrial market.

Economically, Europe must promote the use of space technologies for several applications programmes, such as telecommunications, meteorology, remote sensing, etc. for benefits in terms of wealth and well-being, in Europe as well as elsewhere.

The European nations have demonstrated not only their ability to deliver first-class space products, but also their capacity for cooperating together in an efficient and cost-effective manner. Had this been a failure, it would no doubt have had a negative effect on other European cooperative ventures.

These European achievements have put us on a par with the World's foremost space powers.

The proof lies in the fact that the European technological community has demonstrated its scientific and technical competence by entering into, and providing hardware for, worldwide organisations who use operational space systems (e.g. Intelsat and Inmarsat), but it has also set up its own, regional organisations using European-developed satellite systems (e.g. Eutelsat and Eumetsat). Had we failed in these fields, European users would have been excluded from the benefits of space techniques, forcing us to buy from elsewhere the hardware and the services that we ourselves can now develop.

European industry has shown that it is capable of restructuring itself and creating industrial consortia capable of undertaking large and costly technological ventures in space and other domains. New employment, so important for the future, has been created in areas of high technology.

In a World in which economic progress is dominated by communications, the European economy as a whole is now ready to reap – through regional or national telecommunications systems that already exist or will be set up in the near future (e.g. Eutelsat, and national systems in the United Kingdom, France, Germany, Italy and Sweden) – the benefits that will accrue from the introduction of new and flexible communications services.

European industry has proved itself capable of building its own launchers, and Ariane is now a commercial success. Further proof of this success is given by the fact that we have recently received a firm order for one Ariane-4 launch for the Intelsat-VI Programme, which also wishes to have an option for an additional Ariane-4 launch.

European industry has proved itself capable of building Spacelab, thereby gaining an entry into manned space operations. We have also built a second Spacelab and sold it to NASA.

Looking at all of this and looking back at the efforts that we have made, we can be justifiably proud of our results so far. We know that the future needs of science and technology will not be met by sitting back and being satisfied with the results obtained so far; further efforts must be made. When we look around us at the World's industrial and economic structure, we see that new World powers are emerging today to occupy the industrial and technological ground that we once considered our prerogative.

The newcomers in these areas are often stronger than we are. We have to try to concentrate on fields in which we can best benefit from our scientific and technical potential, with its roots deep in our cultural traditions. Modern technology is a typical example of such a field, and we are fortunate in Europe in having the academic and educational infrastructure to support advanced research and development.

When talking to people working on space programmes you may have noticed the frequent occurrence of the word 'users' – a word hardly ever heard in space circles until the early 1970s. Up until then, space was a fascinating new technology in which engineers were proud of sending hardware where no manmade objects had ever gone before. This in itself was reaching a goal, meeting a challenge. The user scientists discovered immediately that things could be done, and measurements made 'in situ' of phenomena not accessible to measurement on Earth. The next step in space exploitation was the use of orbital satellites for telecommunications and meteorology. Experimental/preoperational spacecraft were designed, built and flown by ESA, including Meteosat for the meteorology users and the Orbital Test Satellite (OTS) for the telecommunications users.

The time had come to get the so-called 'users' organised, through such bodies as the PTT Authorities and the European Meteorological Services, into European user organisations able to reap the fruits of all the previous developments.

Space technology has become a field that is no longer a technologists' playground, but a field that has developed for the users.

The question now is: What will happen in space in the future? Future space systems must be designed to be 'useful'; that is to say adapted to the needs of the users. This will become increasingly difficult, and we realise that.

The 'obvious users' – the telecommunications operators and the meteorologists – were already at hand. The future users, such as remote-sensing and microgravity/material-sciences specialists, are now coming on the scene. They will have to learn their trade in using space and develop methods using experimental space programmes. In the future, and in contrast to the earlier users, new users will appear and perfect their activities as a result of the new means that space has put at their disposal.

This makes the planning of space programmes very complicated. We have a loop in which the end result will most certainly be affected by the initial assumptions we are bound to make.

This is no new situation in research and development. It so happens that we celebrate this 20th anniversary of European space cooperation at a time when some fundamental decisions have to be taken about the future of space programmes in Europe. These decisions are imminent and unavoidable. The need for making them now stems from some recent events, which I will try to outline.

The USA has decided to build a manned Space Station and has invited Europe, along with others, to participate in this programme. At the same time Germany and Italy have taken the initiative in studying a European manned flight programme, baptised 'Columbus', and offered this project for Europeanisation.

These two initiatives relevant to the future of space policy as a whole have led to unease about the objectives and constituents of a coherent Long-Term European Space Programme which we are at present trying to define.

These are not the only initiatives relevant to the future of European space activities. Even prior to these events, France offered the Agency the possibility of Europeanising a Large Cryogenic Engine, which will be an essential part of a new European launcher. We hope to decide on this launcher in 1985, but here, once again, its characteristics must obviously depend on the objectives of a European Space Policy and Europe's attitude vis-à-vis a Space Station.

Space programmes have so far been designed to deliver scientific, technological and economic benefits. The so-called 'space infrastructure', which is composed of satellites for science, telecommunications, remote sensing, microgravity, etc., is constituted by the systems that allow us to obtain benefits and results only achievable by having hardware present in space. To reach this environment we have the space-transportation systems exemplified by the Ariane launcher and the American Space Shuttle. The Shuttle has again, with Spacelab, become a hybrid system, coming within both the space-transportation and space-infrastructure categories. It is mandatory for the future of European space activities that we – despite our funding limitations – maintain a presence with both a space infrastructure and space-transportation systems and that a balance in the funding requirements be obtained for the two systems. The permanent presence of man in an orbiting Space Station represents the next logical step for manned spaceflight after the Shuttle.

A Space-Station programme and a large European launcher would put a heavy burden on the funds presently available for space activities in Europe. It is also for this reason that, from the outset, a substantial utilisation programme for the new activities, when they become available, must be planned and its funding must be provided for. All European Member States must soon get together and decide on their mutual objectives and priorities, in order for ESA to be able to draw up a coherent programme, taking into account priorities, objectives and desires. This is a matter of urgency.

Once again we come back to our dilemmas: space-transportation systems and orbital systems will soon be developed to serve for a period of 20 to 30 years, maybe even 50. Our problem is: How can we foresee today, with any confidence, the needs of future 'users' of these systems, and how and for what purposes they will be used?

For the moment all we can be sure of is:
- The future will not be exactly as we imagine it today.
- The early users, in telecommunications and in meteorology, will remain 'in business'; these are two areas that will always be of interest. But they will go on competing with other means arising from new technologies that are being developed at the moment.
- There will certainly be new users in all fields of Earth observation, such as remote sensing, oceanography, solid-Earth studies, climatology and long-term weather forecasting.

There will also be new users in the fields of microgravity applied to material sciences for the development, and perhaps even mass production of, exotic materials which can only be manufactured outside the sphere of influence of the Earth's gravitational field.

Last but not least, I must mention one thing that we have witnessed over the last decades, and that is literally an explosion in the space sciences.

Not only have we come closer to understanding the mysteries of the Earth's immediate environment and the Sun/Earth relationship, but also astronomy and the endless Universe, and its population of stellar objects, keep teaching us more and more fundamental points about matter and energy, which together are the constituents of the whole Universe, including mankind itself.

Space is complicated; it costs money to develop space products; it takes some of the best brains, a highly developed industry, and above all, the political will to continue this long-term development. Over the last 20 years, European space research has achieved spectacular results, thanks largely to all our devoted people in the Agency, in the national agencies, in industry and in the political forums of our Member States. Also the vision of our founding fathers should not be forgotten. We who today witness with honour and pride the results of 20 years of effort must be truly thankful to and cannot but greatly admire all the people who made the European space endeavours possible.

We succeeded in going outside our sphere for the first time only 27 years ago; with accelerated pace, we have since experienced an indispensable evolution in science and technology. We can not and will not stop here; our future requires that we continue diligently together.

The European space effort is an outstanding demonstration of what we can do on the old Continent when united; let it be an example for European unity in a broad sense and the base on which we can design a new, fruitful and successful European space programme for the next 20 years.

Staff party

Social activities


esa 20 JAAR 1964-1984 estec

Twentieth Anniversary of the ESA/NASA Scientific and Technical Information Exchange Agreement

M.F. Saksida & I. Mader, ESA Information Retrieval Service, Frascati, Italy

The exchange of scientific and technical information between NASA and ESA, foreseen in the early sixties during the work of the European Preparatory Commission for Space Research, has fully matured. The development of European space programmes has been accompanied by the establishment of an advanced European aerospace information system, which is now a valuable European resource, covering many millions of scientific and technical publications issued during the last two decades. The system's use is not limited to the classical aerospace field and it is of wider relevance to many high-technology areas and aerospace applications.

Introduction

One of the more visible recent manifestations of cooperation between the European Space Agency and the United States National Aeronautics and Space Administration (NASA) has been the Space-Shuttle-borne flight of the European-built Spacelab last autumn. The foundations for the extremely high level of collaboration involved in the complex Spacelab project were laid as mutual confidence was steadily established between the two space organisations through a series of earlier, smaller cooperative spacecraft projects. These began with NASA's launch of ESRO's International Radiation Investigation Satellite (IRIS) in 1968.

For the last twenty years there has been, however, another perhaps less visible but no less vital area of collaboration between NASA and ESRO/ESA: in the domain of 'Scientific and Technical Information (STI)'. Preparations for this collaboration were initiated even before the formal creation of ESRO, during the work of COPERS, the European Preparatory Commission for Space Research. The degree, scope and technical complexity of the joint venture have grown steadily with the passing years.

The NASA/ESA STI Exchange Agreement

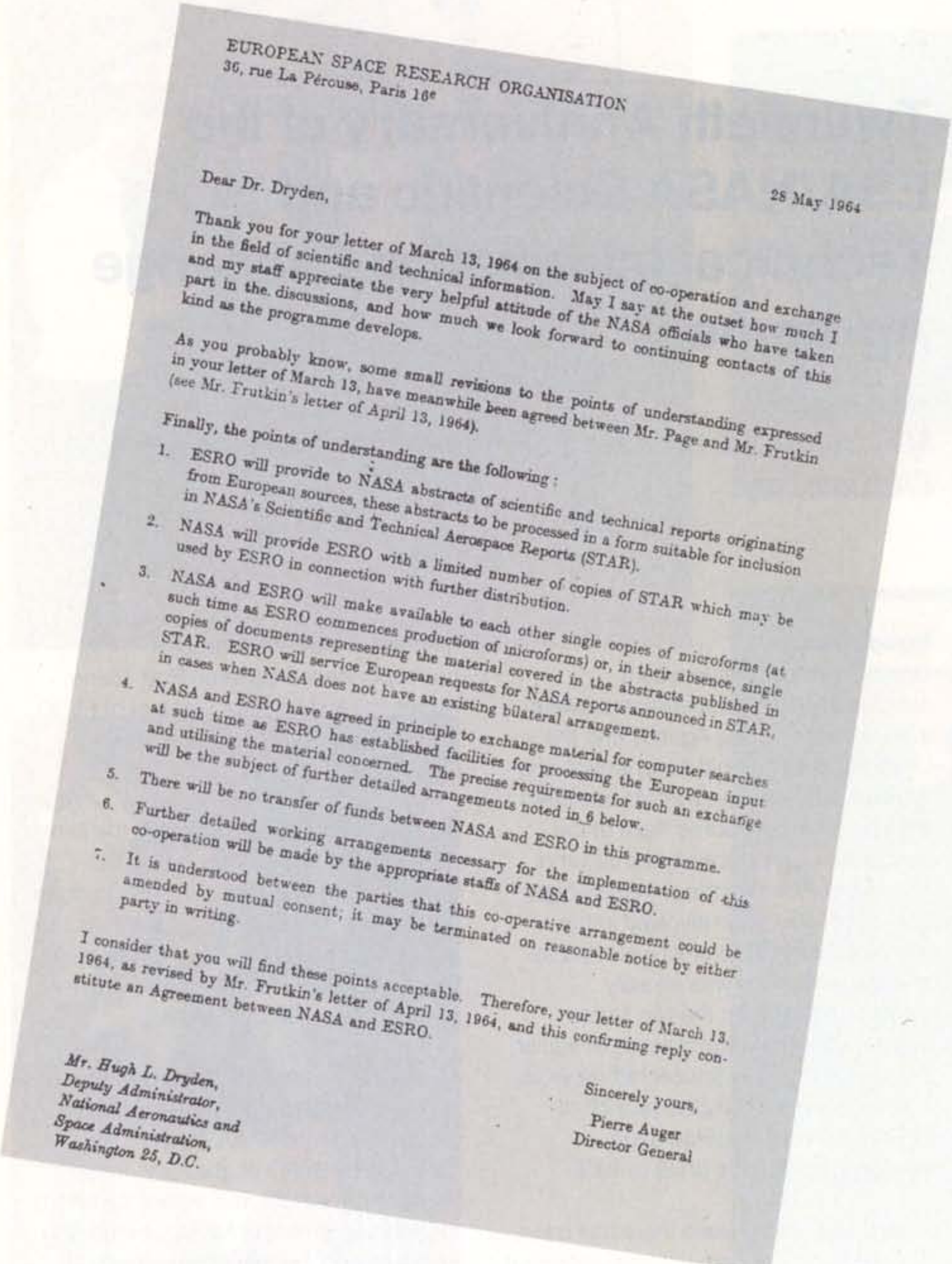
Following a preliminary exchange of letters between Mr. J.R.U. Page (ESRO Assistant Director for Scientific and Technical Information) and Mr. W. Frutkin (NASA Assistant Administrator for International Programs), the original Agreement between NASA and ESRO was reached in May 1964 through correspondence between Prof. Pierre Auger, the first Director General of ESRO, and Dr. Hugh L. Dryden, the NASA Deputy Administrator.

Building on these relationships, the joint ESRO/ELDO Space Documentation Service (SDS) was set up in 1965 to cover both space research and space technology and serve not only the staff of the two European space organisations, but also their Member States.

The NASA Information System was by this time well-established and the initial STI cooperation with NASA involved the provision by ESRO of abstracts from European scientific and technical reports for announcement in NASA's bi-monthly Scientific and Technical Aerospace Reports (STAR) Abstract Journal. In return, NASA provided copies of STAR to ESRO, and the two bodies exchanged both microforms and hard-copy versions of documents announced in STAR. The Space Documentation Service began to provide a reproduction service based on a microfiche holding in Paris of the majority of the NASA STAR reports.

The Agreement had also foreseen an exchange of information in machine-readable form for computer searching and a pilot operation was initiated by SDS for questions prepared by SDS staff in Paris, with batch searching of the NASA tapes in Washington using Selective Dissemination of Information (SDI) profiles provided by SDS staff.

Following this initial phase, in order to



EUROPEAN SPACE RESEARCH ORGANISATION
36, rue La Pérouse, Paris 16e

Dear Dr. Dryden, 28 May 1964

Thank you for your letter of March 13, 1964 on the subject of co-operation and exchange in the field of scientific and technical information. May I say at the outset how much I and my staff appreciate the very helpful attitude of the NASA officials who have taken part in the discussions, and how much we look forward to continuing contacts of this kind as the programme develops.

As you probably know, some small revisions to the points of understanding expressed in your letter of March 13, have meanwhile been agreed between Mr. Page and Mr. Frutkin (see Mr. Frutkin's letter of April 13, 1964).

Finally, the points of understanding are the following :

1. ESRO will provide to NASA abstracts of scientific and technical reports originating from European sources, these abstracts to be processed in a form suitable for inclusion in NASA's Scientific and Technical Aerospace Reports (STAR).
2. NASA will provide ESRO with a limited number of copies of STAR which may be used by ESRO in connection with further distribution.
3. NASA and ESRO will make available to each other single copies of microforms (at such time as ESRO commences production of microforms) or, in their absence, single copies of documents representing the material covered in the abstracts published in STAR. ESRO will service European requests for NASA reports announced in STAR, in cases when NASA does not have an existing bilateral arrangement.
4. NASA and ESRO have agreed in principle to exchange material for computer searches at such time as ESRO has established facilities for processing the European input and utilising the material concerned. The precise requirements for such an exchange will be the subject of further detailed arrangements noted in 6 below.
5. There will be no transfer of funds between NASA and ESRO in this programme.
6. Further detailed working arrangements necessary for the implementation of this co-operation will be made by the appropriate staffs of NASA and ESRO.
7. It is understood between the parties that this co-operative arrangement could be amended by mutual consent; it may be terminated on reasonable notice by either party in writing.

I consider that you will find these points acceptable. Therefore, your letter of March 13, 1964, as revised by Mr. Frutkin's letter of April 13, 1964, and this confirming reply constitute an Agreement between NASA and ESRO.

Mr. Hugh L. Dryden,
Deputy Administrator,
National Aeronautics and
Space Administration,
Washington 25, D.C.

Sincerely yours,

Pierre Auger
Director General

Figure 1 — The letter of 28 May 1964 from Prof. Pierre Auger to Dr. Hugh Dryden confirming the information-exchange Agreement between ESRO and NASA

provide a bibliographic retrieval capability in Europe from the computer tapes that NASA regularly sent to SDS as part of the Information Exchange Agreement, and incorporating material submitted by ESRO itself, the Organisation introduced an advanced online interactive searching system at ESOC in Darmstadt very similar to that used by NASA, known as NASA-RECON (the latter implying remote consoles). By analogy, the European system was called ESRO-RECON. Remote terminals were installed at ESRO's Headquarters in Paris, at ESTEC in Noordwijk and at some Member States' national documentation centres.

In 1972, after some eight years of consolidation, the first major revision of the NASA/ESRO Agreement took place. It was agreed to make the NASA STAR and IAA (International Aerospace Abstracts, published by AIAA) database – maintained by SDS – available online to suitably qualified organisations in the ESRO Member States.

In effect, the Agreement was recognising the technical advances that had taken place in the STI field, which meant that the entire aerospace database, covering the World literature in this sector, could now be instantly available on the desk of any space scientist or engineer via a low-cost data-communication terminal connected by public telephone network to the remote computer.

The concept of a tripartite scheme then emerged, with the requirement that users having access to the NASA STAR/IAA database provide technical reports within the scope of the NASA STI system in lieu of royalties on a 'best-effort basis'.

As part of its European contribution, ESRO/SDS now undertook to process (cataloguing, indexing, abstracting, microfiching and preparation of magnetic tapes in accordance with the procedures and standards used by NASA) documents submitted by organisations having an agreement with NASA and which had previously been sent directly to the latter.

ESRO also agreed to provide English translations of certain technical reports' series issued by specific German and French sources. These requirements were incorporated as 'a further amplification and extension of the existing Agreement', following an exchange of letters between Dr. A. Hocker, then Director General of ESRO, and Mr. Arnold W. Frutkin, NASA Assistant Administrator for International Affairs.

The ESRO Space Documentation Service was relocated to the ESRIN establishment in Frascati, Italy, in 1973, the same year that the decision was taken to merge the activities of ELDO and ESRO. NASA extended the STI Agreement to the new European Space Agency, formed in 1975, which thus assumed the responsibilities previously shared by ESRO and ELDO.

After the demise of ELDO, a special documentation group including ex-ELDO engineers was set up in 1974 under the supervision of ESRO-SDS to process some 15 000 technical documents generated during the ELDO programmes. The group was given instruction in NASA descriptive cataloguing, abstracting and indexing. Some 1600 documents were selected for their scientific and technological value (3500 other documents were microfiched and archived at ESA HQ). An arrangement was made with NASA for the final computer processing of the 1600

Figure 2 — The signatories of the exchange of letters constituting the Agreement between ESRO and NASA concerning the exchange of scientific and technical information: Left — Prof. Pierre Auger; Right — Dr. Hugh Latimer Dryden

documents, which were announced in NASA's abstract journal, L-STAR. The tapes prepared by NASA for photo-composition were augmented with ELDO references previously announced in STAR and used to produce an index of ELDO publications, and to enrich the NASA STAR/IAA database operated by ESRO/SDS in Frascati and NASA's own database.

In 1978, the Space Documentation Service (SDS) was renamed the Information Retrieval Service (IRS) of the European Space Agency.

Conclusions
It is widely recognised today that every successful human venture is heavily dependent on the availability of the right information at the right time. Where that venture calls for technology at and beyond the existing frontiers of scientific knowledge, as with developments in space research and exploration, this is even more true.

Thanks to the STI Exchange Agreement, some 100 000 scientific and technical documents of European origin, instead of lying unnoticed on the shelves of libraries, universities, institutions or industrial operations, have been made known worldwide and retrieved online a truly incalculable number of times. They have been building blocks on which many a technical improvement or step forward in research has been based, sometimes in areas unrelated to the original work.

The STI Exchange Agreement also enables us to measure the dynamism of the European scientific and technical research effort. The European contribution to the NASA STAR/IAA database currently represents some 7% of the total of 1 300 000 references that it contains. The importance of the European contribution is also reflected in the fact that in-depth studies contained in about 1000 reports have been translated cover to cover into English prior to their incorporation into the NASA Information System.

ESA/IRS has developed in many areas to meet specific ESA and European requirements, but its role still continues to incorporate this long-standing basic collaboration with NASA. As the European capabilities in the area of scientific and technical information have fully matured, the ESA/NASA relationship has grown even closer, to reflect the evolving interest of the parties involved and ensure that this cooperation remains effective and of mutual interest, in the service of the worldwide scientific and technical aerospace community.

Development of Spacecraft Operations at ESOC – Fifteen Years in Retrospect

D.E.B. Wilkins, Spacecraft Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany

The European Space Operations Centre (ESOC) in Darmstadt has been responsible for operating the Agency's satellite missions since 1968. In the more than fifteen years since the establishment of ESOC, the role of the Centre has continued to develop as the Agency's programmes have expanded. As ESOC itself has expanded, so has the complexity and sophistication of the ground-control systems used to carry out its primary function as ESA's mission-control centre.

The evolution of the operating systems

1967–1969

When the first ESRO satellite was ready for launch in May 1967, the operating systems needed for mission control were of a very basic design. The tracking station at Redu in Belgium and the Control Centre at ESTEC in Noordwijk constituted the complete ground segment. In the event, ESRO-II was destroyed when the NASA Scout launcher failed shortly after lift-off from Vandenburg Air Force Base in California, on 29 May 1967.

During the preceding two years, much work had been done by ESRO in defining a tracking-station network, designing the station electronics systems and negotiating agreements allowing the installation of these facilities at various remote locations. In the year following the ESRO-II launcher failure, two significant events took place which contributed to the development of the Organisation's control system:

- First, the European Space Tracking Network of stations – 'Estrack' – was installed and commissioned, with stations at Redu (Belgium), Fairbanks (Alaska) and Spitzbergen (Norway) and in the Falkland Islands.
- Secondly, the decision was taken to establish the European Space Operations Centre in Darmstadt, approximately 30 km south of Frankfurt. ESOC was formed by consolidating the European Space Data Centre, already in Darmstadt, with the Control Centre Division which had previously been at ESTEC. This decision meant that all Control Centre equipment then at ESTEC had to be transported and re-integrated in Darmstadt and the associated staff relocated.

By 17 May 1968, the date of the launch of ESRO-IIB, both ESOC and the Estrack stations were fully operational and the satellite was fully supported by the Centre until it re-entered the Earth's atmosphere in May 1971. Planned originally for a six-month mission, ESRO-IIB was eventually operated for three years.

During the remainder of 1968, two further missions were successfully supported from ESOC:

- ESRO-IA launched on 3 October 1968, on a Scout vehicle, and
- Heos-1 launched on 5 December 1968, on a Thor-Delta vehicle.

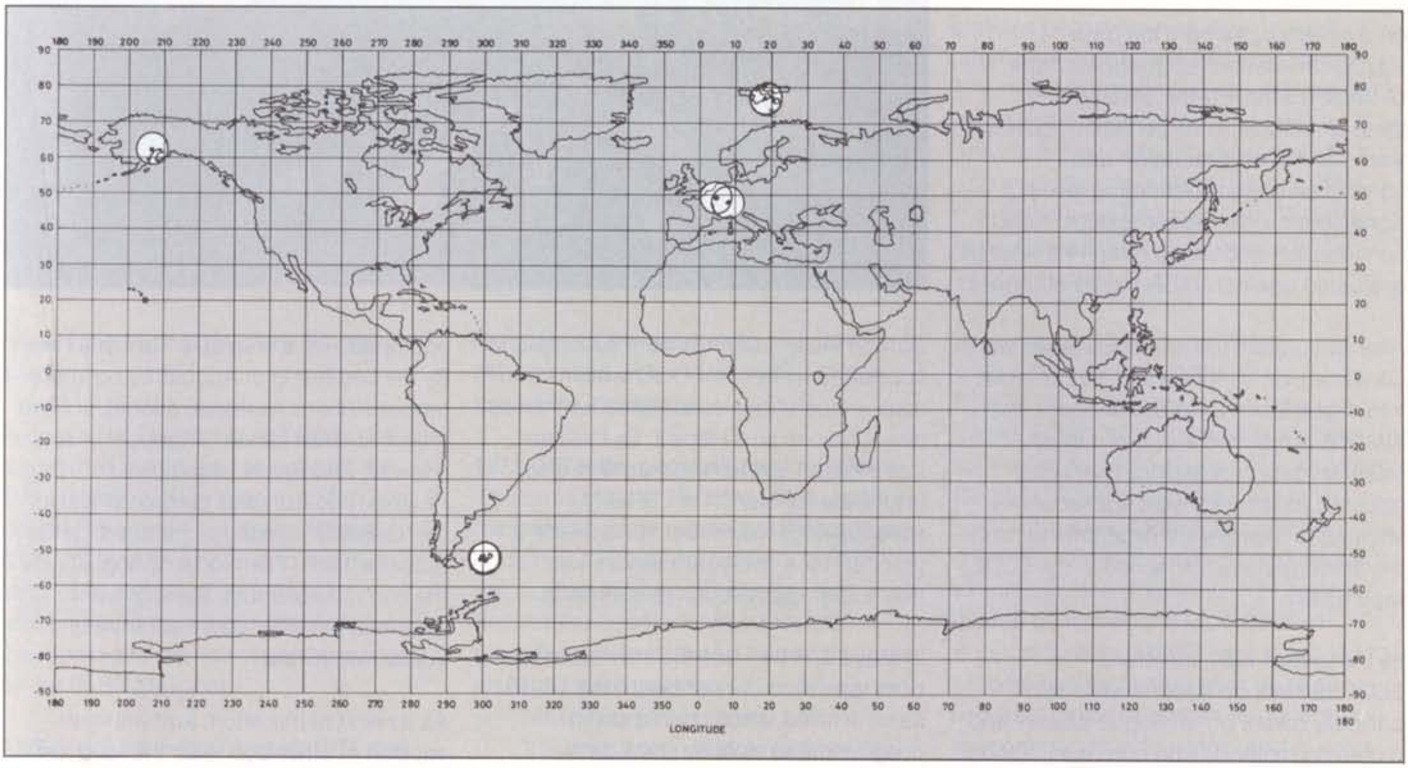
By the beginning of October 1969, when a further successful Scout launch placed ESRO-IB into orbit, ESRO had four scientific satellites in orbit.

Data acquisition and control systems

At the end of 1969 the Estrack network consisted of four stations and a Control Centre (Fig. 1). The geographical locations of the stations were dictated by the planned orbits for the satellites, which were all polar-orbiting missions. Heos-1 was in a highly elliptical orbit, and the remaining three in near-Earth, circular orbits.

The network stations were controlled by telex schedules and messages issued by the ESOC Control Centre via a dedicated

Figure 1 — The Estrack network of stations in 1969



telex network. Control of the orbiting spacecraft also relied to a large extent on telex schedules for telecommand operations and telex messages for quick-look telemetry readouts. No real-time command capability existed at that time and most important telecommand operations were carried out by Redu station staff under voice control from ESOC. Real-time telemetry (PCM/NRZL) data were transmitted from Redu to Darmstadt (at up to 1280 bit/s) via the voice circuit on a scheduled basis (voice/data). Real-time telemetry data could also be received from Spitzbergen, via high-frequency radio circuits and from NASA's NASCOM network via their switching centre in London. The Norwegian station at Tromsø provided data for certain periods and was used extensively for later missions.

The tracking data needed for satellite orbit determination were transmitted from the tracking stations as telex messages derived from the three electronic tracking systems of the Estrack network:

- the interferometer tracking system at Redu
- the tone-range systems at Redu and Fairbanks
- the angular telemetry tracking data from all stations.

The Estrack network operated entirely in the VHF band, with telemetry and tracking at 136–138 MHz and telecommanding at 148–156 MHz.

Network communications relied to a large extent on telex traffic with voice and data circuits confined to Redu and to the NASA/NASCOM stations used during launch operations. High-frequency radio circuits from Spitzbergen were used for voice and data communication (via SKI radio near Oslo) when propagation conditions permitted. Data circuits were used successfully between Darmstadt and the Norwegian station at Tromsø during this period.

The ESOC Control Centre (Fig. 2) carried out the major tasks of spacecraft control, network control, orbit determination and communications, with a minimum of computer assistance in those days. The IBM 360–65 computer then installed at ESOC was mainly devoted to scientific data processing, although the orbit-determination work was performed on this machine.

Spacecraft control data were derived from printouts of Redu real-time data processed by the IBM 360, from telex quick-look messages transmitted from the Estrack stations, and from voice reports given by Redu and Spitzbergen. The use of binary/decimal PCM displays and binary lamps was common practice for monitoring telemetry parameters, both at the tracking stations and at ESOC (when data was available). It was not until early 1970 that telemetry displays were available for the presentation of decommutated telemetry data, in engineering units, to the spacecraft controllers.

Scientific data were airfreighted to ESOC

Figure 2 — ESOC's Operations Control Centre in 1969

on a weekly basis from the data-acquisition stations on magnetic tape (7-track, 0.5-inch). After cataloguing, these analogue instrumentation tapes were fed into an evaluation and conversion system. Recording levels, signal levels, noise levels, telecommand confirmation and timing reference were all evaluated against NASA-based standards.

After evaluation, the analogue tapes were converted, on a Honeywell 116 computer, into digital tapes for presentation to the IBM 360 computers and preliminary scientific data processing. The digital scientific data tapes were subsequently shipped to the relevant experimenter and the analogue tape remained in the ESOC tape library.

By the end of 1969, therefore, ESOC/Estrack operations were still basically reliant on analogue display and recording methods and communications still relied heavily on telex circuits for data and control purposes.

1970–1975

The year 1970 was marked at ESOC by the beginning in February of construction of a new, purpose-built Operations Control Centre (OCC). This project, completed in March 1971, was to provide ESRO with a dedicated control facility capable of processing three simultaneous telemetry data streams and displaying the data to several spacecraft control positions. The completion date for the OCC, including all electronics systems, was July 1971, based on the planned December 1971 launch date for the Heos-A2 spacecraft (Fig. 3).

The new OCC operational system was the subject of an intensive test programme during July and August 1971, covering all the major subsystems.

The entire system was accepted in the course of September and preparations began for the simulations leading up to the launch of Heos-A2, by then to be in January, and TD-1A in March 1972.

Both of these launches were successfully supported by the new OCC systems and routine operations established for the two new missions plus Heos-1. By this time training and software testing was also underway for launch of ESRO-IV, scheduled for November 1972. (Heos-2, planned for a two-year mission, was eventually operated for seven years).

In May 1972, two months after launch, both tape recorders onboard the TD-1A satellite failed, resulting in a crash programme to establish new data-acquisition stations in order to salvage as much data as possible in real time.

As soon as the emergency arose, ESOC requested emergency data-recovery support. Immediate support was received from the NASA stations at Quito, Santiago, Rosman (USA) and Ororal (Australia). Assistance from the CNES stations at Kourou, Pretoria and the Canary Islands followed, and a few days later from its stations at Brazzaville and Quagadougou also. The inclusion of these emergency stations increased the 'real-time only' coverage to around 30% of the total data. With NASA's help it was possible to increase the coverage further to about 40% by including the stations at Carnarvon, Guam, Ascension Island, Western Test Range and the Seychelles. To these were later added the Japanese station at Kashima and the French Antarctic station at Terre Adelie.

With hardware acquired from many sources, ESOC managed to assemble six additional transportable ground stations. Receivers and tape recorders were integrated into special containers equipped with a steerable Yagi antenna. By the beginning of August, five of these mobile stations were operational, at Suva (Fiji), Papeete (Tahiti), Singapore, Kauai (Hawaii) and Easter Island (South Pacific). The sixth was placed on a ship, the 'Candide', specially chartered for the purpose. From the middle of August until the end of September, the ship was stationed at 45°S, 100°W, southwest of Valparaiso (Chile).

As a result of this effort, and with the support of other agencies, the total real-time coverage was boosted from 30% immediately after the tape-recorder failures to about 60%, with a record of 62.6% in the third week of October 1972.

In the November, ESRO-IV was launched successfully into polar orbit from Vandenberg in California on a Scout vehicle. This mission was again supported successfully by ESOC and the Estrack network until the spacecraft burned up in April 1974.

In 1973, ESRO entered a further phase in the development of its operational systems, with an agreement between it and the Netherlands Space Agency (NLR) permitting the latter to use the OCC facilities and the Redu station to control the ANS astronomy satellite, scheduled for launch in 1974. This required extensive modification of the communications interfaces between the OCC and Redu to provide a real-time keyboard telecommand capability plus real-time PCM telemetry reception and processing. This was the first installation of the so-called 'STAMAC' system, providing an integrated communications processor/

Figure 3 — ESOC's Operations Control Centre in 1972

control centre computer/ tracking station interface.

Because the Fairbanks and Redu stations would also be required to support the Cos-B mission, beginning in 1975, it was decided to equip Fairbanks with the STAMAC system also and to modify both stations to the new ESRO PCM telecommand standard (modified from the tone digital standard used previously by the ESRO stations).

ANS was launched in August 1974 and was supported very successfully until March 1976 by the ESOC OCC and the Redu station. The newly installed PCM telecommand system, plus the new STAMAC system, provided a capability for real-time dumping and reloading of the ANS onboard computer during two periods each day. This was ESOC's first experience with onboard computers, experience not to be repeated until 1983 with Exosat.

With the launch of Cos-B, ESA's first satellite, in August 1975, the Estrack network entered a new era. The satellite's highly elliptical orbit, with a 110 000 km apogee over the northern polar region, meant that two stations – Redu and Fairbanks – could acquire more than 90% of the telemetry data transmitted. This led to the decision to close the tracking stations in the Falkland Islands and Spitzbergen, in December 1973 and April 1974, respectively, because no further near-Earth polar-orbiter missions were planned. Cos-B continued to be supported by Fairbanks and Redu until 1977, when Fairbanks was closed down for economic reasons, and because reduction of the network to one station still permitted acquisition of 85% of the available Cos-B data.

1975–1978: the geostationary missions

It became clear in 1975 that, to support the geostationary missions scheduled for launch in 1978, a new network of VHF tracking stations would be required around the equatorial regions. After considerable studies and trade-offs, three locations were selected:

- Malindi in Kenya, where a VHF tracking station was already being operated by the Italian Agency CRA (Centro Richerce Aerospaziale)
- Kourou in French Guiana, where an existing VHF tracking station was being operated by CNES
- Carnarvon in Western Australia, where VHF telemetry, tracking and command (TT&C) facilities would be installed at the OTC Communications Site.

The provision of this network would also reduce reliance on the NASA VHF Space Tracking and Data Network (STDN) network, during the subsequent Ariane launcher era.

The Estrack VHF network, consisting of the above stations plus the VHF stations in Redu, provided the necessary coverage for launch and early-orbit phase operations, including transfer orbit, apogee-boost motor firing and near-geostationary orbit. Its limitations were basically that seventh-apogee injection was not feasible because of coverage constraints.

The Malindi, Kourou and Carnarvon stations became operational in April 1977, June 1978 and June 1980, respectively. The network equipment was extensively upgraded between 1977 and 1981 to provide higher telemetry, telecommand and tracking availabilities (during 1984 the network will be upgraded still further to provide an S-band as well as a VHF TT&C capability).

Beginning in 1974, a very large programme was undertaken by ESRO/ESA to prepare for the new geostationary missions with launches scheduled to begin in late 1976, including Geos, OTS, Meteosat and Marots. At ESOC, this meant that a much more powerful computing system was needed to support these missions. This system, later to be termed the Multi-Satellite Support System (MSSS), was designed to process telemetry data from up to six separate satellite sources, to generate telecommands in real-time, and to drive up to 13 alphanumeric displays in the OCC Control Room. In addition, the system had to cope with Geos data reception at 112 kbit/s, 24 h per day, a volume far in excess of anything that ESOC had previously had to handle (for comparison, Heos-1 transmitted data at 12 bit/s and Cos-B at 320 bit/s).

The MSS system (Fig. 4) was installed by early 1976 and consisted of a network of Siemens-330 (64 kbyte) machines as 'front-end' processors with two (redundant) CII-10070 machines as 'back-end' processors. The back-end machines provided telemetry and telecommand data storage and retrieval, plus the necessary hardware for accommodating the orbit- and attitude-determination and manoeuvre software necessary to support the transfer- and geostationary-orbit phases of a geostationary mission.

In addition to this new computer system, a second and even larger system was needed to support Meteosat, which would transmit raw-image data at 166 kbit/s every half an hour, 24 h per day. To cope with this mammoth image-data-processing

Figure 4 — The Multi-Satellite Support System (MSSS)

task and to provide all the other functions needed to support the Meteosat mission, the MGCS (Meteosat Ground Computer System) was installed, beginning in 1976. This consisted of two ICL 2980 mainframes plus a large complement of peripherals. The ICL 2980 was replaced by a Siemens 7865 in 1980.

To support a geostationary mission, a dedicated ground station is needed for each satellite to maintain the payload- and spacecraft-control functions. Consequently, the following facilities were designed and installed in the course of 1975 and 1976:

- a Geos receiving station (S-band) in the Odenwald, Germany
- a Meteosat Data Acquisition, Telemetry and Tracking System (DATTS); S-band, in the Odenwald, Germany
- an OTS Spacecraft Control and Tracking Station (SCTS); Ku-band, at Fucino, Italy
- a Marots TT&C station; Ku-band, at Villafranca, Spain (later converted to Marecs, C-band)
- an IUE Control Station and Observatory; S-band, at Villafranca, Spain.

An intensive test programme conducted at ESOC, at all of the newly commissioned stations, and at the Estrack stations ensured that all systems were fully operational prior to the launch of each satellite. Also, for the first time, representative spacecraft models were used as test data sources to validate ESOC Ground Support Systems, including hardware and software. This was later to become standard ESA practice.

At first glance, 1977, with a Delta launcher anomaly affecting Geos-1 in April, a Delta launcher failure causing the loss of OTS-1 in September, and the only successful launch that of Meteosat-1 in November, would appear to have been a bad year. This assumption would not really be correct, since although Geos-1 did not achieve its correct orbit, ESOC was able to mount a rescue mission that resulted in the acquisition of much useful scientific data.

The Delta launcher failure resulted in the injection of Geos-1 into a highly non-nominal orbit (apogee 11 750 km instead of the planned 36 000 km). Also, the spacecraft was not spinning at the planned 90 rpm, but was apparently tumbling.

ESOC took immediate action to establish control by spinning up the spacecraft to 12 rpm, while orbit determination was conducted. In the meantime, real-time mission replanning was being conducted by the Mission Control Team and the Project Manager. Solar-array degradation caused by the repeated passages through the Van Allen belts made it essential that Geos-1 be injected into a higher orbit as soon as possible. But the question was, which type of orbit would be the best scientifically? Because Geos's ABM was of fixed thrust ($\Delta V = 1790$ m/s), it was evident once the initial orbit was determined (11 752 × 246 km) that a geosynchronous orbit could no longer be achieved. Systematic studies of 8, 12 and 24 h orbits were carried out by ESOC Mission Analysts and intensive discussion with the Project and the Scientific Teams took place. After trading-off various parameters, it was decided to inject into a 12 h orbit.

Geos-1 was subsequently injected successfully into this 'rescue' orbit and returned valuable scientific data between April 1977 and July 1978, when Geos-2 was launched.

Meteosat-1 was launched in November

Figure 5 – Monitoring of GOES data in progress at ESOC

Figure 6 – Monitoring of Exosat real-time data in the dedicated Exosat Control Room at ESOC

1977 and the first visible image was received at ESOC on 9 December. Since then visible and infrared images have been regularly produced for the European meteorological community. The Meteosat products provided to the community have become a vital tool for European meteorologists and climatologists. Meteosat-2 took over the primary imaging mission from Meteosat-1 in July 1981.

The complex computers, communication circuits and tracking stations were very thoroughly tested and de-bugged that year, so that when OTS-2 was launched successfully in May 1978 and Geos-2 in July 1978, the Ground Control System performed absolutely nominally.

Geos-2 was injected into a geostationary orbit and provided valuable scientific data for the next 5.5 years. This mission required a powerful computing system not only to process the vast amount of scientific data being continually received, but also to schedule and process the Automatic Telecommand Schedule. At the peak of scientific activity during 1978/79, more than 40 000 telecommands per day were being transmitted to Geos-2 for experiment control.

An additional mission supported by ESA at very short notice was GOES-A (later renamed GOES-I/O – for Indian Ocean). This weather satellite, similar to Meteosat, had been offered by NOAA to the World Meteorological Organisation (WMO) as a replacement for the unavailable Russian GOMS satellite during the Global Atmospheric Research Programme (GARP) in 1979. This offer was conditional upon ESA taking over control of the GOES satellite for the duration of the GARP. In less than a year, assisted by NASA and NOAA, ESA succeeded in:

- installing an S-band TT&C station with a 10 m antenna, at Villafranca
- installing an L-band image dissemination system at Villafranca
- installing a dedicated spacecraft control room, with all the hardware and software needed to support the GOES-A mission, at ESOC (Fig. 5)
- establishing the communications interface between GOES, Villafranca and the ESOC-OCC
- training a team of spacecraft controllers and system engineers to perform GOES mission operations
- validating and testing the complete ground segment to the satisfaction of NOAA, before handover of GOES control to ESOC
- taking over control of GOES-I/O at 15°N longitude and drifting the satellite to 57°E, positioning it, and then maintaining it on station
- performing GOES mission control from 1 December 1978 until 30 November 1979, when the satellite was drifted eastwards to Guam and returned to NOAA's control.

This is believed to be a still unique example of international cooperation.

1979–1983: the Ariane era

By 1979, ESA had an ambitious launch programme of its own based on the imminent availability of its European Ariane launcher; the schedule included:

- Meteosat-2, the second European weather satellite, to be injected in dual-launch configuration with ISRO's Apple satellite

Table 1 — Summary of special facilities provided for the last five spacecraft launches

MISSION	Special facilities for LEOP		Special facilities for routine phase operations	
	Stations	Control Centre	Stations	Control Centre
Marecs-A (1981)	–	–	Villafranca Station dedicated facilities provided for TT&C and PTL with links to ESOC.	Dedicated facilities in Telecom DCR at ESOC for spacecraft control functions and payload test execution.
Marecs-B (1982)	–	First full double launch control requirement in ESOC. Reallocation of console facilities etc.	Ibaraki Station dedicated facilities provided for TT&C and PTL with links to ESOC	As above.
Sirio-2 (1982)	Provision of tone digital command equipment to all stations		Fucino Station dedicated facilities for TT&C	Dedicated control centre provided at Fucino with all operations control responsibility contracted to Telespazio
ECS (1983)	–	–	Redu Station dedicated facilities for ECS TT&C and PTL.	Dedicated control centre provided at Redu with all operations control.
Exosat (1983)	NASA used for early orbit support. Only ESA site used was Villafranca	–	Villafranca Station dedicated facilities provided for TT&C, with links to ESOC.	Dedicated facilities provided in Exosat DCR at ESOC for spacecraft control functions and observatory. Special computer facilities additional to MSSS.

- Marecs-A and B, the first European maritime communications satellites
- Sirio-2, a combined scientific and meteorological data-relay satellite
- ECS-1, the first operational European communications satellite (OTS was designated a test satellite)
- Exosat, the first European X-ray astronomical satellite.

To support all of the above missions (except Meteosat-2), it was necessary to construct and install the dedicated operational facilities outlined in Table 1. All of these facilities were installed, tested and operationally validated between 1978 and 1983, prior to the launch of each satellite. In 1983, because of launch delays, the launch and early orbit phases of two satellites had to be supported within three weeks of each other and both operated from the ESOC-OCC at Darmstadt – Exosat being launched from Western Test Range, California on 26 May and ECS-1 from Kourou on 16 June (Fig. 6).

On 12 October 1983, when ECS-1 was officially handed over to service with Eutelsat, ESA was operating a total of nine satellites: Meteosat-1 and 2 (meteorological), OTS-2, Marecs-A, ECS-1 (communications), and ISEE-B, Geos-2, IUE and Exosat (scientific) – the majority being geostationary satellites requiring dedicated ground stations and control rooms, and 24 h per day surveillance.

The contrast between the early days of the Estrack network, with 50 baud telex communications and the present ESA worldwide network equipped with 9.6 kbit/s digital data links, providing real-time command and telemetry functions, is certainly extraordinary in its degree.

Exploration of Halley's Comet from the Ground: The International Halley Watch (IHW) and its Observing Nets

*The IHW Staff**

Halley's comet is a unique object for many reasons. Scientifically, it is the only periodic comet that exhibits the full range of cometary phenomena, i.e. large coma, plasma and dust tails. Historically, it has been observed for over 2000 years and has often been the source of great public interest as well as an object of curiosity, awe and fear. Preparations for Halley's next visit were initiated already in 1980 with the formation of the International Halley Watch (IHW), six years before the comet's closest approach to the Sun. The IHW is responsible for stimulating, coordinating and archiving all ground-based observations of Halley's comet throughout the apparition.

Coordinated observations in 1910

The scientific need for an *organised* network of ground-based photographic instruments in the study of a comet was felt by E.E. Barnard in papers written as early as the 1890s, and it became an actual working concept during the 1909–1910 apparition of Halley's comet. The justification of that project was essentially identical to what it is today: to provide as continuous as possible a photographic record of a comet and its large-scale structures and changes, from which to build physical models of observed phenomena.

Rapid changes in the type-I (plasma) tails of comets were observed as early as 1892 in photographs of comet Swift and it was the desire to trace the evolution of these rather short-lived but dramatic disturbances that was foremost among the reasons for organising a photographic network for Halley in 1910. For example, the following passage appeared in a report dated 10 November 1909 by the Committee on Comets, established by the Astronomical and Astrophysical Society of America to prepare a photographic history of Halley's comet:

'The ends to be served by these photographs and similar ones obtained elsewhere are conceived by the Committee as follows: To give a permanent record, as continuous as possible, of the phenomena and changes, (i) in the tail of the comet, with special reference to outgoing masses; (ii) in the head and nucleus of the comet, particularly as to the formation of envelopes and jets.'

Given the considerable talent which comprised this Committee, it is surprising that the Halley network of 1910 fell far short of its intended goals, despite the obvious existence of some superb time sequences. It is important, however, as well as encouraging, to realise that the project 'suffered' essentially from the inundation of useful material, and not from the lack of it. The plans for the collection of data were successfully carried out, but the publication and analysis of these data were less exemplary.

Although the 1910 network had much in its favour – thorough organisation, the establishment of a central committee in charge, and well-defined goals – it lacked two important ingredients: cooperation of the individual observatories participating in the campaign to forward the material obtained to the Committee, and adequate funding and manpower to perform and follow-up the scientific research that it had inspired. The cooperation problem is illustrated by the following statement from a 1915 report of the Committee on Comets:

'Subsequent developments have made it seem inexpedient to carry out the program above outlined. The photographs obtained at the Lick Observatory and at Cordoba are so numerous and excellent that they must have constituted a large part of the material reproduced and, since these observatories have indicated a purpose to reproduce their own photographs and a similar policy seems to be contemplated elsewhere, the Committee deems it unwise

* See Tables 1 and 2

Figure 1 — Time-sequence photography of Halley's comet, 6–7 June 1910

to undertake a duplicate publication, and equally unwise to make one from which this material is omitted.'

The magnitude of the scientific research problem is easy to grasp when one considers the effort required to handle, reduce, and analyse many hundreds of photographic plates of different quality, emulsion, exposure time, plate scale, and other properties.

Systematic worldwide networks have proved their worth in other areas. For instance, at the beginning of this decade networks obtained observations of an entire rotation of Mars at approximately two-hourly intervals, and nearly hourly coverage of the development and recession of the great dust storm on Mars in 1971 at the time of the Mariner-9 encounter. A more relevant example is the sequence of photographs secured at Yerkes Observatory, Hawaii, and Beirut (from left to right in Fig. 1). The sequence illustrates the recession of a disconnected plasma tail from the head of Halley's comet during 6-7 June 1910. The measured average recession speed is 57 km/s. It bears noting that, despite the numerous examples of disconnection event (DEs) which are known to have occurred in many comets in the last 85 years, very few of them have been observed with the excellent temporal coverage of the event in Figure 1. That excellent coverage was almost solely attributable to the timely planning made by the Committee on Comets.

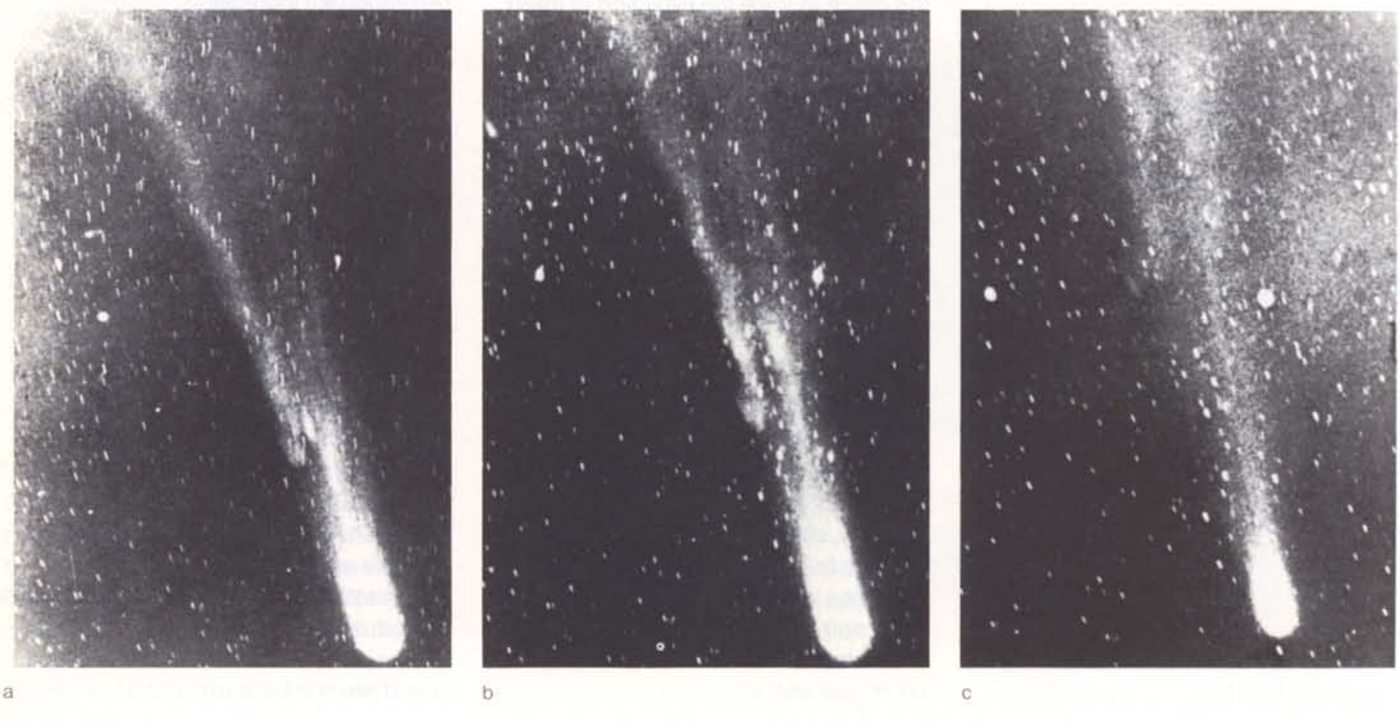
It was not until 1931, 20 years after Halley's appearance, that a summary report was available, due to the efforts of one man, N.T. Bobrovnikoff, and even that late report fell far short of the original intent of the Committee on Comets to publish all available data.

The scientific objectives of the International Halley Watch during Halley's present apparition are to characterise the structure, basic physical processes, and chemical nature of the cometary nucleus, atmospheres, and tails, and to determine the changes that occur as a function of time and position.

These objectives are basically the same as during its last apparition, but we have learnt a great deal from the 1910 experience. Clearly, the setting up of the observations themselves is just the first element of the overall task; the observations must be 'standardised' beforehand and thoroughly collated before being made widely available to the scientific community in published form. It is with this concerted follow through in mind that a comprehensive programme to prepare for the next apparition, called the 'International Halley Watch' (IHW), has been initiated.

The goals of the IHW are:

(i) To stimulate, encourage and coordinate scientific observations throughout the entire apparition.
(ii) To help ensure that observing techniques and instrumentation are standardised whenever possible.
(iii) To help ensure that the data and results are properly documented and archived.
(iv) To receive and distribute data to participating scientists and to provide information to the public and media.



a b c

INTERNATIONAL ASTRONOMICAL UNION

UNION ASTRONOMIQUE INTERNATIONALE

The 18th General Assembly of the International Astronomical Union, in session in Patras, Greece, on August 26, 1982, adopted the following Resolutions:

The International Astronomical Union
recognising that it is particularly desirable that pre-selected Comet Halley Days for co-ordinated observation over a limited time be supported
recommends that observatory directors and observing program committees give high priority to Comet Halley observation during the interval 1985-1987.

The International Astronomical Union
noting that in order to organise and marshall ground-based observations of Comet Halley throughout its 1986 perihelion passage and to co-ordinate them with space missions, an international program, the International Halley Watch, has been established
and wishing to avoid duplication of effort at the international level and to encourage participation in this program
endorses the International Halley Watch as the international co-ordinating agency for Comet Halley observations.

R.M. West
General Secretary

The IHW will assume an advocacy role for the study of Halley's comet and will provide liaison with facilities (missions, experiments, and observatories) outside the IHW organisation itself for an active programme of scientific measurements during the Halley apparition.

Organisation and staff of the IHW

The purpose of the IHW organisation is to promote communication and cooperation among scientists interested in comets, in pursuit of its goals of advocacy, coordination, standardisation, and archiving. It is intended that existing ties and cooperation among scientists be strengthened and new ones promoted, while avoiding the creation of a hierarchical command structure. The organisation chart shown in Figure 2 should be viewed as an information flowchart, a chart showing lines of communication.

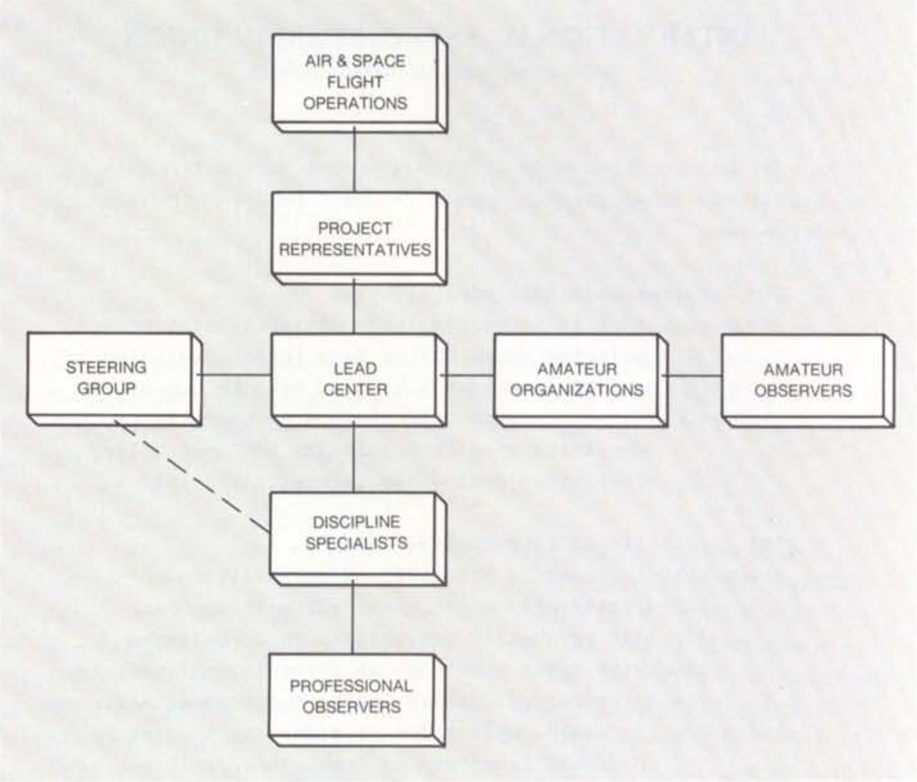
The most important elements in the IHW are the Professional Observers and the Discipline Specialist Teams. Without the Observers there can be no Halley Watch, and without the Discipline Specialists (DSs) there would be no coordination of observations. Experts have been selected for seven DS Teams in each of seven areas of astronomical technology. Their first job, still under way, is to assemble nets of observers willing to observe P/Halley* using those techniques. The DSs, in consultation with their net members, have recommended standards, data formats, and objectives and priorities for observations. In short, the DS teams each coordinate the activities of observers using a particular observing technique. The intent is to maximise the scientific value of all Halley observations worldwide without unduly constraining the prerogatives of the individual observers. The DS teams as presently constituted are given in Table 1. Each team member is supported by their own government and/or university.

The Lead Center Organisation (LCO) consists of two offices, one in Pasadena, California, USA, and one in Bamberg, Germany. The primary purpose of the LCO is to coordinate activities among the various disciplines and between the IHW and various flight projects. The LCO also coordinates amateur activities, as described later. The LCO will store all Halley data and ultimately produce the Halley Archive. To a large extent, all of these activities will be carried out in parallel in Pasadena and Bamberg. This will serve to ease communication problems caused by the nine-hour time difference between Europe and California and also offers assurance that the IHW can and will be brought to a successful conclusion, even in the event of some catastrophe (natural or man-made). Financial support for the Pasadena and Bamberg offices comes from the American and West-German Governments, respectively. The LCO personnel are listed in Table 2.

The IHW Steering Group (SG) serves in an advisory capacity to the LCO, making available many years of experience in the problems of cometary science and

* P/ indicates periodic comet

Figure 2. International Halley Watch (IHW) organisation



international cooperation. The SG selected the DSs and will continue to meet with them at least once each year to review the development of the observing nets. The advice of the SG has proved invaluable in advancing the IHW along its intended path. Its current membership is shown in Table 3.

It is recognised by the Halley flight projects – Giotto, Vega and Planet-A – that their chances of success will be greatly improved by mutual cooperation and by cooperation with the IHW. Cooperation among the flight projects is achieved through the Inter Agency Consultative Group (IACG), which was initiated in September 1981 (see ESA Bulletin No. 29, p. 82). Cooperation of the flight projects with the IHW is achieved through the Project Representatives (Table 4) designated by each flight project to serve as single-path communication links. The IHW will supply the flight projects with ephemeris data and will place the brief spacecraft encounters with Halley into the context of the entire apparition. The flight projects will supply their scientific results to the Halley Archive and will support the ground-based efforts of the IHW.

Earth-orbiting Halley studies using the Shuttle Astro-1 payload are treated as a

Table 1 – Discipline Specialist teams

Astrometry	
D.K. Yeomans	JPL
R.M. West	ESO
R.S. Harrington	USNO
B.G. Marsden	CFA
IR Spectroscopy & Radiometry	
R.F. Knacke	SUNY (Stony Brook)
T. Encrenaz	Meudon Observatory
Large-Scale Phenomena	
J.C. Brandt	GSFC
M.B. Niedner	GSFC
J. Rahe	Bamberg Observatory
Near-Nucleus Studies	
S. Larson	Univ. of Arizona
Z. Sekanina	JPL
J. Rahe	Bamberg Observatory
Photometry & Polarimetry	
A. A.Hearn	Univ. of Maryland
V. Vanysek	Charles University
H. Campins	Univ. of Maryland
Radio Studies	
W.M. Irvine	Univ. of Massachussetts
E. Gerard	Meudon Observatory
R.D. Brown	Monash University
P. Godfrey	Monash University
F.P. Schloerb	Univ. of Massachussetts
Spectroscopy & Spectrophotometry	
S. Wyckoff	Arizona State University
P.A. Wehinger	Arizona State University
M.C. Festou	Institut d'Astrophysique

Table 2 – Lead Centre arrangement for the IHW

	Eastern Hemisphere Office, Pasadena, USA	Western Hemisphere Office Bamberg, Germany
Leader	J. Rahe	R.L. Newburn
Deputy	H. Drechsel	M. Geller
Amateur Activities	R. Knigge	S.J. Edberg

Archive Editor – Z. Sekanina

Table 3 – IHW Steering Group

W.I. Axford	R. Lüst
M.J.S. Belton	A. Massevitch
J. Blamont	A.J. Meadows
G. Briggs	C.R. O'Dell
A. Delsemme	R. Reinhard
B. Donn	H.E. Schuster
H. Fechtig	K.R. Sivaraman
L. Friedman	V. Vanysek
S.M. Gong	J.F. Veverka
I. Halliday	K.W. Weiler
G. Herbig	G. Wetherill
L. Kresak	F.L. Whipple
Y. Kozai	Ya. S. Yatskiv

flight project (Table 4). Aircraft, balloon, or sounding-rocket studies will be treated as ground-based and a part of the appropriate discipline.

Data rights and the Halley Archive

The question most often asked by astronomers hearing about the IHW for the first time is 'Why should I give you my data?' In many cases, the answer is 'We don't want your data until after you have already published it in the normal manner.' In the real world of the IHW, in fact, there will be many different arrangements with observers. In the Astrometry Discipline, observers will measure Halley's position the minute the plates are dry and transmit all data immediately, for the sake of ephemeris calculations for the flight projects. Publication of the positions will still take place in the traditional manner, however. Some observers may choose to transmit information to help other observers and the flight projects while retaining all publication rights. Other observers may simply take data as a courtesy, supplying it uninterpreted to the IHW as reduced or even raw data. In some areas observers may choose to work as one large team, with joint publication in a chosen journal, with the reduced data sent to the IHW by 1 January 1988. In all cases, data transmitted to the IHW will include a code in the data bank indicating the release status. Unless we have definite evidence to the contrary, that code will always indicate 'do not release before 1988'.

Table 4 — Project Representatives

Vega	R. Sagdeev
Giotto	R. Reinhard
Planet-A	K. Hirao
Astro-1	J.C. Brandt

Table 5 — Net statistics

Discipline	No. of Countries Participating	No. of Participating Astronomers (Net Members)
Astrometry	35	192
Infrared	26	121
Large Scale	36	169
Near Nucleus	38	204
Photometry	27	122
Radio	33	173
Spectroscopy	41	405
Totals	47*	875*

* Some astronomers participate in more than one net.

It is the intent of the IHW to publish an Archive of all Halley observations taken during the 1986 apparition. Actual publication is expected to occur in 1989 under the editorship of Dr. Zdenek Sekanina. The Archive will not be a collection of interpretations of ordinary papers, although an index to published papers might be furnished. The Archive will consist of reduced data, probably arranged chronologically. How many W/m^2 at wavelength λ were received through a diaphragm of X arcsec diameter at time t, etc. The Archive, will be published both in book form and as digital video discs, the latter to permit full quantitative presentation of imaging-type data.

The format of the archived data in each discipline will be worked out jointly by the Discipline Specialists and the astronomers cooperating with them. If the format is inconvenient for some observers, the Discipline Specialist will accept what is available and format it. Standardisation also will be the product of joint agreement, but no one will be 'forced' to accept particular standards in order to participate in the IHW. We hope, for example, that photometry specialists will see that it is to everyone's advantage to take at least part of their data using standard filters, filters which in some cases can even be supplied by the IHW. The IHW will archive all properly documented photometry, whether standardised or not.

One goal of the IHW is to see P/Halley studied as no comet has ever been studied before, with thorough coverage by all practical means throughout the apparition. Another goal is to see the observations of P/Halley gathered together in a single Archive for the use of current and future scientists in deriving a clearer picture of the nature of the phenomenon called a comet. These goals can only be achieved by worldwide cooperation in the best traditions of astronomy as exemplified by the IAU. Their wide acceptance can be shown by the current makeup of the nets given in Tables 5 and 6. Now 875 astronomers from 47 countries are a part of the IHW.

Astrometry

The Astrometry Network of observers will provide the accurate astrometric and nucleus magnitude data that are required for orbit and ephemeris computations, for dynamical modelling of the rocket effect due to the comet's outgassing, and for estimates of the comet's photometric cross-section. The astrometric observations of the comet will be made from the comet's initial recovery until the last successful observation after perihelion. These observations will be used to update the comet's orbit and ephemeris continually – a function that is important for supporting ground-based observations of the comet and critically important for supporting the flyby spacecraft of ESA, Japan, and the Soviet Union. Astrometric observations will also allow refinements in the existing model for the so-called 'nongravitational forces' affecting the motion of comet Halley. These forces are thought to be due to the rocket-like thrusting of the outgassing icy nucleus.

Using the astrometric data, the Office of the Astrometry Discipline Specialists will generate and distribute various types of ephemeris data to observers using ground-based and Earth-orbiting instrumentation. The USSR Intercosmos will send two Vega spacecraft past the comet on 6 and 9 March 1986, the Japanese Planet-A spacecraft will pass

Table 6 – Participating countries

	Number Participating	Astrometry	Infrared	Large Scale	Near Nucleus	Photometry	Radio	Spectroscopy
Argentina	10	x	x	x	x	x	x	x
Australia	22	x	x	x	x	x	x	x
Austria	6	x		x	x			x
Belgium	12	x	x	x	x			x
Bolivia	1						x	
Brazil	16	x	x	x	x		x	x
Bulgaria	2	x						x
Canada	23	x	x			x	x	x
Chile	16	x	x	x	x	x	x	x
Rep. of China	1				x			
People's Rep. of China	38	x	x	x	x	x	x	x
Colombia	2	x		x		x		
Czechoslovakia	7	x	x	x	x	x	x	x
DDR/Germany	4			x	x	x		x
Denmark	4	x	x	x		x	x	x
Egypt	5				x			x
Finland	7	x		x		x	x	x
France	33	x	x	x	x	x	x	x
FRG/Germany	43	x	x	x	x	x	x	x
Greece	5	x		x	x			x
Hungary	2	x	x	x	x	x	x	x
India	24	x	x	x	x	x	x	x
Indonesia	2	x		x	x			x
Iraq	3	x	x	x	x	x	x	x
Ireland	1							x
Israel	6			x	x		x	x
Italy	31	x	x	x	x	x	x	x
Japan	28	x	x	x	x	x	x	x
Mexico	10			x	x	x	x	x
Netherlands	4		x		x		x	x
New Zealand	11	x		x	x	x		x
Norway	1						x	
Poland	11	x	x	x	x		x	x
Portugal	2	x			x		x	x
Romania	2	x		x	x			
South Africa	11	x	x	x	x	x	x	x
Spain	10	x	x	x	x	x	x	x
Sri Lanka	1			x	x		x	x
Sweden	9	x		x	x		x	
Switzerland	3	x	x	x	x		x	x
Thailand	2	x	x	x	x	x	x	x
Turkey	1							x
UK	47	x	x	x	x	x	x	x
USA	289	x	x	x	x	x	x	x
USSR	55	x	x	x	x	x	x	x
Vatican	2				x	x		x
Venezuela	10	x	x	x	x	x	x	x

the comet on 8 March 1986, while ESA's Giotto spacecraft will encounter the comet on 13 March 1986. Planet-A will pass by at a distance of 200 000 km, the flyby distance for the two Vega spacecraft will be about 10 000 km, while Giotto will be targeted about 500 km on the sunward side. It is estimated that the 1 σ targeting uncertainty that can be provided by the Astrometry Network is about 700 km. Clearly, special efforts will be required to reduce this uncertainty in order to ensure that Giotto can fulfil its scientific objectives. In this sense, Giotto is the driver for the accuracy required from the Astrometry Network.

An accurate comet-Halley ephemeris for these three flight projects will depend upon an experienced and well-coordinated group of astrometric observers. Comet Halley will be in solar conjunction from mid-January to late-February 1986, so that only a week or two of astrometric data will be available to update the comet's ephemeris prior to the final mid-course manoeuvre of each spacecraft. Hence, experienced astrometric observers who have the facilities for rapid data reduction are particularly important to the success of these flight projects.

Shortest possible exposure times are required for accurate results in Astrometry.

Infrared spectroscopy and radiometry
The 1986 apparition of Comet Halley provides an opportunity for infrared observers to investigate cometary gases and dust. Clarifying a number of long-standing questions about the nature of comets, processes in the formation of the solar system, and the relation of comets to the interstellar medium are major goals. In early, exploratory work, the power of infrared techniques in cometary studies was demonstrated with, for example, studies of the evolution of thermal emission in several comets and the identification of silicate dust in comets Bennett and Kohoutek. Improvements in infrared instrumentation since the early 1970s promise considerably greater sensitivity for Halley observations, and consequently much more information about comet structure and composition should now be accessible.

At this time, no molecular bands have been unambiguously established in infrared spectra of comets, despite the presence of strong vibration-rotation bands in the spectra of molecules of greatest interest, such as H_2O, NH_3, CH_4 and their fragments. The problem has been one of sensitivity, but with new techniques such as grating spectrometers with multichannel detection systems now becoming operational, the infrared should become the source of significant new information complementing what has been learned from the ultraviolet, visible, and radio spectral regions. A limited number of high-resolution observations with Fourier-transform spectrometers should also be possible with a bright comet like Halley. A great deal will be learned if the IHW infrared net can follow Halley and record both photometric and spectroscopic developments as the comet passes through the inner solar system.

The composition of cometary ices is presently inferred indirectly through observation of daughter products such as H_2O^+. The infrared opens up the possibility of observing the ices directly through detection of infrared solid bands, perhaps similar to those observed in interstellar dust. Searches for water and methane ices in the middle-infrared have already begun, with interesting results. Halley, being much brighter than the comets searched for ice so far, may give us detailed information about cometary ices and their volatile content. Such studies have wide-ranging implications for the understanding of the composition of the outer solar system, including the atmospheres of Titan, Uranus, and Neptune, and may be relevant to the evolution of the Earth's atmosphere.

In addition, more work needs to be done on the cometary silicates. How similar are they to interstellar silicates, to meteoritic silicates, or to particles condensed in laboratory simulations? What is the connection with Brownlee particles? What other nonvolatile compounds are present? Since micron-sized particles are best studied in the infrared, cometary dust will be a natural target for the IHW Infrared Net.

Structural information will also be a goal of the Infrared Net. Imaging of the comet with modern techniques should be very interesting. The comet should be studied over as much of the orbit as possible. Heating and chemical reaction processes depend on the heliocentric distance and should be followed in the infrared. If, for example, the nucleus is layered, the stripping of the surface as it ablates could be observed. Particle size will be measured as a function of time.

Large-scale phenomena
A worldwide network of ground-based observatories with wide-field imaging capability will be of inestimable value in the study of comet Halley in 1985/1986. It will:

(i) provide a set of images with high time resolution necessary for a detailed study of highly variable plasma-tail phenomena
(ii) permit the 'calibration' of plasma-tail events with solar-wind properties (measured *in-situ* by the Halley missions and by near-Earth spacecraft) required for the general use of comets as solar-wind probes, and
(iii) serve as a 'barometer' of the large-scale state of the comet as the Giotto, the two Vega, and the Planet-A spacecraft fly by, thus assisting the interpretation of the *in-situ* data.

The need for the network approach has been recognised for many years. Commenting on the spectacular and unusual tail structures seen in a photograph he had taken of comet

Morehouse on 15 October 1908, at Yerkes Observatory, structures that were not visible in photographs taken the previous night, E.E. Barnard had the following to say:

> 'Photographs of the comet... made in the early evening of the 15th in England or on the Continent ought to show the masses quite close to the head of the comet... It will be a great pity if photographs were not made in Europe to give a complete history of the transformation of some of these masses throughout their visible existence.'

Thus, as Barnard recognised, *the great changes in the tail were much too rapid to follow from photographs taken on successive nights at one (namely, Yerkes) observatory, and greater coverage was needed.* Fortunately, Pidoux, at the Observatory of Geneva, and Quenisset, at Juvisy Observatory, had both secured photographs early on 15 October which did show an earlier stage of development of the tail disturbance.

The event recorded by Barnard, Pidoux, and Quenisset is one of a general class of tail structures known as *disconnection events* (or DEs), in which the entire plasma tail uproots itself from the head of the comet, recedes in the antisunward direction, and is replaced by a 'new' plasma tail. The phenomenon – by no means confined to anomalous comet Morehouse – was well-known to Barnard and his contemporaries, and it is undoubtedly the most spectacular wide-field phenomenon exhibited by comets. At least five DEs are known to have occurred in comet Halley during the 1910 apparition; given the rapidity of the phenomenon, a proper study of DEs in 1985/1986 will require a worldwide network.

Halley's is one of a class of comets which display prominent plasma ('type-I') and dust ('type-II') tails *simultaneously*. In most of the discussion that follows, however, we will be emphasising plasma-tail phenomena, since the associated time scales for major change are much shorter than those of dust phenomena. Although a network is probably not essential for the study of the dust tail, an added benefit of having an effective wide-field network would be the existence of images suitable for such studies.

Comets of Halley's brightness generally have plasma-tail lengths greater than 2×10^7 km for heliocentric distances less than 1 AU. With this assumption, angular lengths approaching 8–10° are expected, especially when the comet is a southern-hemisphere object in March– April 1986. Thus, cameras with field-of-view $\gtrsim 5°$ will be the most productive instruments for the wide-field imaging of the tail. The periods of closest approach to Earth – late-November 1985 (northern hemisphere) and early-April 1986 (southern hemisphere) – occur at large r (1.55 and 1.33 AU, respectively), where both the tail's brightness and linear extent are difficult to predict.

Plasma tails radiate principally via resonance fluorescence of the CO^+ molecule whose strong band system at λ4273 dominates the spectral response range of blue-sensitive photographic plates. Our experience is that unfiltered IIa-O plates yield very satisfactory results. The correct exposure times for plasma-tail photographic imaging is less a matter of calculation than of experimentation. Generally speaking, however, a fast system like the Schmidt (f/2) at the Joint Observatory for Cometary Research (JOCR) records deep, usable tail images on unfiltered IIa-O in 3–10 min for the inner tail regions, whereas the most distant tail regions usually require exposure times $\gtrsim$20 min.

The network goal is to obtain wide-angle images at approximately 1 h intervals for extended periods during the prime observing periods from Earth – roughly November-December 1985 and March-April 1986 – and during the special period of spacecraft closest approach, i.e. 4-18 March 1986 (see p. 50).

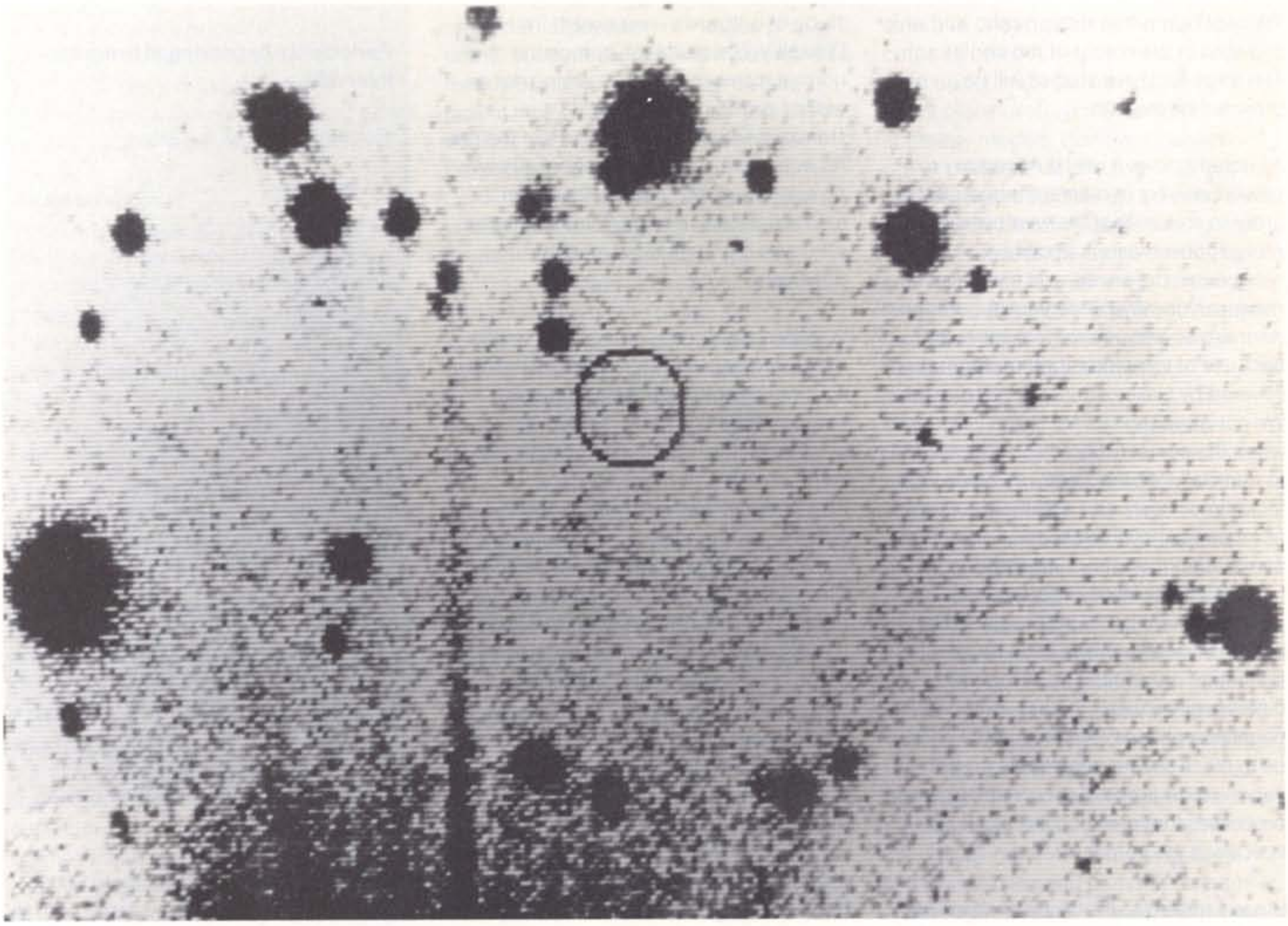
A large fraction of the participating instruments are fast ($\sim$f/2) Schmidt cameras (typical FOV = 5–10°), which are probably the ideal (but not the only useful) telescope for wide-field imaging of the plasma tail, an extended ($\sim$10°) object of moderate to low surface brightness. One of the present concerns is the lack of coverage near $\sim$75°E (India) and between 15° and 45° W (W. Africa – E. Brazil). Telescopes in either of these longitudinal ranges would be of particular use to the planned programme. In consideration of uncertainties caused by weather, the addition of observers/ instruments anywhere to our net is of course welcome.

Near-nucleus studies

The purpose of the Network for Near-Nucleus Studies is to provide the observational basis for an in-depth investigation of the large-scale surface morphology of Halley's nucleus, its thermophysical properties, spin-axis orientation, and rotation period.

Halley's nucleus is believed to be structurally nonhomogeneous, the source of the comet's well-known outgassing asymmetry. This asymmetry is reflected in the anisotropic distribution of dust in its atmosphere and is observed as discrete coma structure such as jets, shells, envelopes, etc. These features vary considerably from day to day, but do not necessarily show perceptible motions during the usually short observing window accessible from a single observatory. It is therefore essential that the Network for Near-Nucleus Studies be well-distributed in longitude. High-resolution images of the near-nucleus region obtained by the Network will eventually be analysed by computer techniques. The goal is to produce a map of the active areas on the nucleus based on systematic changes in the pattern of the discrete dust phenomena (see Fig. 3, ESA Bulletin No. 38, p. 94).

Figure 3 – The recovery of P/Halley 1982i on 16 October 1982 by astronomers D.C. Jewitt and G.E. Danielson, using the 5.1 m Mount Palomar telescope and a CCD electronic camera. The comet's magnitude was then 24.2. This is the earliest recovery ever made of a comet.



The proposed collaborative effort of the Network members will be the first organised attempt of its kind. The extensive temporal coverage advocated is essential for the proper interpretation of the individual observations and for the understanding of the global morphology of Halley's nucleus. Since the fly-through spacecraft will provide only a snapshot view of the nucleus, the interpretation of these data should be facilitated by comprehensive information from the Near-Nucleus Studies Network.

The peak activity of the Network is expected to take place in late 1985 through the middle of 1986. Special campaigns of intensive observation will be organised at critical times when the comet is well placed for observing, and during spacecraft encounters to supply valuable support data.

Photometry and polarimetry

The Photometry and Polarimetry Net has several related goals. We hope to have some observers participate in observations with standardised techniques which will provide homogeneous data that can be combined from different sites and compared with results from other nets such as the radio or infrared. In addition, we hope that other observers will carry out programmes of their own design, but basically in coordination with the standardised observing so that standardised data can be provided for the time of their observations. We will describe first some of the standardised observations.

The first of the standardised programmes will involve filter photometry of the comet with a variety of different diaphragms, but with standard interference filters. Observations at selected intervals of heliocentric distance by several observers at different longitudes (to be reasonably sure of not losing data due to bad weather) will enable us to study the variation in the production of different gaseous species as a function of heliocentric disance, and particularly to look for asymmetries between the pre- and post-perihelion phases. These data will also enable us to study the changes in the continuum-to-emission ratio and any changes in the colour of the continuum. The filters for these studies will be provided by the IHW.

As noted above, it will be necessary to have observers at different longitudes in order to ensure that the weather does not prohibit observations at certain heliocentric distances, and it will also be necessary to have observers in both the northern and southern hemispheres because of the wide range of declinations covered by Halley during this apparition. We envisage using a few large telescopes when the comet is faint (from late fall 1984 to early fall 1985 and early summer 1986 to summer 1987) and a somewhat larger number of smaller telescopes when the comet is brighter (fall 1985 through summer 1986). Halley should provide us with a unique opportunity to determine production rates over a wide range of perihelion distances and to look for differences between the pre- and post-perihelion phases. This in turn will allow us to place severe constraints on the vaporisation process and on the chemical processes that produce the observed species in the coma.

Closely related to the study of chemical processes will be the study of outbursts, which now seem to be a relatively common phenomenon among comets. When the comet is fairly bright, say in late 1985 and early 1986, in certain designated periods of two or three days we will attempt to obtain filter photometry from as many different longitudes as possible in order to study the changes that take place during an outburst. If a number of such periods are selected, presumably coincident with the attempts to determine the heliocentric distance variation, we are likely to observe an outburst on one or more of those occasions. Since a typical outburst lasts only a few days at most, the wide coverage in longitude will provide us with the first detailed study of the time variation during an outburst. In both of these programmes – the study of the heliocentric distance variation and the study of outbursts – we expect that the Discipline Specialist will participate as a normal member of the observing net as well as providing advice and standardisation to all members of the net. As with all nets, individual observers will be encouraged to publish their own results in addition to participating in the synthesis of the data from many observers.

We also hope to encourage systematic measurements of the polarisation of the continuum of the comet, again using standardised filters that isolate various portions of the continuum, and again using a variety of sites to ensure observations that are well-spaced in time (to look for changes in the nature of the particles released) and are well-spaced in phase angle (to study the scattering function of the particles). Again the role of the Discipline Specialist will be to provide some coordination and synthesis, but in this case we will rely on the participating experienced photometrists to both carry out the observations and do the analysis.

One other type of coordinated programme seems to be appropriate, and that is an attempt to study the optical depth of the grains in the comet by means of occultations of stars by the comet. The occurrence of occultations will be predicted by the astrometry net of the IHW, and, for opportune ones, we will attempt to organise teams of observers with portable equipment to monitor the occultations, much as has been done for occultations by asteroids.

Observations of the attenuation of the starlight along several chords through the cometary coma provide the only means for directly determining the optical depth of the coma in the continuum. Simultaneous measurements of the surface brightness will yield directly the scattering function of the particles for that particular scattering angle.

All of these standardised programmes, however, should not deter people from considering their own photometric and polarimetric programmes which do not fit into any of these standard programmes. We anticipate that many observers will have special measurements that they wish to make (e.g. intensities of certain weak spectral features, spatial profiles of surface brightness, etc.). If these measurements are coordinated with the standard observing programmes, the observer can be assured that at the time of his observations there will also be other data available regarding production rates of gas and dust and the polarisation in standard bandpasses. In many cases, the availability of contemporaneous standardised data can greatly assist in the interpretation of unique results.

The first significant result obtained during Halley's present apparition was the determination of the comet's visual magnitude at its recovery (Fig. 3), from

Periodicals Appearing at Irregular Intervals

IHW Newsletter (5 numbers issued)

Net Newsletters

Astrometry (2 numbers issued)
Large-Scale (2 numbers issued)
Near Nucleus (2 numbers issued)
Radio Science (2 numbers issued)
Spectroscopy and Spectrophotometry (1 number issued)
Amateur Bulletin (6 numbers issued)

Selected publications
Amateur Manual, Parts I and II (appeared in English and Japanese; to appear in 11 more languages)
Comet Halley Handbook (2 editions)
Modern Observational Techniques for Comets (JPL Publication 81 – 68)

To obtain any of these publications, please write to:

International Halley Watch, T-1166
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
USA

which the comet's photometric cross-section pR^2 could be determined ($pR^2 = 1.34\ km^2$). With reasonable assumptions on the comet's albedo 'p' the nuclear radius 'R' can be estimated.

Radio science

There is great potential for radio-science studies of a bright comet coming under predictable circumstances. Observations of radio-frequency spectral lines from molecules in the coma can provide unique information about the composition of the nucleus; continuum observations may reveal the nature of particulate material and/or complex plasma processes in the coma; and radar studies have the potential for directly measuring the size and surface properties of the nucleus.

Until now only the OH transitions at 18 cm wavelength have been repeatedly observed in comets, providing fundamental data on production rates and flow velocities and serving to confirm indirectly the importance of H_2O as a major constituent of the nucleus. Radio detections of many other types have been claimed including thermal-emission and spectral lines of the important HCN and CH_3CN molecules, but they have often not been confirmed in subsequent comets or even in the same comet at different times. This behaviour is typical of astronomical phenomena at the limit of existing sensitivity, but it may also be typical of the behaviour of comets, which are known to be highly diverse and time variable. Fortunately, both new, powerful radio telescopes and increasingly sensitive receivers are now becoming available. The International Halley Watch hopes to ensure that the most sensitive radio facilities in the World will participate in coordinated observations, so that the full promise of ground-based radio observations of comets may actually be realised.

Spectral lines at $\lambda > 0.5$ mm arise mainly from molecular rotational or hyperfine transitions and may be used to probe the chemical composition of the gas-phase coma. Such measurements thus provide a means of studying the nature of the parent molecules sublimating from the nucleus into the coma, the chemical processes in the coma itself, and the production and dispersal of molecular ions into the tail. Analysis will provide fundamental information on the conditions under which comets were formed, including the physical and chemical state of the condensing solar nebula, the nature of interstellar grains and gas, and (more speculatively) the early stages of chemical evolution and the origin of life.

The determination of molecular abundances from radio measurements is a difficult problem. Quantitative results demand simultaneous observations of multiple transitions of the same molecule, preferably with similar spatial resolution and (if possible) including isotopic variants. Nonequilibrium excitation is known to occur for OH via solar UV radiation, and such population inversions may be important for other molecules as well. Monitoring the temporal behaviour of any emission, both as a function of heliocentric distance and velocity and during 'flares' or other sporadic phenomena, will be particularly important to the unravelling of such questions.

Continuum cometary radio emission may, in principle, arise either as thermal emission from solid particles in the coma (ice or dust) or as nonthermal emission produced by plasma effects. Reports of both phenomena have been published. Confirmation and study of the radio continuum emission would thus provide important basic data on the nature, spatial distribution, and temporal behaviour of particulate matter including the hypothesis of an icy grain halo and on the poorly understood plasma processes in comets.

Radar detection of comet Halley would be very valuable, but also very difficult. Information about the size, surface structure and rotation of the nucleus could all be obtained in this way, and even upper limits on the nuclear size might place useful constraints on cometary models. However, it seems rather unlikely that any presently existing radar system could detect an echo unless the nuclear radius is larger than about 4 km (which is at the upper limit of present size estimates). Nonetheless, both the Arecibo Observatory (the World's largest radio-radar telecope) and the NASA Goldstone antenna plan radar observations.

Since all radio-science observations are severely technology-limited for comet Halley, it is imperative to mobilise significant participation by the most powerful radio astronomical facilities that will be functioning in 1985–86. It will be especially important to involve southern-hemisphere observatories in the net, since the comet will be very far south after perihelion and unobservable in the northern hemisphere during its closest approach to the Earth. Rapid developments in receivers at the very highest radio frequencies also point out the critical importance of using some telescopes designed primarily for shorter wavelength observations at millimetre and submillimetre wavelengths as well, where rotational transitions of small molecules have large line strengths.

Spectroscopy and spectrophotometry

For the first time, observers will have the opportunity to plan well in advance for the reappearance of a bright, active comet with both an accurately determined orbit and spectroscopic observations from a previous apparition. Comet Halley was spectroscopically observable as early as October 1983 (heliocentric distance ~9 AU) and will remain so into 1988, as the comet approaches and recedes from perihelion in February 1986.

Some specific goals of spectroscopic observers in the International Halley Watch (IHW) are: (i) to observe the comet over as large a range in heliocentric distance as possible; (ii) to identify new chemical species, (iii) to monitor production rates and column densities of various chemical species; (iv) to determine abundances of as many species as possible; (v) to measure scale lengths of various molecules, atoms, and ions using long-slit spectroscopic techniques; and (vi) to map the velocity field of the expanding coma and the plasma tail using high-resolution spectra. From such observations of comet Halley, we may expect to determine its chemical composition, evolutionary history, and the nature of the comet's interaction with the solar wind and radiation.

The objectives of the IHW in spectroscopy and spectrophotometry are to organise and coordinate a worldwide network of spectroscopic observers in order to optimise the scientific returns of the pending apparition of comet Halley.

The Amateur Observation Net

The Amateur Observation Net of the International Halley Watch (IHW) is being organised to encourage useful participation of amateur astronomers in the IHW. Amateur enthusiasm for comet Halley is growing and the goal of this net is to harness this energy to supply useful primary and supplemental data. The intention is to use amateur-supplied data and the data obtained by the professional nets to provide a complete record of this apparition of the comet.

The primary goal is to obtain visual and photographic records of this apparition for direct comparison with similar data from 1910. Professional astronomers have almost completely relinquished visual comet studies, but such studies are a very active pursuit among amateurs. Photographic techniques that were state-of-the-art in 1910 are now commonly available to amateurs, who are therefore eminently well-suited to share in the achievement of this goal.

Because amateur astronomers have the freedom to choose when and where they

Where to Look for Comet Halley (Northern Hemisphere)

Because of the orbital motions of the Earth and comet around the Sun, this appearance of comet Halley will be much less spectacular than the one in 1910 or, in fact, any in the past 2000 years.

To see Halley's comet well it will be important to observe it from an area with little pollution, haze, or dust in the air and away from city lights and moonlight. This will allow the faint, gossamer glow of the comet, like thin moonlit clouds, to be seen easily in the sky.

The Earth's southern hemisphere is the favoured viewing area for this appearance of the comet. Observers in mid-northern latitudes will see a modest display.

Figure 4 traces the path of the comet on the celestial sphere during July 1984 to November 1986. Note the comet's retrograde loops and its transition from a primarily northern-hemisphere object in late 1985 to a southern-hemisphere one in early 1986.

The comet will be visible to small telescopes during the autumn of 1985. In December it will be visible to binoculars about halfway between the horizon and zenith in the southwest at the end of evening twilight (about 1.5 hours after sunset). By early January 1986 the comet should be visible to the naked eye. Observers will see it brighten rapidly and develop a tail as it approaches the Sun during January. While this is occurring, it will also be seen lower in the sky and more towards due west each night at the end of twilight.

Figure 5a shows the comet's position at the end of evening astronomical twilight during January. Approximate total visual magnitudes, with a smaller number implying a brighter comet, are given in parentheses following dates. Viewing with binoculars and ideal observing conditions are assumed.

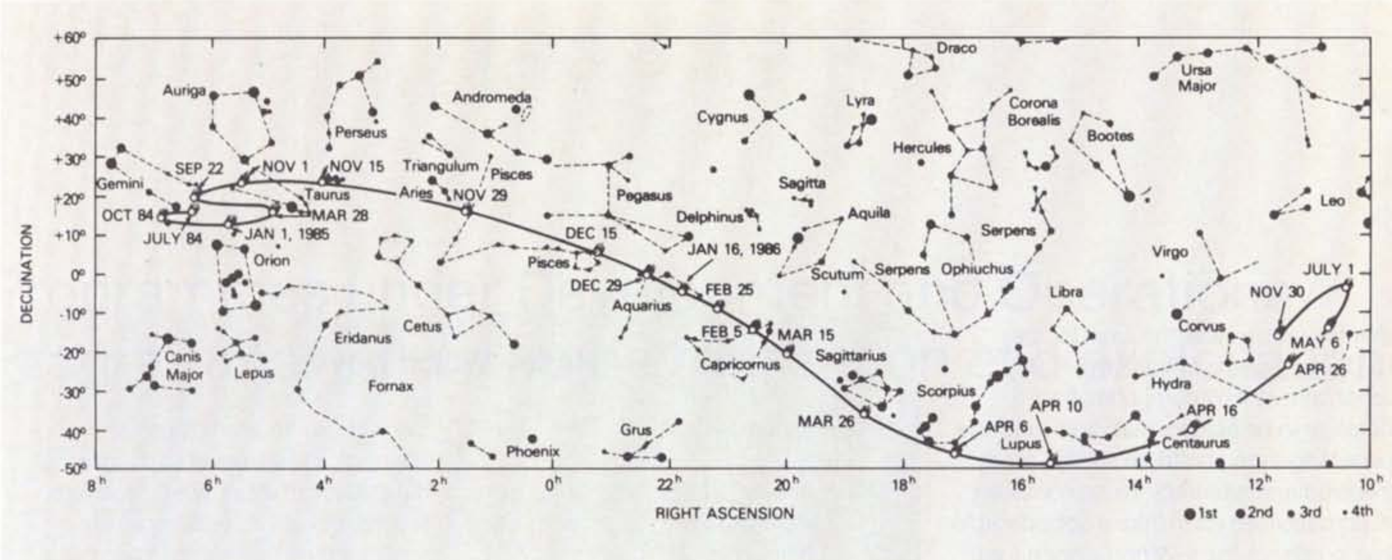
By the end of January the comet will be lost in the solar glare. A month later Halley will reappear in the morning sky (Fig. 5b) slightly south of due east and low on the horizon before the onset of morning twilight (1.5 hours before sunrise). The comet's tail will be better developed than in January. As March progresses the comet will move higher in the sky and more towards the south, slowly brightening through the end of the month as it approaches Earth.

The comet will be closest to Earth in late March and early April. Seen low in the southeast and moving further towards the south daily, the comet will be at its brightest and show its greatest tail extent for this appearance. At northern temperate latitudes (~ 25–60°), the Earth's atmosphere will prevent the full extent of the tail from being seen while the comet is at low elevations.

During the second week of April the comet will essentially disappear for mid-northern-latitude observers because of its extreme southern position in the sky.

During the last half of April the comet will be in the southeast after evening twilight, rising higher in the sky each day (Fig. 5c). The tail will decrease in length and the comet will then approach the limit of naked-eye visibility.

By May binoculars will be required to see the comet as it returns to the deep freeze of the outer solar system. It then can be followed with binoculars or a small telescope for several more months.



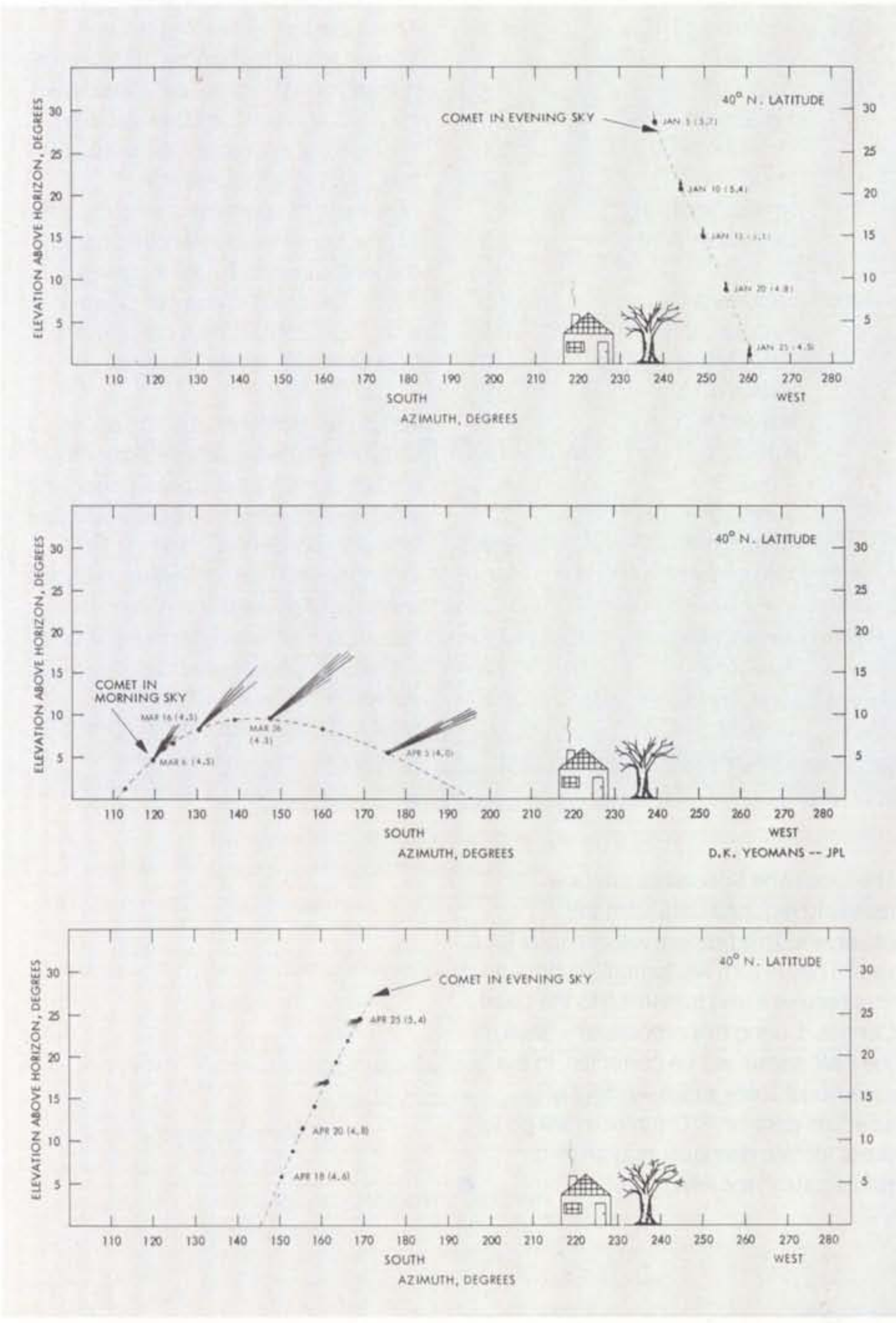


Figure 4 – Comet Halley's path on the celestial sphere from 1984 to 1986

Figure 5 – Comet Halley's position between January and April 1986

observe, they can provide valuable supplementary data and occasionally primary data for analysis. Weather, observatory geographical position, telescope time allotments, and certain equipment limitations may all act to inhibit data acquisition by professional observers. The freedom mentioned earlier and the sophisticated equipment in many amateur hands, given guidance, will allow the data they collect to plug gaps in professional coverage.

Overall coordination for the amateur net will take place from the Pasadena Lead Center of the IHW. Each country's national amateur astronomical organisation(s) will be asked to collect and appraise the observations made by their nationals before forwarding it to the Pasadena centre for dispersal to the Discipline Specialists and/or Archives.

The P/Crommelin trial run

A 'trial run' was included in IHW plans from the very beginning. It was clear from the outset that the volume of data on Halley would be enormous and that selected parts of that data would be time-critical. Clearly, the entire process of data handling, reduction, and formatting had to be as automated as possible or the IHW Archive too might appear 21 years after the fact, as was the case for the major monograph on the 1910 Halley apparition. All IHW computers had therefore to be able to 'read and write' the same language and to do so with great precision and accuracy. Since computer incompatibilities often take a considerable time to correct, the IHW could not afford to wait until actual Halley data are pouring in; hence the trial run. Although the IHW needs were pragmatic and utilitarian, the trial run also offered the chance of scientific accomplishment. The appropriate time for the trial run was the first few months of 1984, by which time the observing nets and organisation were all in place, but largely untested.

After considerable debate at several IHW meetings, P/Crommelin was selected as the trial-run comet and the week of 25-31 March 1984 as the time. Crommelin was at roughly the same declination and solar elongation at that time as Halley will be during the critical spacecraft encounter period in the first half of March 1986, although Crommelin was in the evening sky rather than the morning. Crommelin was even at roughly the same distance from the Earth and from the Sun as Halley will be at encounter, although Crommelin was roughly 100 times fainter than Halley will be. It is not easy to work near the horizon with large telescopes and so it was also good practice for the observers. Moreover, Crommelin is an interesting object of 27.9 year period, which had never before received significant study.

The trial run seems to have gone well. The weather was generally good, although perhaps better in the American telescope belt – which had an unusually mild, clear winter – than in Europe. All seven nets acquired at least some data. Rather complete results are available at the time of writing only from the Astrometry Net, which practised rapid turnaround as well as general exercise of the system. Two hundred and thirty-one astrometric positions have been reported by 34 observatories in 16 countries, the largest number coming from the USSR.

Halley Watch Days

1983	December 9-11	8.4 AU*
1984	January 27-29	8.0
	March 23-25	7.6
	October 29-31	5.8
	December 21-23	5.4
1985	February 13-15	4.9
	April 9-11	4.3
	August 24-26	2.8
	September 21-23	2.5
	October 18-20	2.1
	November 3-5	1.9
	November 12-18	1.7
	December 8-13	1.3
1986	January 4-6	1.0
	February 3-6	0.6
	February 17-19	0.6
	March 4-18	0.9
	March 28-30	1.1
	April 6-13	1.3
	May 3-5	1.7
	June 1-3	2.1
	August 1-3	2.9
	November 12-14	4.0
1987	January 6-8	4.6
	April 22-24	5.6
	June 16-18	6.1
	December 27-29	7.6

* Heliocentric distance in Astronomical Units.

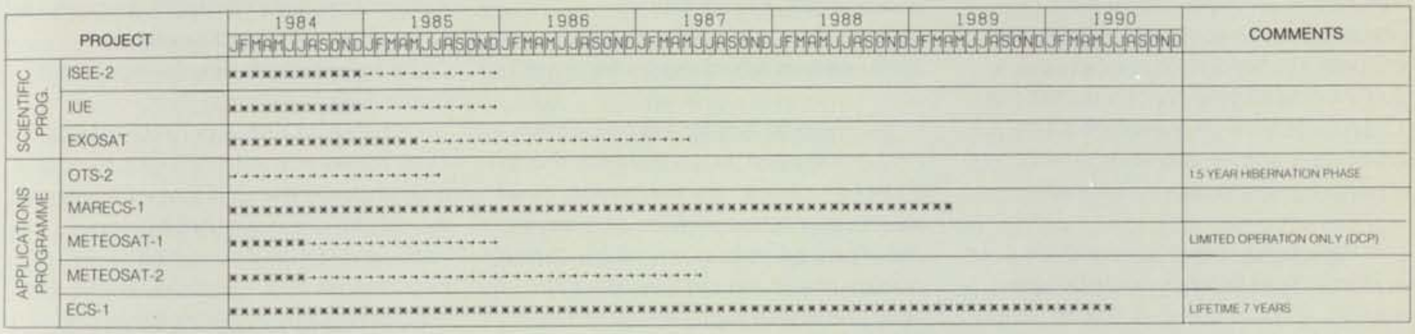
Since Halley can exhibit rapid changes, it is extremely important that data be taken often by all disciplines simultaneously. As telescopes are scheduled far in advance, days must be selected for simultaneous work by all disciplines far in advance as well. These are the 'Halley Watch Days', spaced to study changes in the comet with heliocentric distance and chosen for periods when the Moon is below the horizon, since some nets require this. It is also important that observations be made during the times of spacecraft encounters and during the periods when Halley is closest to Earth. The final list was put together after much debate as a compromise between various requirements.

Of course, Halley will also be observed in between these intervals. Astrometry and photometry have been under way since the recovery on 16 October 1982 and will continue well beyond 1987. During the 12–18 November 1985 and the 6–13 April 1986 intervals Halley has close Earth approaches (0.7 and 0.42 AU, respectively) and Halley radar detection will be tried. The 4–18 March 1986 interval covers all the spacecraft encounters.

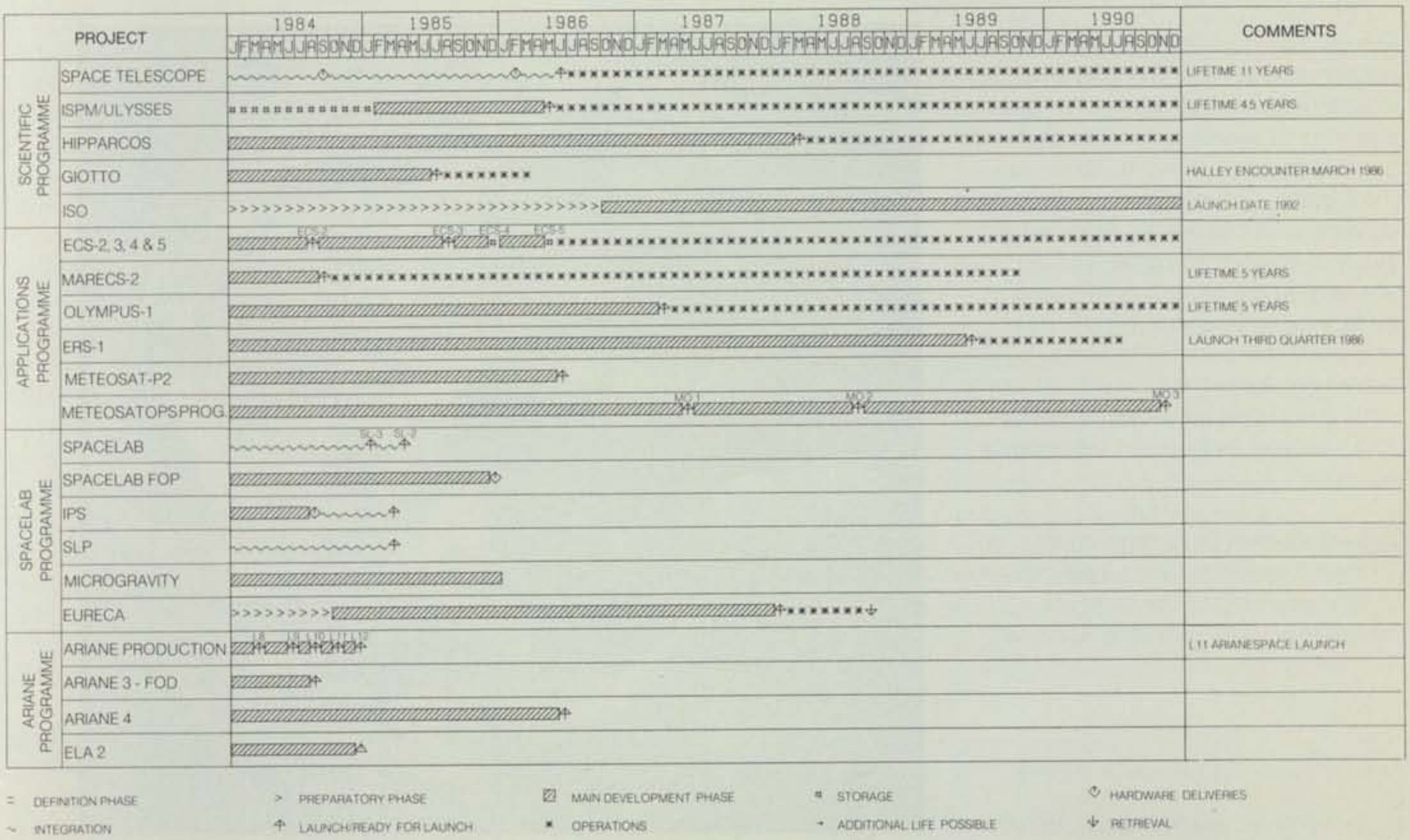
The Discipline Specialists are now receiving reduced data from the observers. This process will continue for a year. They in turn will format the data as they receive it and transmit it to the Lead Centres. During this process any flaws in the IHW system will be corrected. In the summer of 1985, a mini-Archive of scientific data on P/Crommelin will go to press for free distribution to all who participate in the IHW.

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

In Orbit / En orbite



Under Development / En cours de réalisation



OTS

OTS-2 a été mis progressivement hors service opérationnel pour le compte d'Eutelsat à la fin de 1983 et a servi peu après à procéder à un programme d'essais 'de fin de service' (EOS) intensifs (voir Bulletin ESA no. 38, page 54). La période fin février — fin mai a vu l'essentiel du programme d'essais EOS, l'achèvement de la douzième saison d'éclipses et l'entrée d'OTS dans sa septième année en orbite.

Les sous-systèmes du véhicule spatial ont continué de fonctionner sans poser de problèmes au cours de cette période. Vu le manque d'ergols pour le maintien à poste Nord-Sud, l'inclinaison de l'orbite est désormais portée à environ 0,7°, mais le maintien à poste Est-Ouest se poursuit dans les limites fixées initialement. Les réseaux solaires continuent à fournir un important excès d'énergie tandis que le BAPTA et la batterie sont en parfait état. Le sous-système de régulation thermique continue d'assurer aux équipements des niveaux de température acceptables.

L'orientation du satellite est assurée pour le moment par la méthode de la 'voile solaire', les propulseurs du mode normal (NM) étant disponibles en renfort. On trouvera ci-dessous quelques remarques sur les essais EOS menés pendant la période mars-mai.

Les résultats du premier essai de décharge de la batterie ont été si bons — la batterie fournissant au bout de quelque 6 années de service sensiblement plus de courant que ne le prévoyait sa charge théorique — qu'une répétition de l'essai a été menée en avril à la fin de la douzième saison d'éclipses. Cet essai a confirmé les résultats du premier et montré que la batterie nickel-cadmium d'OTS, d'une puissance théorique de 18 Ah au lancement, était en fait capable de fournir, pour un fort taux de décharge, environ 22 Ah au bout de 6 années de présence en orbite.

Des essais particuliers de télémétrie ont été menés au cours de cette période, en collaboration avec l'Université de Stuttgart, au moyen de techniques de bruits binaires pseudo-aléatoires. Les essais ont démontré qu'il est possible de déterminer avec une extrême précision la position d'un satellite géosynchrone en utilisant un signal sur l'une des voies opérationnelles normales à partir d'une seule station terrienne disposant du matériel spécialisé voulu. De plus, il s'est révélé faisable de déterminer avec un bon niveau de précision la position 'instantanée' en orbite en utilisant les signaux de télémétrie en retour de Fucino et de Villafranca.

Au cours de la douzième saison d'éclipses, la batterie a assuré l'alimentation des trois canaux en exploitation pendant chacune des phases d'éclipse. Un essai thermique en mode normal non perturbé a été mené à l'équinoxe, et ses premiers résultats ont confirmé que le processus de dégradation de la surface des nappes a apparemment atteint ses limites virtuelles.

Il était prévu de répéter à la fin de mai l'important essai de récupération d'une sortie 'spin à plat', qui avait été mené en février, mais cette opération sera menée début juin, après quoi on entrera dans la période dite 'd'hibernation', peut-être pour une année supplémentaire. Un rapport sera publié en temps opportun sur les essais EOS.

Météosat

Programme préopérationnel

Toutes les missions dévolues au programme sont actuellement remplies par les satellites Météosat-F1 et F2. Le satellite F2, lancé depuis Kourou sur le vol Apex L03, atteindra les trois ans de vie en orbite en juin 1984. On peut constater, grâce à la large diffusion par les média, l'excellente qualité des images.

Le satellite P2, prévu pour être lancé sur le premier vol Ariane-4/Apex, a été destocké et se trouve actuellement en salle propre dans l'établissement de l'Aérospatiale à Cannes où il subit une inspection approfondie de tous ses éléments les plus critiques.

Le Conseil Directeur des satellites météorologiques (PB-Met) a, au cours de sa session du 27 mars, approuvé l'embarquement de l'expérience Lasso (Laser Synchronisation from Synchronous Orbit) à bord du satellite P2. Cette expérience était initialement montée à bord du satellite Sirio-2 qui n'avait pu être mis en orbite. En conséquence, l'équipe de projet poursuit les négociations avec l'Industrie, le CNES, et le Ma'tre d'Oeuvre (Aérospatiale, Cannes) pour aboutir à une proposition finale fin juin 1984.

Meteosat image of the Earth (visible channel)

Image de la Terre prise par Météosat (canal visible)

OTS

OTS-2 was phased out of operational service with Eutelsat at the end of 1983, and was involved shortly afterwards in a concentrated End-of-Service (EOS) test programme (see ESA Bulletin No. 38, p. 55). The period March through May has seen the end of the main part of the EOS test programme, completion of the twelfth eclipse season, and the beginning of OTS's seventh year in orbit.

The spacecraft subsystems continued to perform faultlessly during this period. Because of lack of fuel for north-south stationkeeping, the orbit's inclination has now risen to about 0.7°, but east-west stationkeeping has been maintained within the originally specified limits. The solar arrays still provide a large excess of power, and the BAPTAs (bearing and power-transfer assemblies) and battery are in good condition. The thermal subsystem continues to maintain equipment items at acceptable levels.

Attitude is being maintained for the time being by solar sailing, with the normal-mode thrusters available as backup.

The results of the original battery-discharge test had been so good – the battery giving significantly more than rated charge after nearly six years of use – that a repeat test was carried out in April after the end of the twelfth eclipse season. This confirmed the results of the first test, showing that the OTS nickel-cadmium battery, with a designated rating of 18 Ah at launch, was in fact capable of delivering (at a high discharge rate) about 22 Ah after six years in orbit.

Special ranging tests have been carried out recently, in collaboration with the University of Stuttgart, using pseudo-random binary noise techniques. The tests demonstrated that it is possible to carry out extremely accurate ranging on a geosynchronous satellite, using a signal in one of the normal operational channels, from a single ground station having the necessary specialised equipment. In addition, by utilising return ranging from Fucino and Villafranca, 'instantaneous' orbit determination proved feasible, with good accuracy.

During the twelfth eclipse season, the battery supported all three operating channels throughout each eclipse. A standard steady-state thermal test was carried out at the equinox, preliminary results confirming that the degradation of the blanket surfaces appears to have virtually reached its limit.

A repeat of the important flat-spin recovery test, successfully accomplished in February, was scheduled for late May, but this will now be performed in early June. After that, the so-called 'hibernation' period will be entered, for possibly a further year. A full report on the EOS tests will be issued in due course.

Meteosat

Preoperational programme

All the missions allocated to the programme are now being fulfilled by the Meteosat-F1 and F2 satellites. Meteosat-F2, launched from Kourou on the Apex L03 flight, will have spent three years in orbit by June 1984. The quality of its images is excellent, as their widespread distribution by the media testifies.

The P2 satellite, scheduled for launch on the first Ariane-4/Apex flight, has been taken out of storage and is now in a clean room in the Aérospatiale establishment at Cannes, where its most critical elements are undergoing a thorough check.

During its meeting on 27 March, the Meteorological Satellite Programme Board (PB-MET) approved the flight of the Lasso (Laser Synchronisation from Synchronous Orbit) experiment on board P2. This experiment was originally installed on the Sirio-2 satellite, which was lost through a launch failure. Consequently, the Project Team is continuing negotiations with industry, CNES and the prime contractor (Aerospatiale, Cannes) to arrive at a final proposal in late June 1984.

Operational programme

General activities

The 13th meeting of the Coordination of Geostationary Meteorological Satellites (CGMS) Group took place at WMO in Geneva from 10 to 13 April 1984. During this meeting an agreement was concluded on the data format for the operational ASDAR system: 200 Data-Collection Platforms (DCPs) will be fitted on large long-haul aircraft, and will transmit continuous meteorological data to the geostationary satellite operation centres for distribution on WMO's GTS network. This is a new Meteosat operational application.

Furthermore, it has been dedicated to coordinate, as far as possible, the satellite – ground interface specifications for future generations of spacecraft.

Space segment

On 15 May 1984, ESA and Aerospatiale officially signed the contract covering the space segment of the Meteosat Operational Programme (see page 99). This contributes an important programme milestone.

The Operational Programme is proceeding exactly on schedule. Almost all the subsystem critical design reviews have already taken place. There have been very few difficulties, and they have all been solved quickly and effectively, thus making it possible to start manufacture at the proper time.

A stringent check on the programming schedules of the various co-contractors has been carried out with a view to assessing their ability to fulfil their undertakings. To date there is nothing to suggest any slippage. Special attention has been paid to monitoring component procurement. In this area, too, activities and supplies are progressing smoothly.

Station d'utilisateurs des données secondaires de Météosat

Meteosat Secondary Data Users Station (SDUS)

Programme opérationnel

Activités générales

La 13ème réunion du Groupe de Coordination des satellites météorologiques géostationnaires (CGMS) s'est tenue à l'OMM à Genève du 10 au 13 avril 1984. Au cours de cette réunion, un accord concernant le format des données du système ASDAR opérationnel a été atteint: 200 plates-formes de collecte de données (DCP) seront installées sur les avions gros-porteurs effectuant de long trajets, et transmettront de façon continue des informations météorologiques aux centres d'opérations des satellites géostationnaires pour diffusion sur le GTS. Ceci représente une nouvelle application opérationnelle de Météosat.

De plus, il a été décidé de coordonner le plus possible les spécifications d'interfaces entre le satellite et le sol pour les prochaines générations.

Segment spatial

L'Agence et l'Aérospatiale ont procédé officiellement, le 15 mai 1984, à la signature du contrat couvrant le Segment Spatial du Programme Météosat Opérationnel. Cette signature est l'événement le plus marquant dans la vie du programme au cours de ce dernier mois.

Le déroulement du Programme Opérationnel se poursuit conformément à toutes les prévisions. La quasi totalité des revues critiques de conception des sous-systèmes a déjà été tenue. Très peu de difficultés ont été rencontrées et toutes ont été rapidement et efficacement surmontées, ce qui permet le démarrage des fabrications en temps voulu.

Un contrôle poussé des plannings des différents co-contractants a été effectué en vue d'apprécier leur aptitude à tenir leurs engagements. Rien à ce jour ne permet d'envisager un glissement des objectifs. Un soin particulier a été apporté dans le suivi de l'approvisionnement des composants. Dans ce domaine, également, les activités et les fournitures se déroulent normalement.

Secteur sol

Les activités opérationnelles ont donné satisfaction pendant les quatre premiers mois de 1984, aucune défaillance marquante n'étant signalée dans le secteur sol. Toutefois, la limitation de l'énergie disponible à bord du satellite pendant la période d'éclipses a freiné le service de collecte des données entre le 20 février et le 31 mars ainsi que l'acquisition et la dissémination des images entre le 28 février et le 11 avril.

L'extension de la zone de traitement MIEC de 50 à 55° (angle de grand cercle) est devenue opérationnelle le 25 avril 1984.

Travaillant en coordination avec les autres exploitants de satellites météorologiques géostationnaires, le système Météosat fournira un indice de précipitation et des données sur la couverture nuageuse à l'expérience ISCCP (Programme international sur la couverture nuageuse).

Les activités d'approvisionnement ayant trait à la remise en état des équipements du secteur sol se poursuivent conformément au calendrier.

Météosat de deuxième génération

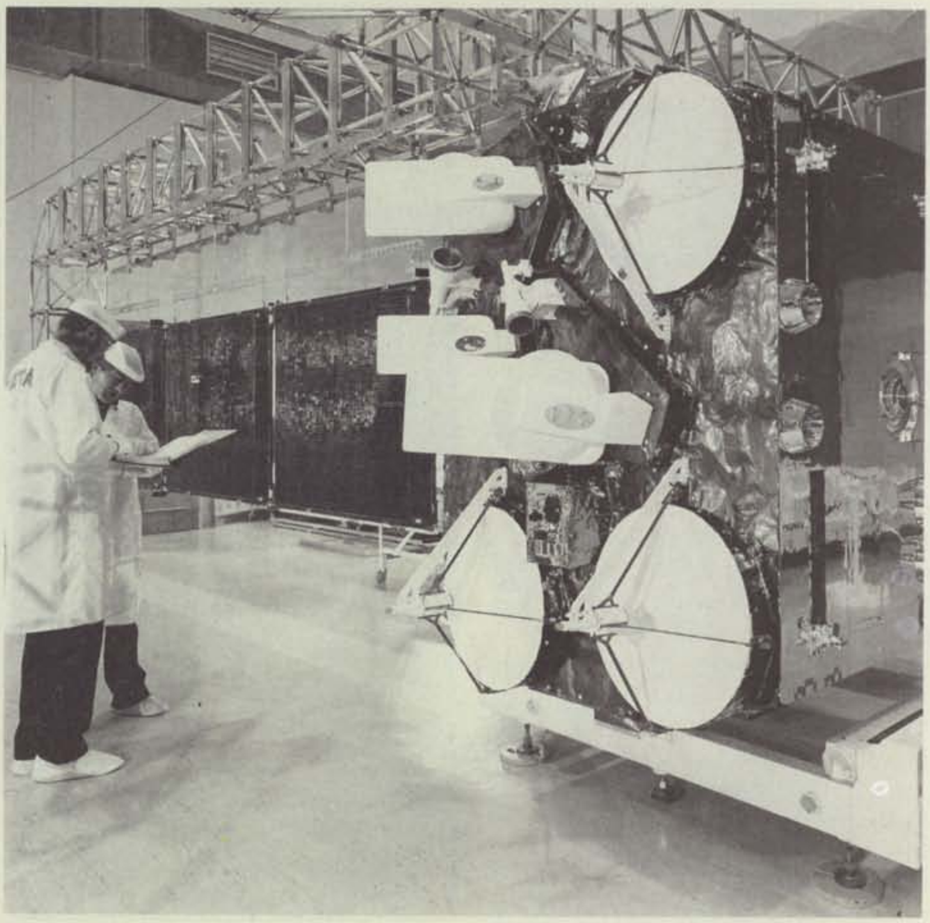
La deuxième phase de l'étude industrielle a pris fin. Au cours de la première phase, les besoins des utilisateurs avaient servi à définir la dimension et le coût des satellites de base selon un ordre croissant de capacités. Au vu des qualités attribuées à une plate-forme légèrement oscillante, cette conception a fait l'objet d'un supplément d'analyse au cours de la deuxième phase afin d'évaluer l'interaction des différents paramètres sur la qualité de la mission.

Les résultats de l'étude industrielle ont été soumis au Groupe consultatif scientifique et technique (STAG) de l'Agence.

ECS

ECS-1, lancé par Ariane L6 le 16 juin 1983, continue de donner toute satisfaction à son propriétaire et exploitant, Eutelsat. Le satellite sert à la transmission de programmes de télévision pour réseaux câblés ou récepteurs communs (hôtels par exemple).

ECS-2 doit partager en configuration double avec le satellite de



ECS-2 solar-array deployment test at Matra, Toulouse

Essai de déploiement du générateur solaire d'ECS-2, chez Matra, Toulouse

Ground segment
The performance during the first four months of 1984 has been satisfactory, with no significant failures in the ground segment. However, the limited availability of power on-board the satellite in the eclipse period restricted the data-collection service between 20 February and 31 March and image acquisition and dissemination between 28 February and 11 April.

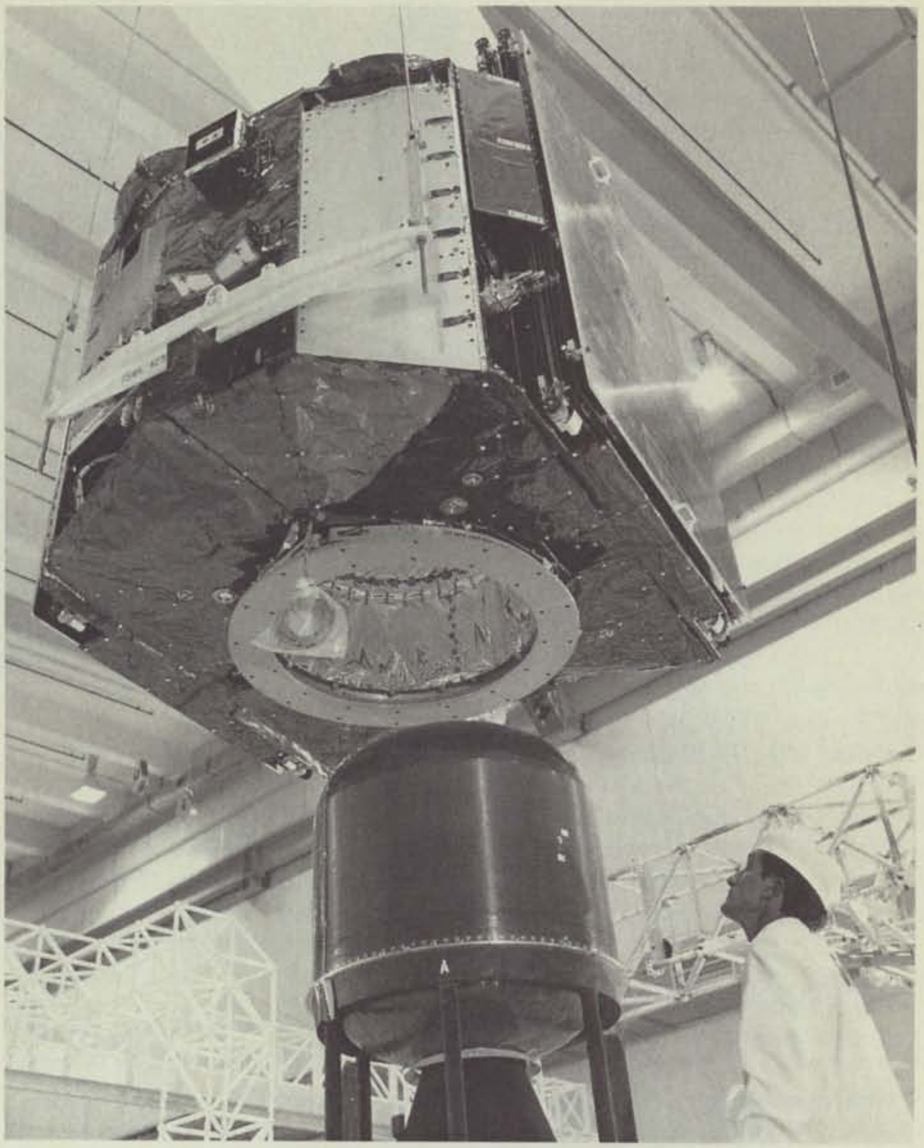
The extension of the MIEC processing area from 50° to 55° great circle arc was implemented operationally from 25 April 1984.

In coordination with the other geostationary meteorological satellite operators, the Meteosat System will provide a precipitation index and cloud coverage for the ISCCP experiment (International Satellite Cloud Coverage Programme).

The procurement actions linked to the refurbishment of the ground-segment equipment are progressing according to schedule.

Second-generation Meteosat
The second phase of the industrial study has been completed. During the first phase, user requirements were used to define size and cost of basic satellites in growing order of capability. Due to the attractive capabilities predicted for a slowly oscillating platform, this concept was further analysed in the second phase to assess the effects of various parameters on mission quality.

The results of the industrial study have been presented to the Agency's Scientific and Technical Advisory Group (STAG).



Essai de montage du moteur d'apogée d'ECS-2, chez Matra, Toulouse

ECS-2 apogee-boost-motor fit check at Matra, Toulouse

ECS

ECS-1, launched on L6 on 16 June 1983, continues to give satisfaction to its operational owner Eutelsat. The satellite is used for transmission of television programmes for cable-television networks or community receivers (e.g. hotels).

ECS-2 is scheduled to be launched on an Ariane-3 launcher (V10) in a dual-launch configuration with the French telecommunications satellite Telecom-1A. The planning of the final stages of integration for the satellite remains nominal, for the planned 4 August 1984 launch. ECS-2, when accepted in orbit, will extend the present telecommunications capacity for cable-television transmission and, in addition, will be used by the EBU for Eurovision programme exchanges, by PTTs for trunk telephony in Europe, and will initiate the multiservices mission in Western Europe, permitting data transmission between small dedicated earth stations.

At the request of the ECS customer Eutelsat, ECS-3 is being prepared for a launch in mid-1985, in order to complement the ECS system, which will then have three satellites in orbit simultaneously.

Space Telescope

NASA
All NASA activities are proceeding on schedule for the launching of the Space Telescope by mid-1986. From the results of some tests and additional systems analyses, NASA have identified the need for ten percent more electrical power than previously specified. The most effective solution to this problem is the manufacture of new solar-array blankets using more modern cells that have recently become available. NASA have asked ESA to implement this solution, for which NASA will refund the associated costs.

Solar array
All flight electronics for the solar array have been delivered to Lockheed, the Space Telescope system contractor, and have subsequently been integrated into the spacecraft.

télécommunications français Télécom 1A le lancement V10 d'Ariane 3. Les dernières étapes de l'intégration du satellite se déroulent toujours conformément au calendrier en vue d'un lancement fixé désormais au 4 août 1984. Après recette en orbite, ECS-2 viendra compléter la capacité actuelle de télécommunications affectée à la transmission de télévision câblée, servira à l'UER pour des échanges de programmes d'Eurovision et aux administrations des PTT pour les communications téléphoniques interurbaines en Europe, et sera à l'origine d'une mission multiservice en Europe occidentale. Cette dernière permettra la transmission de données entre petites stations terriennes spécialisées.

A la demande d'Eutelsat, le client de l'Agence pour ECS, le modèle ECS-3 est en cours de préparation en vue d'un lancement à la mi-1985 afin de porter le système ECS à sa configuration complète: 3 satellites simultanément en orbite.

Télescope spatial

Activités NASA
Toutes les activités de la NASA se poursuivent conformément au calendrier qui prévoit que le Télescope spatial sera lancé à la mi-1986. Les résultats de certains essais et d'analyses supplémentaires du système ont fait apparaître que la puissance électrique doit être augmentée de 10% par rapport aux spécifications fixées à ce jour. La meilleure façon de résoudre ce problème est de fabriquer de nouvelles nappes de photopiles utilisant des cellules plus modernes disponibles depuis peu. La NASA a demandé à l'ESA de mettre en oeuvre cette solution et lui remboursera les frais correspondants.

Réseau solaire
Toute l'électronique de vol du Réseau solaire a été livrée à Lockheed, contractant responsable du Télescope spatial au niveau système qui a procédé à son intégration.

La fabrication des nouvelles nappes de photopiles a commencé et la livraison des ailes du modèle de vol équipées de ces nouvelles nappes est prévue pour février 1986.

Chambre pour astres faibles (FOC)
Tous les essais électriques, de logiciel et de simulation de mission du modèle de vol de la FOC ont été menés à bien, conformément au calendrier, au Centre des vols spatiaux Goddard. La préparation de l'étalonnage de l'instrument qui doit avoir lieu en juillet 1984 avance comme prévu.

ISPM

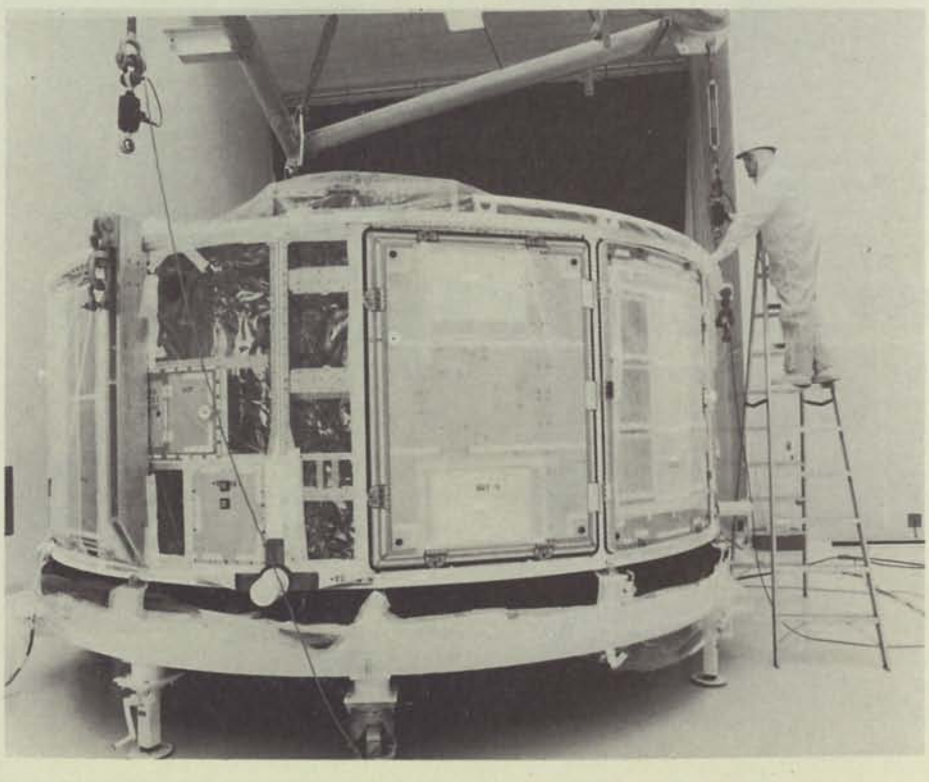
Bien que le véhicule spatial ISPM ait été mis en réserve l'an dernier pour une période qui s'étendra jusqu'en février 1985, les activités relatives à la nouvelle certification, au lancement et aux opérations se poursuivent comme prévu.

Au Kennedy Space Center, la Phase II de l'Examen de sécurité au sol s'est terminée de façon satisfaisante en mai et un Examen des opérations de mission au niveau système ainsi qu'une réunion de l'Equipe scientifique ont eu lieu à l'ESOC au mois de juin. Les groupes 'Conception de la mission' et 'Intégration de la mission' qui sont responsables des relations nombreuses et très complexes avec le STS et le lanceur Centaur se sont également réunis.

La réalisation du RTG (générateur radio-isotopique à thermo-couples) se poursuit aux Etats-Unis conformément au calendrier tandis qu'en Europe, la mise sur pied de procédures de manipulation et d'installation de cet équipement a bien avancé. Ces procédures ont pour but de réduire au minimum l'exposition du personnel au rayonnement du RTG lorsque celui-ci sera installé sur le véhicule spatial au KSC.

En ce qui concerne la charge utile, on procède à l'étalonnage de toutes les expériences à embarquer ou à leur remise en état finale après les phases d'essai du véhicule spatial. Certains chercheurs principaux ont commencé à remplacer les pièces de haute fiabilité dont on a estimé qu'elles n'étaient pas suffisamment protégées contre le rayonnement intense régnant dans la région de Jupiter.

Enfin, sur proposition du Prof. B. Bertotti de l'Université de Pavie, il a été décidé de



Space Telescope support system module electronics bay

Equipement électronique du module de soutien du Télescope spatial

Le miroir primaire de l'ensemble optique du Télescope spatial

Primary mirror for the Optical Telescope Assembly of the Space Telescope

The manufacture of the new solar-array blankets has been initiated and delivery of the flight wings with the new blankets is foreseen for February 1986.

Faint Object Camera
All electrical, software and mission-simulation tests with the Faint Object Camera flight model at Goddard Space Flight Center have been completed successfully and on schedule. Preparations for the calibration of the instrument at Goddard during July 1984 are proceeding as planned.

ISPM

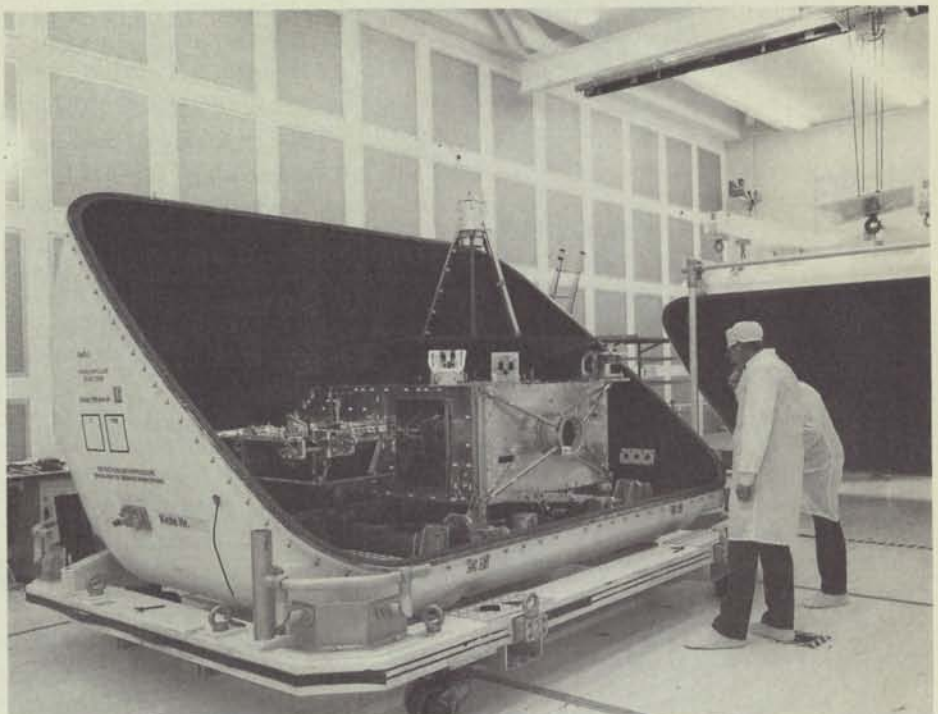
Although the ISPM spacecraft was put into storage last year, and will remain there until February 1985, activities associated with the recertification, the launch and operations continue as planned.

The Phase II Ground Safety Review at Kennedy Space Center (KSC) was concluded successfully in May and a Mission Operations System Review, together with a Science Working Team Meeting, took place at ESOC during the month of June. Meetings of the Mission Design Panel and the Mission Integration Panel, which control the numerous and very complex relationships with the STS and the Centaur Launcher, have also been held.

The development of the Radio-isotope Thermo-electric Generator (RTG) continues on schedule in the USA, whilst in Europe good progress has been made in developing RTG handling and installation procedures, aimed at minimising human exposure to radiation from the RTG during its installation in the spacecraft at KSC.

On the payload side, all flight experiments are being calibrated or are undergoing the final refurbishment necessary after the spacecraft test phases. Some Principal Investigators have started to exchange hi-rel parts which were not considered sufficiently radiation-hardened against the Jupiter environment.

Finally, following a proposal from Prof. B. Bertotti, of the University of Pavia, it has been decided to rename ISPM at launch. The new name will be 'Ulysses', in reference to Dante's Inferno and 'the uninhabited World beyond the Sun'.



Modèle de vol du véhicule spatial d'ISPM avant stockage

The ISPM flight-model spacecraft being readied for storage *rebaptiser l'ISPM au moment du lancement. Il s'appellera Ulysse, d'après l''Enfer' de Dante qui évoque un 'monde inhabité au-delà du soleil'.*

Hipparcos

Les négociations contractuelles avec le contractant principal et les sous-traitants responsables de la charge utile et des sous-systèmes du véhicule spatial ont progressé et des réunions ont eu lieu entre pratiquement tous les intéressés. Ces réunions ont de façon générale abouti à un accord sur la conception de référence technique et à l'élimination de nombreux problèmes qui n'avaient pas trouvé de solution depuis le démarrage du projet. Sur le plan technique la situation a dans l'ensemble progressé conformément aux plans et certains éléments de matériel au niveau 'modèle sur table' et 'développement' sont en cours de fabrication, notamment pour la charge utile. Le combinateur de faisceaux mérite une mention spéciale. Il s'agit d'un miroir découpé en deux parties collées de façon à superposer dans le plan focal du télescope d'Hipparcos deux champs de visée séparés par un angle de 58°. Les impératifs à satisfaire en ce qui concerne la qualité de la surface du combinateur de faisceaux se situent à la pointe de la technologie et le fait d'avoir récemment démontré la possibilité de conserver au miroir sa qualité de surface après l'avoir taillé est considéré comme un succès majeur en matière de développement.

Artist's impression of the Hipparcos spacecraft

Vue conceptuelle d'Hipparcos

Giotto

L'intégration du modèle de vol du véhicule spatial a débuté ce printemps chez BAe à Bristol. Le programme d'intégration a fait appel, en cas de besoin, à des rechanges à la place des unités de vol avec lesquelles on a rencontré des difficultés. La dernière semaine de mai, le véhicule spatial a subi avec des résultats encourageants les essais EMC préliminaires au niveau système. Les activités d'intégration finale se poursuivent aux installations du CNES à Toulouse en préparation de l'essai de simulation solaire qui débute le 16 juillet 1984. La rigidité du calendrier de Giotto ne laissant pas de place à un modèle de vérification thermique, l'essai dans le simulateur solaire constituera un élément extrêmement important de la validation du véhicule spatial car ce sera le premier essai comparatif avec la conception thermique modélisée sur calculateur.

Les négociations commerciales au sujet du lanceur Ariane 1 se poursuivent; l'accord s'est fait sur les aspects techniques du lancement. La campagne commencera le 25 avril 1985 pour durer une dizaine de semaines, la date prévue pour le lancement à l'ouverture du créneau d'un mois étant fixée au 1er juillet 1985. L'allongement de la campagne a été négocié de façon à disposer dans le programme lui-même d'une marge d'aléas sur la base de lancement.

A propos des activités en vol, un grand pas a été franchi avec la conclusion d'un accord avec l'Académie des Sciences de l'Union soviétique et la NASA pour l'utilisation des données de 'l'Eclaireur'. Le satellite soviétique VEGA, dont la trajectographie sera assurée avec une très grande précision par la NASA au moyen des techniques d'interférométrie à très longue base, fournira à Giotto des données précises sur la position du noyau de la comète quelques jours avant la rencontre du satellite avec la comète de Halley. Les incertitudes de visée réduites ainsi dans des proportions spectaculaires se traduiront par une amélioration générale de la mission.

ISO

Après le choix de l'ISO comme le prochain projet scientifique de l'Agence, les travaux préparatoires ont commencé dans deux directions. Au cours des deux derniers mois, deux étapes importantes pour l'ensemble du projet ont été franchies.

Il s'agit d'abord de l'approbation d'une politique d'approvisionnement d'ensemble par le Comité de la Politique industrielle (IPC) le 25 avril 1984. Celle-ci a eu pour conséquence directe les négociations de gré à gré actuellement menées avec la SNIAS (France) et, par son intermédiaire, d'autres sociétés destinées à constituer l'équipe industrielle chargée de mener à bien la réalisation de ce satellite qui pose des problèmes délicats et appelle des solutions spécifiques.

Le 6 juin 1984, le Comité de la Politique scientifique (SPC) a approuvé le plan de gestion scientifique de l'ISO concernant les relations entre l'Agence et la communauté scientifique (y compris les chercheurs principaux) pendant la phase de réalisation ainsi que les plans relatifs à l'Observatoire ISO. Ceci aura pour résultat immédiat le lancement officiel des offres de participation aux communautés scientifiques européennes et américaines au mois de juillet de cette année.

Olympus

Tous les examens de la base de référence de développement qui restaient à faire au niveau des sous-systèmes de la plate-forme et de la charge utile ont été tenus dans l'industrie par le contractant principal. La documentation technique nécessaire à l'examen de la base de référence de développement (DBR) au niveau système qui doit être menée par l'Agence au début de juillet, est en cours d'acheminement.

Les principaux essais statiques sur le modèle structurel du véhicule spatial pour les deux hypothèses de lancement Ariane et STS ont été menés à bonne fin. Le modèle structurel va être déposé à partir du montage d'essai et remis en configuration avec des masses simulées pour la série d'essais dynamiques.

Hipparcos

Contractual negotiations with the Prime Contractor and subcontractors for payload and spacecraft subsystems have progressed to the point where meetings have been held with almost all parties. The meetings have generally resulted in the agreement of the technical baseline and closure of many of the issues that were regarded as open at the time of project kick-off. Technical progress has continued generally to plan, with certain items of breadboard and development hardware, particularly for the payload, being produced.

An item of special interest is the beam combiner; this is a mirror which is cut in half and the two pieces glued together in such a way as to achieve superposition of two fields of view in the focal plane of the Hipparcos telescope separated by a wide angle (58°). The requirements for the beam combiner's surface quality are at the limits of the available technology and the recently demonstrated ability to retain surface quality after mirror cutting is seen as a major accomplishment.

Giotto

Flight-model spacecraft integration was initiated in the spring at BAe, Bristol. The integration programme has proceeded using backup units where necessary as substitutes for those flight units that were experiencing problems. During the last week of May, the spacecraft was subjected to preliminary EMC system tests with encouraging results. The final integration activities are continuing at the CNES facilities in Toulouse in preparation for the Solar Simulation Test, starting on 16 July 1984. Since the tight Giotto schedule could not accommodate a thermal-verification model, the Solar Simulation Test is an extremely important part of the spacecraft's validation and will represent the first test comparison with thermal computer-model design.

Commercial negotiations for the Ariane-1 launcher are continuing and agreement on the technical aspects has been reached. The Giotto launch campaign will begin on 25 April 1985, lasting some 10 weeks, for a scheduled launch at the opening of the one-month launch window on 1 July 1985. This extended campaign was negotiated to provide a built-in contingency at the launch range.

Concerning flight operations, a major milestone was reached in achieving agreement with the Russian Academy of Sciences and NASA for Pathfinder implementation. The Soviet Vega spacecraft, which will be accurately tracked by NASA using very-long-baseline interferometry techniques, will provide accurate comet-nucleus position data to Giotto a few days before the Giotto encounter with Halley. The reduction in targeting uncertainty will be dramatic, resulting in overall enhancement of the mission.

ISO

Following the selection of ISO as the next scientific project in the ESA programme, preparatory work has been started along two main lines. Within the last two months, two major milestones have been achieved, which have a significant influence upon the overall project.

The first was the agreement on an overall ISO procurement policy by the Agency's Industrial Policy Committee (IPC) on 25 April 1984. As a consequence, direct negotiations are now underway with SNIAS (France) and, through them, with other companies to form the industrial team that will be responsible for the successful completion of this difficult and challenging satellite.

On 6 June 1984, the ESA Science Programme Committee (SPC) approved the ISO Science Management Plan, which deals with relationships between ESA and the scientific community (including the Principal Investigators) during the ISO development phase and the plans for the ISO Observatory. An immediate result of this will be the formal Announcement of Opportunity to the scientific communities in Europe and the USA in July of this year.

Olympus

All the remaining payload- and platform-subsystem Development Baseline Reviews have now been held with industry by the Prime Contractor. Technical documentation is being received for the system-level Development Baseline Review (DBR), which is due to be conducted by the Agency at the beginning of July.

The major static tests on the spacecraft structural model, for both the Ariane and STS launch options, have been completed with satisfactory results. The structural model will be disassembled from the test rig and reconfigured with mass dummies for the series of dynamic tests.

Work has continued on thermally equipping the service and propulsion modules of the spacecraft thermal model, while thermal-vacuum tests have been conducted successfully on the north and south communications module radiators.

Engineering-model equipment level manufacture and test continues. Integration has started on each of the four payload-element engineering-model subsystems and is driven by the availability of equipment. Antennas have been tested on the antenna ranges and the first part of the qualification testing of the Astromast for the solar array has been completed satisfactorily.

The small study contracts placed to investigate the potentially critical areas of the earth segment are nearing completion. Specifications for the earth stations needed for the Olympus earth segment are being prepared by the Agency and the first of the series of calls for tender are in the process of being issued.

Spacelab

The de-integration of Spacelab-1 has been completed and the preparations for Spacelab-2 are well underway at Kennedy Space Center.

The subsystem checkout is proceeding and should be completed by mid-June 1984, prior to the IPS delivery from Dornier.

The remaining Spacelab-1 anomalies have been resolved. The High-Data-Rate Recorder (HDRR) design has been updated and the HDRRs will be modified prior to any future flights. The 'RAU 21'

Les travaux d'équipement des modules de service et de propulsion du modèle thermique du véhicule spatial se sont poursuivis tandis que des essais thermiques sous vide étaient menés avec succès sur les radiateurs nord et sud du module de télécommunications.

La fabrication et les essais au niveau équipements se poursuivent sur le modèle d'identification. Les travaux d'intégration ont débuté sur chacune des quatre charges utiles avec des sous-systèmes du modèle d'identification, mais leur progression est subordonnée à la disponibilité des équipements. Les antennes ont été essayées sur les bases d'essai tandis que la première partie des essais de qualification de 'l'Astromast' du réseau solaire a été menée de façon tout à fait satisfaisante.

Les petits contrats d'étude passés pour examiner les points éventuellement critiques du secteur terrien sont en voie d'achèvement. Les spécifications des stations terriennes nécessaires pour le secteur terrien d'Olympus sont en cours de préparation à l'Agence et le premier d'une série d'appels d'offres est en voie de publication.

Spacelab

Le démontage de Spacelab-1 a été achevé et les préparatifs de la mission SL-2 au Centre spatial Kennedy (KSC) sont bien avancés.

La vérification des sous-systèmes progresse et devrait être terminée pour la mi-juin 1984 avant la livraison de l'IPS par Dornier.

Les points qui restaient à résoudre au sujet des anomalies survenues au cours de la mission SL-1 ont été réglés. La conception de l'enregistreur de données à haut débit (HDRR) a été corrigée et ces équipements seront modifiés avant tout nouveau vol. On a constaté que la défaillance qui a affecté l'unité d'acquisition RAU 21 ne tenait pas à l'unité elle-même. Les essais poussés qui ont été faits au SEL, à l'Université de Stuttgart et au Centre des vols spatiaux Marshall (MSFC) ont montré que le problème se situait au niveau du bus de données et non de la RAU proprement dite.

Il n'a malheureusement pas été possible de compléter les recherches par des essais sur la configuration SL-1, le démontage ayant eu lieu. Des essais supplémentaires ont toutefois été introduits dans les futures séquences de vérification du Spacelab de façon à éviter la réapparition de ce problème.

Les vols SL-3 et SL-2 sont maintenant prévus pour janvier et avril 1985.

Production ultérieure (FOP)

Le consortium chargé du Spacelab poursuit ses travaux sur les rechanges et autres pièces d'équipement additionnelles commandées par la NASA. L'Agence américaine continue d'adresser de nouvelles commandes mais en nombre assez limité. Des propositions industrielles sont en préparation pour la fourniture de deux nouveaux lots de rechanges pour sept bâtis d'expériences, un ensemble de planchers à expériences et des matériels multiplexeurs. Des demandes de propositions ont d'autre part été faites pour l'approvisionnement d'un équipement calcul supplémentaire (à fournir par CIMSA) et d'un certain nombre de dispositifs d'affichage de données (à fournir par Thomson-CSF). Il est toutefois difficile d'obtenir des fournisseurs de ces équipements des articles identiques à ceux qui ont été fournis pour la phase C/D, comme le demande la NASA. Ils préfèrent offrir des matériels équivalents basés sur une technologie plus récente.

L'assemblage et l'intégration du module de base court (SCM) se poursuivent.

Les essais 'système' finals du SCM sont en cours. La préparation de l'inspection de la configuration et de l'examen préalable aux essais du module de base court est terminée. Les deux examens 'clients' que la NASA et l'ESA ont effectués au cours de la première semaine de mai ont abouti à des conclusions très satisfaisantes et le feu vert a été donné à ERNO pour l'exécution des essais du SCM au niveau système. La situation de la documentation relative à la configuration du matériel a été jugée excellente et celle du matériel a été jugée adéquate pour le passage aux essais. ERNO, le contractant principal, a réexaminé le calendrier et annonce que moyennant des mesures spéciales, la livraison devrait être possible avec une (seule) semaine de retard par rapport à la date contractuelle, sous réserve qu'aucune défaillance majeure ne se produise au cours des prochains essais. La livraison du SCM aurait lieu le 9 août 1984.

Les essais au niveau système de la configuration Igloo/Porte-instruments sont achevés. Des problèmes assez peu nombreux de matériel/logiciel sont apparus au cours de cette phase d'essai, dont certains sont encore à l'étude. L'ESA et la NASA ont procédé à la recette 'clients' définitive au cours de la première semaine de juin 1984.

Pour l'IPS-FOP, le programme de la phase C/D reste l'élément déterminant du calendrier de la production. Les besoins en matériel FOP ont été redéfinis dans le cadre de ce programme; l'utilisation d'éléments supplémentaires est maintenant prévue. En outre, une défaillance matérielle qui a affecté des éléments FOP a demandé, pour l'analyse de la défaillance, la réparation et les nouveaux essais nécessaires, un temps considérable qui a eu pour incidence directe de retarder de cinq semaines le calendrier de livraison FOP.

SPACELAB MISSIONS MANIFEST, as of 30 May 1984

Date		Designation/Orbiter/Orbit Inclination	Major discipline(s)	Configuration
January	1985	SL-3/DISCOVERY/57 deg.	Material Sciences and Life Sciences	Long module + pallet
April	1985	SL-2/CHALLENGER/50 deg.	Astronomy	Igloo + 3 pallets
October	1985	GERMAN D-1/COLUMBIA/57 deg.	Material Sciences and Life Sciences	Long module + 1 pallet
November	1985	EOM-1/ATLANTIS/57 deg.	Atmospheric Physics + SL-1 reflights	Short module + 1 pallet
January	1986	SL-4/CHALLENGER/28.5 deg.	Life Sciences	Long module
May	1987	SL-8/ATLANTIS/57 deg.	International Microgravity Laboratory	Long module + 1 pallet
January	1988	SL-J/CHALLENGER/57 deg.	Microgravity (Japan)	Long module + 1 pallet
June	1988	SL-10/COLUMBIA/57 deg.	Life Sciences	Long module + 1 pallet
November	1988	German D-2/ATLANTIS/57 deg.	Microgravity	Igloo + 4 pallets

failure has been found not to be due to the Remote-Acquisition Unit itself. Extensive tests at SEL, the University of Stuttgart and at Marshall Space Flight Center have shown that the problem was within the data-bus set up and not within the RAU itself.

Unfortunately the Spacelab-1 configuration had been dismantled so further testing on that configuration was not possible. However, extra testing has been introduced into the future Spacelab checkout sequences so that this problem will not occur in the future.

The present flight dates for Spacelab-3 and Spacelab-2 are now January 1985 and April 1985, respectively.

Follow-on Production (FOP)

Work in the Spacelab Consortium is proceeding on spares and other additional hardware items ordered by NASA. Additional orders continue to be received from NASA, but on a relatively small scale. Industrial proposals are in preparation for two further increments of spares, for seven experiment racks, a set of experiment floors and for multiplexer hardware. Proposals have also been requested for one additional computer (supplied by CIMSA) and some data-display units (supplied by Thomson-CSF). However, in these cases difficulties are being experienced in obtaining offers from the suppliers for items identical to Phase-C/D, as required by NASA. The companies concerned prefer to offer equivalent hardware based on more recent technology.

Assembly and integration of the Short Core Module (SCM) is proceeding; final SCM system testing is in progress. The preparations for the Configuration Inspection and the Pre-Test Review for the Short Core Module have been completed. Two customer reviews were conducted by NASA and ESA during the first week of May, with very satisfactory conclusions. Authorisation to proceed with SCM system-level testing was given to ERNO. The reviews established that the documentation is in excellent condition vis-a-vis the hardware configuration and that the hardware is in acceptable condition to proceed to the subsequent tests. The schedule has been re-assessed by the Prime Contractor (ERNO), and delivery with only a one-week delay relative to the contractual date may still be possible, provided no major failures are experienced in the forthcoming testing. The projected delivery date for the SCM is 9 August 1984.

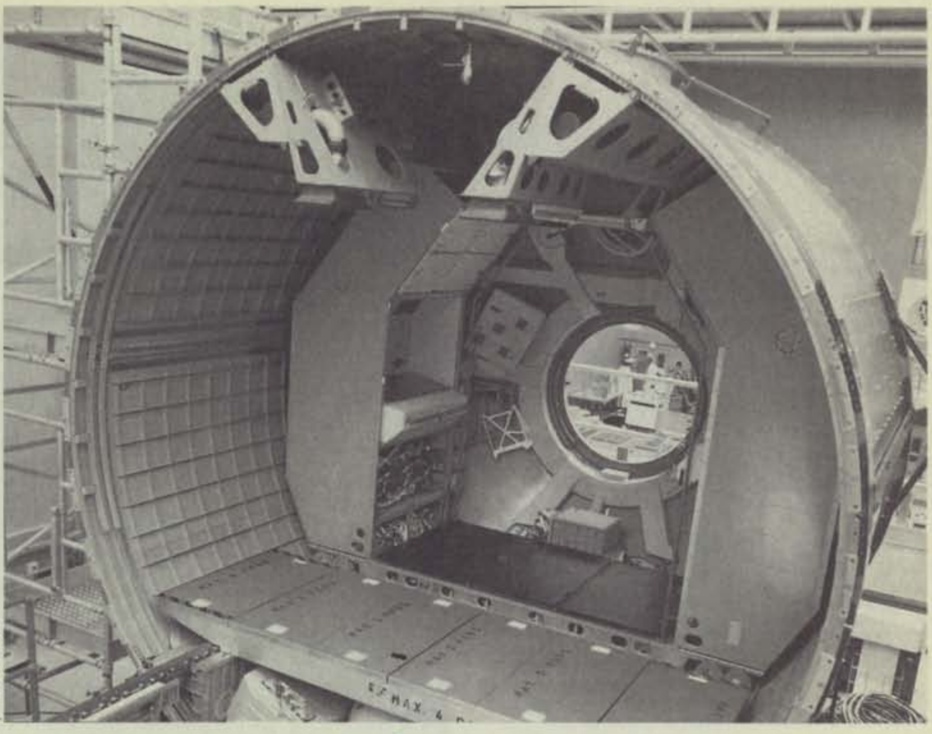


photo: Erno

Module court du Spacelab (SCM) au cours des derniers essais d'intégration chez ERNO, Brême, avant d'être envoyé au Centre Spatial Kennedy en août 1984

Spacelab Short Core Module (SCM) undergoing final test and integration at ERNO, Bremen, prior to shipment to KSC in August 1984

The system test for the Igloo/Pallet configuration has been completed. A relatively small number of hardware/software problems have been experienced during this test phase, some of which are still under investigation. ESA and NASA will conduct the final customer acceptance during the first week of June 1984.

In the Instrument Pointing Subsystem (IPS) FOP, the Phase-C/D programme continues to drive the production schedule. The C/D programme has re-defined the need for FOP hardware; additional items are now planned to be used. In addition, a hardware failure has been experienced on FOP items, which required considerable time for failure analysis, repair and retest, resulting in a direct impact of five weeks delay in the FOP delivery schedule.

Remote Sensing

FSLP

Metric-Camera image dissemination to experimenters is proceeding as fast as possible. Requests for images are arriving faster than the production rate, which is leading to unavoidable, but understandable, frustration. This situation should soon improve. The first results of image analysis are very encouraging. Meanwhile, arrangements are underway to re-fly the camera on Shuttle mission EOM-1 in mid-1985.

The partial failure of the Microwave Remote-Sensing Experiment (MRSE) during the mission is still under investigation.

ERS-1

As a result of the various participants' meetings, and the work of the Remote-Sensing Programme Board, continued cover has been provided by Member States to maintain the industrial effort until the formal arrangement for Phase-C/D and E are signed by the Participating States.

IPS

The flight model of the Instrument Pointing Subsystem (IPS) is now in system qualification testing, and approximately 50% of the tests have been completed

Spacelab-1 Metric Camera image of the Gulf, processed by DFVLR for ESA/Earthnet

Image du Golf prise par la chambre photogrammétrique à bord du Spacelab-1 et traitée par le DFVLR pour le compte du programme Earthnet de l'ESA

Télédetection

FSLP

La production d'images de la chambre photogrammétrique pour les expérimentateurs se poursuit à cadence soutenue. Les demandes d'images affluent à un rythme supérieur à celui de la production, d'où un temps d'attente inévitable et une certaine impatience bien compréhensible. La situation devrait finir par s'améliorer. Les premiers résultats de l'analyse des images sont très encourageants. Pour l'instant, des dispositions sont prises en vue d'un nouvel emport de l'instrument dans le cadre de la mission EOM-1 de la Navette à la mi-1985.

La défaillance partielle de l'expérience de télédétection à hyperfréquences (MRSE) pendant la mission est encore à l'étude.

ERS-1

A la suite des différentes réunions des participants et des travaux du Conseil directeur du programme de télédétection, les Etats membres ont assuré la couverture nécessaire pour soutenir l'effort industriel jusqu'à ce que les Etats participants aient signé la Déclaration relative aux phases C/D et E.

IPS

Le modèle de vol de l'IPS en est maintenant au stade des essais de qualification au niveau système, dont environ 50% ont été menés à bien. Plusieurs problèmes de compatibilité ont été relevés à ce niveau et quelques modifications de la conception sont nécessaires. Le logiciel de l'IPS subit également les essais de qualification et l'achèvement de ces activités sera retardé.

Les essais de qualification au niveau système serviront aussi pour la recette de l'IPS. Du fait des problèmes mentionnés plus haut, l'IPS arrivera au Centre spatial Kennedy en retard sur la date de livraison prévue mais ceci ne devrait pas avoir d'incidence sur la date de lancement de Spacelab-2.

Microgravité

Biorack

La fabrication et l'intégration des éléments du Biorack se poursuivent; en raison de problèmes apparus en cours d'intégration, l'achèvement des essais au niveau des éléments a dû être repoussé à la mi-juillet. On procède actuellement à une révision complète du calendrier de l'intégration et des essais au niveau 'système' afin de déterminer les mesures à prendre pour pouvoir respecter la date fixée pour la livraison du modèle de vol en vue de son intégration dans le Spacelab.

La conception de l'équipement particulier à la mission est terminée et sa fabrication est en cours. L'intégration et les essais des matériels fournis par les expérimentateurs se poursuivent de façon satisfaisante.

Des stages ont été organisés pour familiariser l'équipage de la mission D-1 avec les objectifs scientifiques et la description technique du Biorack. L'examen de sécurité s'est terminé avec de bons résultats.

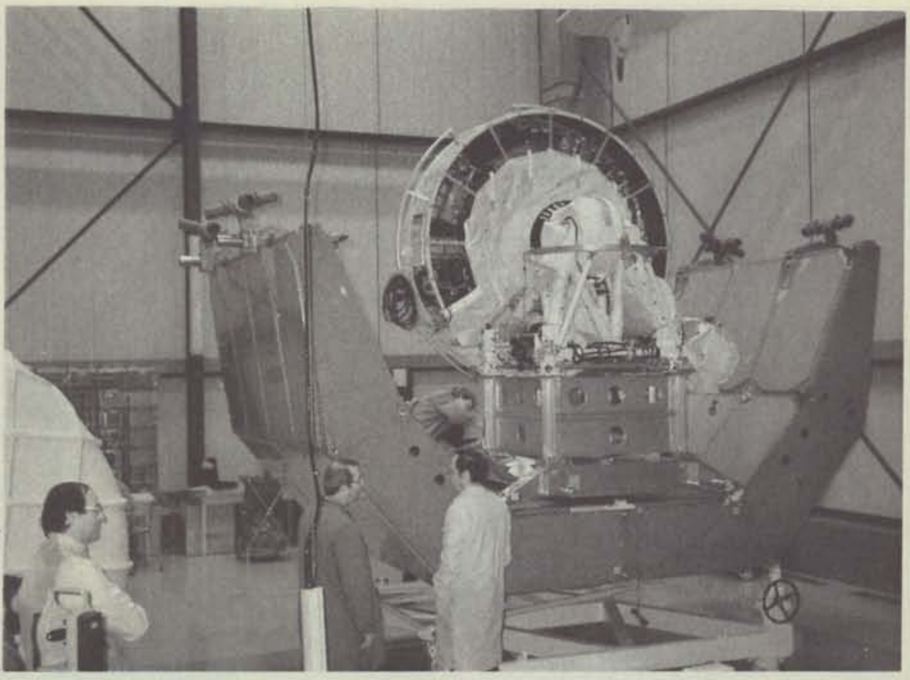
Eureca

Les résultats de l'étude de phase B sur Eureca ont été présentés en avril au Conseil directeur du Programme Spacelab, qui a entériné la recommandation faite par l'ESA de réduire la complexité de la première charge utile Eureca aux fins d'économies. Il a cependant été décidé de retenir le système de refroidissement à fluide pour les fours de recherche en microgravité et d'embarquer pour la première fois dans l'espace la mémoire à bulles magnétiques européenne récemment mise au point.

La demande de prix (RFQ) relative à la phase C/D d'Eureca a été communiquée à la mi-avril à MBB/ERNO, en qualité de chef de file d'une équipe industrielle internationale. De nouvelles directives y étaient données à l'industrie, portant sur l'introduction du bus de données Spacelab pour connecter les charges utiles au moyen des adaptateurs d'interface de processeurs (PIA) mis au point par Laben, du réseau solaire rétractable mis au point par Fokker et de la mémoire à bulles magnétiques de la Sagem.

La définition du noyau de charge utile de recherche en microgravité avance conformément aux plans et le choix final des équipements de vol de la première mission Eureca est prévu pour la mi-juin.

Des études sont en cours sur l'adaptation d'Eureca à des missions futures dans les



Le système de pointage d'instruments du Spacelab

The Spacelab Instrument Pointing Subsystem (IPS)

successfully. Several system-level compatibility problems have been identified and some design changes are necessary. The IPS software is also in qualification testing and completion will be delayed.

The system qualification tests also serve to satisfy the IPS acceptance test objectives. In view of the problems mentioned above, the scheduled delivery date to Kennedy Space Flight Center will not be met, but this delay is not expected to have an impact on the Spacelab-2 launch date.

Microgravity

Biorack

The manufacture and integration of the Biorack units are progressing; problems encountered during unit integration have delayed the completion of unit-level testing to mid-July. The schedule for system-level integration and testing is being completely revised to determine the measures necessary to maintain the delivery need date for the flight model's integration into Spacelab D-1.

Mission-peculiar equipment design has been completed and manufacture is in progress. The integration and testing of the experimenter-provided hardware are progressing satisfactorily.

The scientific objectives and a technical description of the Biorack have been presented to the Spacelab D-1 crew. The Safety Review has been satisfactorily completed.

Eureca

The results of the Eureca Phase-B (definition phase) study were presented in April to the Spacelab Programme Board, which endorsed ESA's recommendation to reduce the complexity of the first Eureca payload for cost reasons. However, it was decided to reinstate the liquid loop for the cooling of the microgravity furnaces and to fly the newly developed European magnetic bubble memory for the first time.

The Request for Quotation (RFQ) for Eureca's Phase-C/D (main development phase) was released by mid April to MBB/ERNO, as leader of an international industrial team. This RFQ included a redirection to industry to introduce the Spacelab data bus to interface with the payloads via Processor Interface Adapters (PIAs) developed by Laben, the retractable solar-array developed by Fokker and the magnetic bubble memory from Sagem.

The definition of the microgravity core payload is proceeding according to plan. Final selection of the flight complement for the first Eureca mission is planned for mid-June.

Studies for the adaptation of Eureca for future missions in the fields of: solar-system observations, geodesy and geophysics, astronomy, Earth observation, technology, and pharmacy are underway, aimed at the development of a Eureca mission model by October this year.

The start of Phase-C/D for Eureca is now planned for October 1984 and launch is anticipated about 40 months later.

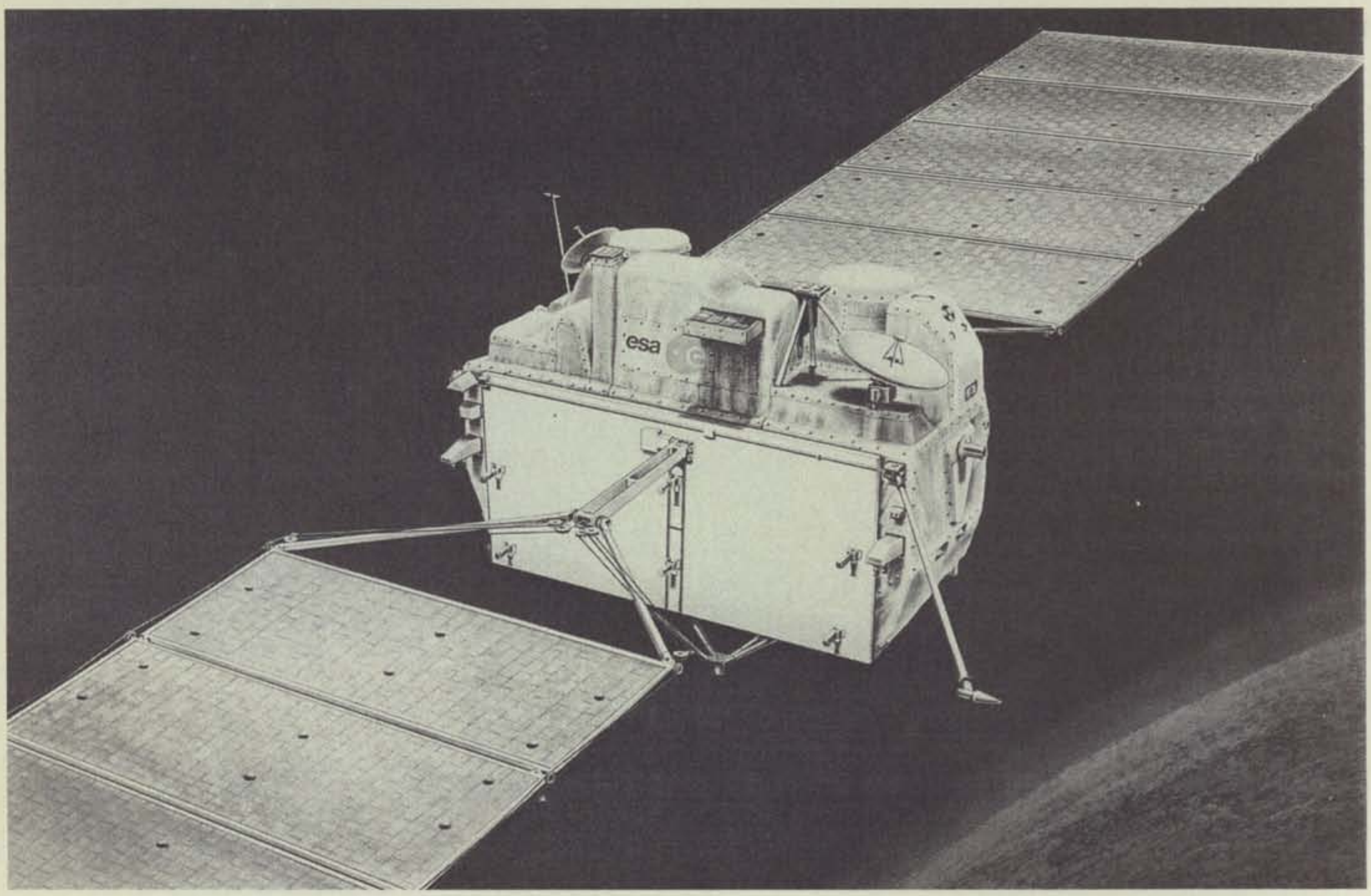
Ariane

Ariane-3 launcher ground qualified

Since the Ariane-3 development programme does not include any test flights, qualification consisted of carrying out two types of check on the ground:

- studies, calculations and tests on the elements that are new or modified compared to Ariane-1 (solid boosters, thrust increase for the first- and second-stage Viking engines, increased burn-time for the third stage, strengthening of the structures and biconic fairing);
- checking the capability of the unmodified elements to fulfil the mission under Ariane-3 conditions (duration and environment).

When about 90% of the qualification reviews of the various elements had taken place, ESA and CNES set up a Ground Qualification Review Board (GQRB) consisting of members of ESA, CNES and Arianespace, plus independent experts whose task was to assess the status of the launcher qualification. The GQRB, whose work started in September 1983, submitted a final report on 12 June 1984 to the ESA and CNES General Directorates, which approved it and presented it to the Ariane Launcher Programme Board on 14 June 1984. The latter declared the launcher qualified subject to the reservations made in the GQRB report, and in particular to the need for some of them to be lifted before the first Ariane-3 launch scheduled for 4 August 1984.



Artist's impression of the Eureca platform

Vue conceptuelle de la plate-forme récupérable Eureca

domaines:

- *observation du système solaire*
- *géodésie et géophysique*
- *astronomie*
- *observation de la Terre*
- *technologie et*
- *pharmacie*

avec pour but l'établissement d'un modèle de mission Eureca pour octobre prochain.

Le démarrage de la phase C/D d'Eureca est maintenant prévu pour octobre 1984, le lancement devant avoir lieu environ 40 mois plus tard.

Ariane

Le lanceur Ariane 3 est qualifié au sol

Le programme de développement du lanceur Ariane 3 ne comportant pas d'essais en vol, le qualification a consisté à effectuer au sol deux types de vérifications:

- *Etudes, calculs et tests sur des éléments nouveaux ou modifiés par rapport à ceux d'Ariane 1 (Propulseurs d'appoint à poudre, augmentation de la poussée des moteurs Viking des 1er et 2ème étages, augmentation de la durée de fonctionnement du 3ème étage, renforcement des structures, coiffe biconique).*
- *Vérification de la capacité des éléments non modifiés à remplir la mission dans les conditions Ariane 3 (durée, environnement).*

Alors que 90% environ des revues de qualification des différents éléments avaient eu lieu, l'ESA et le CNES ont institué une Revue de Qualification au Sol (RQS), constituée de membres de l'ESA, du CNES, d'Arianespace et avec participation d'experts indépendants, dont la tâche était d'évaluer l'état de qualification du lanceur. Cette Revue dont les travaux ont commencé en septembre 1983 a remis un rapport final le 12 juin 1984 aux Directions générales de l'ESA et du CNES qui l'ont approuvé et présenté au Conseil directeur Ariane le 14 juin 1984. Celui-ci a prononcé la qualification avec les réserves proposées dans le rapport de la RQS et notamment la nécessité d'en lever certaines avant le premier vol Ariane 3 prévu le 4 août 1984.

European Test and Operations Language Development Stimulates New Approach for Space Software

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In the development of general-purpose satellite checkout equipment, the software specification of the tests to be performed must be adapted to every project and the necessary data must be prepared by the test engineers responsible for that project. Over many years, a high-order language (user-level language) has been developed at ESTEC which enables each project to program its database and its command sequences. These are then run in real time on the Electrical Ground Support Equipment (EGSE) system for the project.

This approach has been adopted as a standard by the European community of prime contractors and is now being further developed for use in on-board systems.

History and background

In the early days of ESRO satellites, the supply of ground equipment was not the subject of any specific management policy and the development of a central organisation at ESTEC for the procurement and refurbishing of equipment and for programming of software was the result of a series of ad hoc decisions. Within the first five years it became clear that the writing of special software for each project was too inflexible and was not conducive to the development of consistent Assembly, Integration and Validation (AIV) procedures. In 1969, for the TD satellite, a start was made in the development of a monitoring procedure with a database formed by monitor tables which could be updated without reprogramming. To this was added a system for programming sequences of telecommands in a test sequence. In November 1973, when there already existed a sequencing system running on Honeywell computers, a new development called Checkout Test Language 1 (CTL1) was embarked upon, designed to run on the new Modular One machine for the Geos and Meteosat projects.

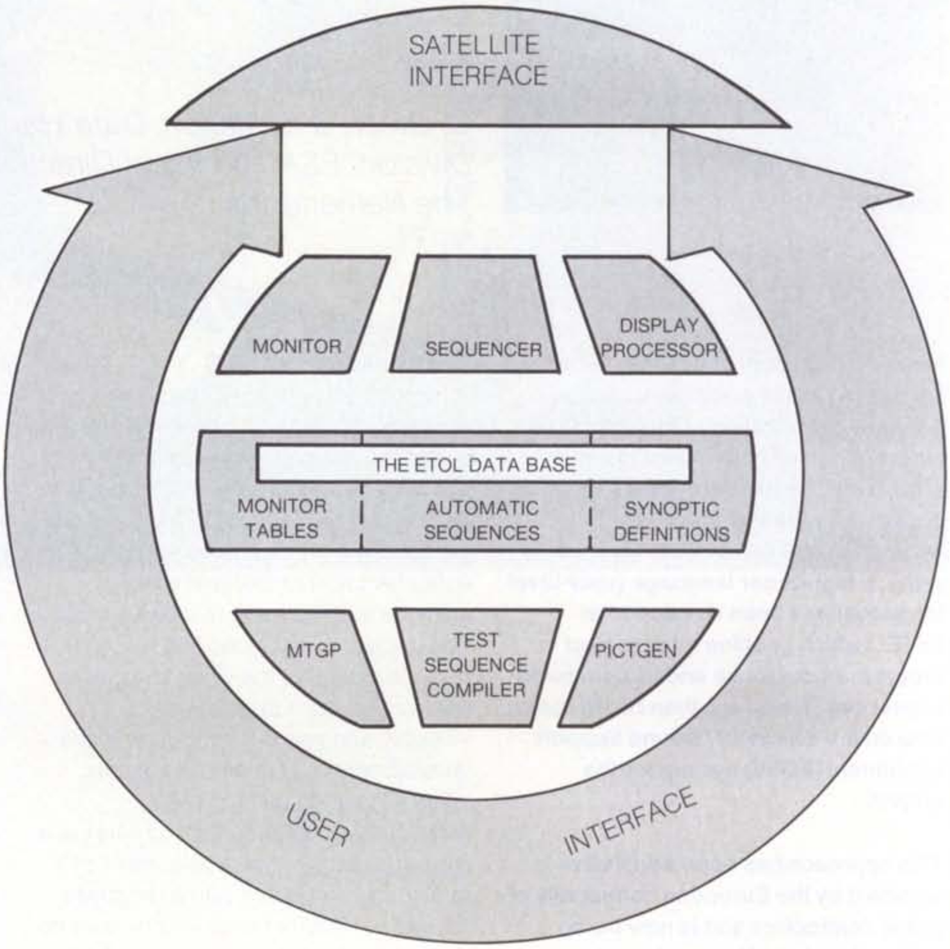
In 1976 a comparison was carried out on CTL1, the Honeywell developments and GOAL, which had just been adopted for Spacelab. The result was the publication in March 1977 of the first European Test and Operations Language (ETOL) draft specification. ETOL has been used on the Agency's Exosat and ECS/Marecs satellites and the Space Telescope Faint Object Camera, as well as for the IRAS satellite. The ECS/Marecs version was supplied to Telecom-1, while ESA's ISPM and Giotto have used later versions. The ISPM version was supplied to BAe for Olympus, while the Giotto version is under revision for supply to Matra (for Hipparcos, Eurostar and Unisat), Dornier (for ERS and Rosat), and ERNO (for Hipparcos and Eureca). During 1983 and 1984 the software running on the British CTL range of computers has been converted to provide an alternative implementation on the DEC VAX 11/750 range.

What is ETOL?

ETOL is a language that provides the means for building up the database needed to test a satellite. This database includes monitor tables, which contain upper and lower limits for any onboard parameter representing a measurement. Monitor tables also contain the logical connection between the current status and a specific pair of limits, as well as the data needed to verify that changes in current status are correctly related to external events such as telecommand sending. The database also includes the definitions of displays of diagrams depicting aspects of satellite status. These displays are built up by the user of the system, using interactive procedures to access a menu of standard possibilities, and can be used to highlight essential monitoring information.

In addition to monitor data and synoptic displays, the database also contains a library of command sequences, which is built up by the user. A sequence normally consists of sending one or more telecommands, collection of resulting

Figure 1 — The ETOL tool set



data, evaluation of the data, and a decision to proceed or to report an error according to the evaluation, this being repeated until the test is complete. Sequences can call other sequences, thus enabling the user to build very complex tests from previously checked short sequences. The language also includes the necessary control statements, which pass instructions to the operational system on which the actual checkout will be performed.

The database produced by ETOL is, of course, of little practical use without an operational checkout system which can use the data to perform a real-time checkout. It is, however, possible for the same database to be used by more than one operational system, eventually with different types of computer. This is of great potential value if the database needed for each phase of a satellite project can be a strict subset of a single database which will be run by an operational system appropriate to that phase. This ETOL could be used as a data specification language for payload units, for overall ground checkout, for autonomous onboard operations and for flight operations.

What does ETOL do for the user?
ETOL makes available a fully integrated set of tools for the satellite test engineer, realised in computer software. The aim of the tools is to provide three major functions, as depicted in Figure 1:
(i) automation of satellite test-procedure execution and documentation
(ii) monitoring of satellite data to verify correctness and assure safety
(iii) visibility into the progress of tests and into satellite current status through displays in ETOL.

The automation of the satellite test procedure
This is achieved by a 'programming' language that provides, in its syntax, the means to perform the measurements, data processing, control functions and data presentation required in the complex, time-consuming, test procedures. The language is similar in facilities and syntax to BASIC and, like BASIC, is interpretative. The statements written by the test engineer are translated by the ETOL 'compiler' into a condensed intermediate language, which is then interpreted in real time by the test-sequence interpreter.

The interpreter will execute 15 such test sequences in parallel, giving the test engineer a multiprogramming environment allowing parallel testing of several satellite functions. This programming language approach to satellite testing ensures fast and repeatable execution of the procedures required to verify the correct operation of satellite functions. Furthermore, the evidence that tests have been executed is provided in the output facilities of the language, which allow both direct printing of satellite test reports on line-printer logs and the long-term archiving of test results.

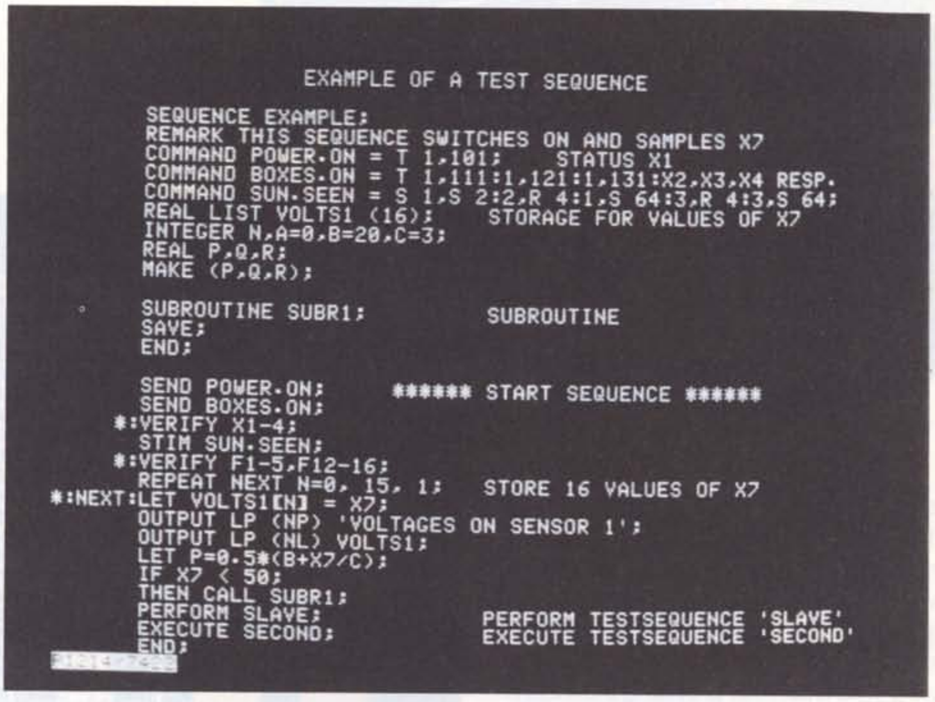
The statements of the language are categorised in Table 1.

Table 1 — ETOL test language statements

1. Boundary	6. Monitor control
2. Declaration	7. Hardware control
3. Control	8. Filing of data
4. Timing	9. Input/Output
5. Conditional	10. Miscellaneous

Figure 2 – Example of a test sequence

Figure 3 – Example of monitor parameters

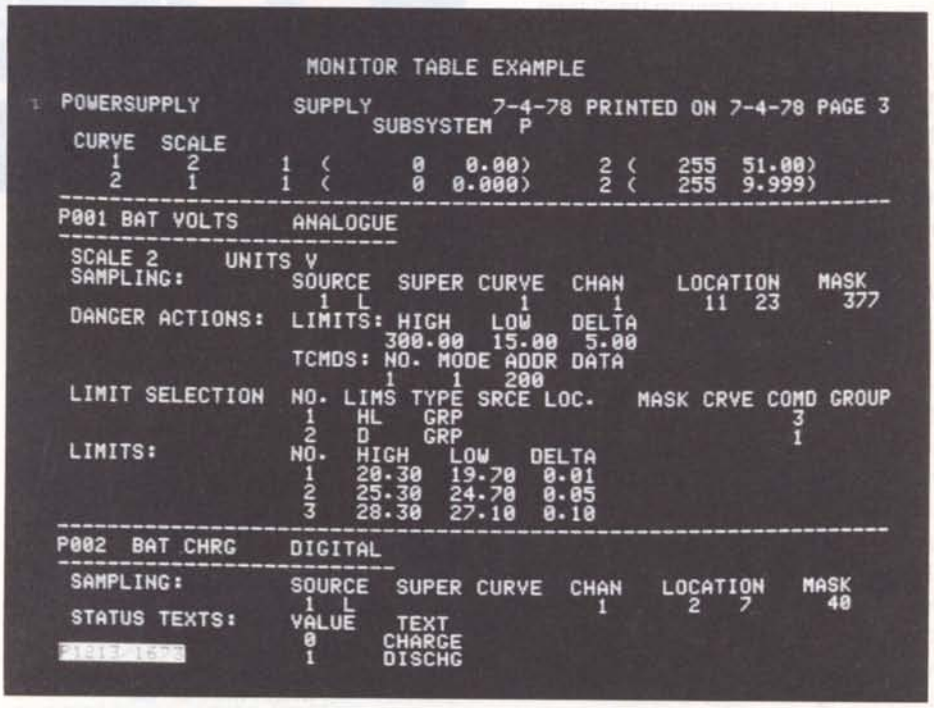


```
                 EXAMPLE OF A TEST SEQUENCE

       SEQUENCE EXAMPLE;
       REMARK THIS SEQUENCE SWITCHES ON AND SAMPLES X7
       COMMAND POWER.ON = T 1,101;    STATUS X1
       COMMAND BOXES.ON = T 1,111:1,121:1,131:X2,X3,X4 RESP.
       COMMAND SUN.SEEN = S 1,S 2:2,R 4:1,S 64:3,R 4:3,S 64;
       REAL LIST VOLTS1 (16);    STORAGE FOR VALUES OF X7
       INTEGER N,A=0,B=20,C=3;
       REAL P,Q,R;
       MAKE (P,Q,R);

       SUBROUTINE SUBR1;          SUBROUTINE
       SAVE;
       END;

       SEND POWER.ON;     ****** START SEQUENCE ******
       SEND BOXES.ON;
     *:VERIFY X1-4;
       STIM SUN.SEEN;
     *:VERIFY F1-5,F12-16;
       REPEAT NEXT N=0, 15, 1;   STORE 16 VALUES OF X7
 *:NEXT:LET VOLTS1[N] = X7;
       OUTPUT LP (NP) 'VOLTAGES ON SENSOR 1';
       OUTPUT LP (NL) VOLTS1;
       LET P=0.5*(B+X7/C);
       IF X7 < 50;
       THEN CALL SUBR1;
       PERFORM SLAVE;            PERFORM TESTSEQUENCE 'SLAVE'
       EXECUTE SECOND;           EXECUTE TESTSEQUENCE 'SECOND'
       END;
```



```
                    MONITOR TABLE EXAMPLE

 POWERSUPPLY       SUPPLY          7-4-78 PRINTED ON 7-4-78 PAGE 3
                         SUBSYSTEM  P
  CURVE  SCALE
    1      2        1  (       0   0.00)     2 (   255  51.00)
    2      1        1  (       0  0.000)     2 (   255  9.999)
-------------------------------------------------------------------
P001 BAT VOLTS     ANALOGUE
-----------------------------
 SCALE 2      UNITS V
 SAMPLING:         SOURCE  SUPER CURVE  CHAN    LOCATION   MASK
                     1  L           1      1      11  23     377
 DANGER ACTIONS:   LIMITS: HIGH   LOW   DELTA
                          300.00 15.00  5.00
                   TCMDS: NO. MODE ADDR DATA
                           1    1   200
 LIMIT SELECTION   NO. LIMS TYPE SRCE LOC.   MASK CRVE COMD GROUP
                    1   HL   GRP                         3
                    2   D    GRP                         1
 LIMITS:           NO.  HIGH   LOW   DELTA
                    1   20.30  19.70  0.01
                    2   25.30  24.70  0.05
                    3   28.30  27.10  0.10
-------------------------------------------------------------------
P002  BAT CHRG     DIGITAL
-----------------------------
 SAMPLING:         SOURCE  SUPER CURVE  CHAN   LOCATION   MASK
                     1  L                 1      2   7      40
 STATUS TEXTS:     VALUE    TEXT
                    0      CHARGE
                    1      DISCHG
```

Monitoring of satellite data

This is a process that must be performed whenever power is applied to the satellite, its purpose being to verify correctness of telemetry and its interactions with telecommanding, and to ensure that satellite parameters are within their prescribed operating limits. In addition, the monitoring facility provides a reference system to name the satellite parameters, conversion of all satellite data into engineering values, and access to this file of values for test sequence use (as a data type and presentation on displays).

The monitoring facility of ETOL is realised in two functions: a means to produce a database that defines the model of satellite telemetry and telecommand; and an on-line monitor program that compares the model with the satellite in real time.

The database program is called MTGP (Monitor Table Generator Program). It provides facilities to define, update, archive, list, regenerate and consistency check the model, in terms of parameters. The major attributes of a parameter are listed in Table 2.

Table 2 – Monitor parameter attributes

Reference code
Descriptive text
Type of measurement (analogue/digital)
Validity criteria
Sample rate
Limits of application
Dependence on other parameters
Actions to take on limit failure
Calibration curve
Status text
Telecommand descriptor

The monitoring program, which runs in real time, receives satellite telemetry and compares it with the data defined in the model for each parameter measured. All transmitted telecommands are also taken into account in order to update the model during the test. When deviations are detected an error report is displayed on the test conductor's display unit and logged on the test log file. If the measurement is outside limits defined in the database as 'danger limits', automatic predefined recovery actions can be executed. The actions take the form of telecommands to switch off (i.e. make safe) the offending satellite function or to commence execution of a test sequence

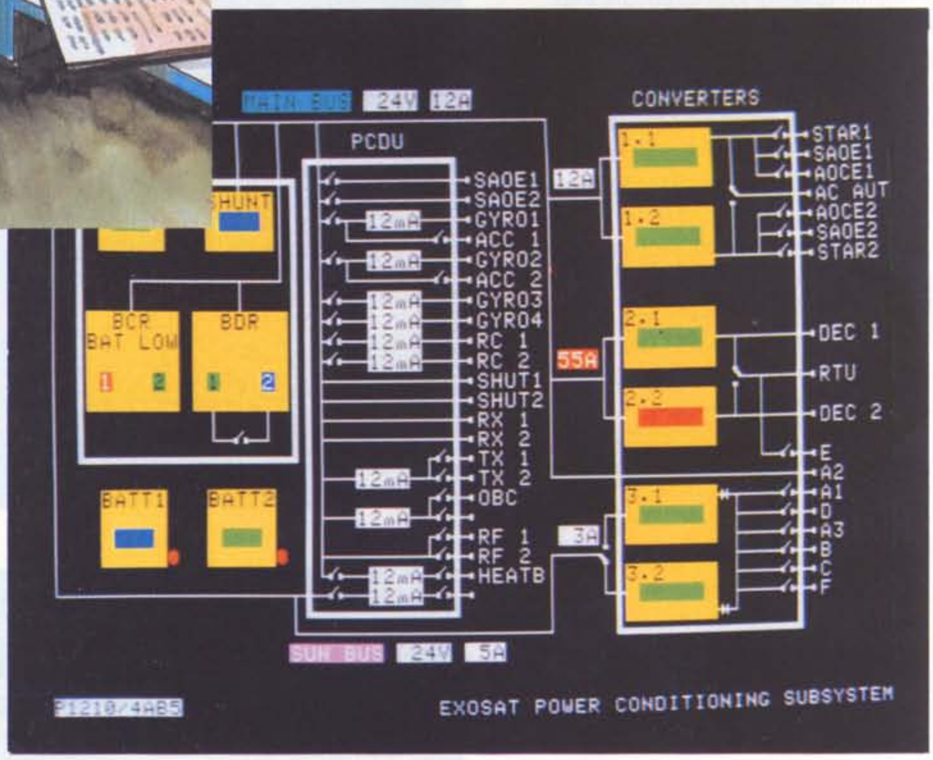


Figure 4 — Diagram of the power system of the Agency's Exosat satellite generated by the ETOL colour synoptic facility

should more complex actions be required. The monitoring process is also responsible for the generation of a file of values for all satellite parameters. The test-sequence language has access to this file by using the parameter reference as a data type, thus providing the means to perform calculations using satellite data directly in engineering (real) form.

The reference system for parameters during satellite-level testing is the same as that used by the Operations Centre, thus ensuring a smooth transition between testing and operations for the personnel involved.

Visibility into the status of running tests is provided by colour synoptic displays, backed up by visual display terminals.

The colour synoptic facility provides the test engineer with the tools to predefine block diagrams depicting satellite functions and to update these diagrams in real time with colour changes and data, to reflect the current state of the satellite test. Using this principle, a tree of synoptic diagrams can be generated, starting at the top with general satellite status and subdividing into major functions (subsystems), down to details of individual satellite measurements.

The diagrams are defined by the engineer using a display generator program (PICTGEN) in an interactive fashion. This generation process produces a display definition file, which will then be interpreted in real time by a display driver program. Table 3 lists the major attributes which can be used to construct a synoptic display diagram.

Table 3 — Colour synoptic display attributes

Blocks	Status text
Lines	Background colours
Arrows	Danger indicator
Text	Lamps
Intersections	Transistors
Engineering values	Diodes

The diagrams needed for a particular test are chosen by the test engineer either from his operating terminal or automatically using statements in the test-sequence language. The synoptic display driver program (TVPICT), having access to satellite telemetry, test-sequence data and monitoring parameter values file, can update the diagrams in real time using colour to identify good, marginal, error or danger situations.

The test engineers can also present information on their visual display terminals either as messages from the monitor process or as outputs from test sequences being controlled from that terminal. A set of control commands are available to operate all the facilities of ETOL as a single integrated system; that is to say, all the aforementioned tools are available as an online facility. It is not necessary to stop the checkout of the satellite in order to add or change test sequences, modify the monitoring database or change colour synoptic diagrams.

The system is structured in an open fashion to allow easy addition of new tools or those specific to a particular satellite project.

The European EGSE Standards

At the EGSE Round Table of 12 July 1983, at which almost all European Prime Contractors were represented, it was decided to set up collaborative Standards covering various aspects of EGSE work, including the user interface. A draft document describing ETOL was tabled at that time and forms the basis of the attempt to establish a firm European standard test language for the space industry. This represents a major change of policy both for the Agency and for industry, since the Agency is proposing to offer reference software and agreed standards for future checkout rather than complete EGSE systems. Industry, on the other hand will undertake EGSE procurement, but will guarantee the maintenance of AIV standards and visibility by using the standard language facilities.

There is, in addition to the ETOL standard, a communications standard, which deals with interfacing of other equipment to the central computer of an EGSE system, in particular by the use of a local-area network. It is anticipated that this standards approach to the control of EGSE systems will bring important benefits both to the Agency and to industry. On the Agency side, direct investment in checkout systems will be reduced, without loss of control or visibility for the Agency's satellite projects. For the user industry, problems of checkout planning, training and reuse of equipment will be minimised.

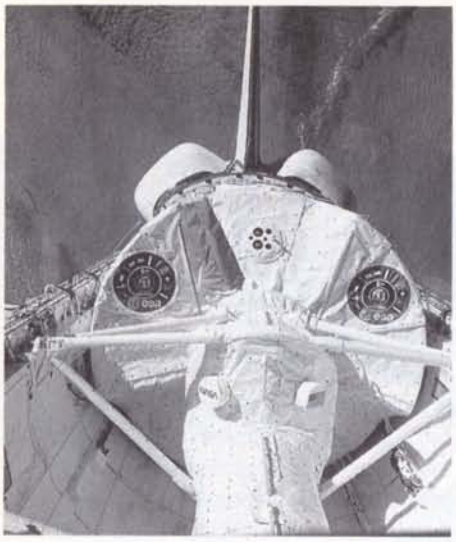
ETOL potential

There is an enormous disparity between the power of computing equipment being put aboard Agency satellites at present and power available in commercially available microprocessor systems. Indeed the challenge of onboard computing has to be seen not as how to fly sufficient processing power, but how to harness available power effectively. For both near-Earth and deep-space missions, strong arguments can be produced for a measure of satellite automomy, while for all satellites systematic methods of self-assessment can lead to a simpler user environment and improved use of communications bandwidth. One way of handling such new requirements is to transfer part of the ground operations into the onboard system.

The monitoring procedure used in checkout could be run by a central onboard system, and in normal operation only errors and anomalies reported. Of course, backup reporting procedures would be used for problem analysis either in flight or during ground testing. Command sequences can be handled in the same way, with command procedures stored onboard corresponding to necessary major functions, these being actuated by a single command from the ground.

Clearly the language used to express such command sequences and monitor procedures would need to be read by suitable software systems. It should not be developed for a single project, but should be developed for the widest possible range of spacecraft. If European industry can agree to a single language for pre-launch checkout, there should be no technical barrier to an agreement on a single language for onboard sequencing and monitoring. Indeed, the most plausible idea is to develop ETOL subsets for onboard use in such a way that the actual database can be verified in the checkout system and loaded into the onboard system. A real-time operating system capable of working with the database would, of course, have to be prepared for the onboard system, but this approach, with its separation of the onboard software system into operating system and applications layers, is demonstrably the most flexible and best adapted to the problem of fitting software production into a satellite project.

For the proposed space platform, where a requirement for checkout of experiments in orbit is involved, a demonstration of a possible ETOL adaptation has been proposed. It is hoped that we shall be able to go ahead with a study of an ETOL subset suitable for providing spacecraft automomy in the near future. The equipment suppliers will be able to make economies of scale, since their units will be compatible with a range of checkout systems.



Spacelab – From Early Integration to First Flight: Part 2

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In Part 1 of this article, Spacelab's integration and test at the ERNO facility in Bremen was described, culminating in the delivery of the prototype (Engineering Model) and flight units to NASA's Kennedy Space Center. Part 2 continues the Spacelab story, from its arrival at KSC until completion of the first mission last December. In addition, the working interfaces between NASA and ESA during this phase are described, and the programme for the future of Spacelab – both missions and development – is briefly discussed.

Introduction

In the late afternoon of 5 December 1980, a USAF C5A 'Galaxy' landed on the KSC Shuttle landing strip. The aircraft's enormous nose was raised and its contents, the Core Segment, Experiment Segment and three Pallets of the Spacelab Engineering Model, began to be unloaded (Fig. 10). The next day a Lufthansa Boeing-747 landed with a cargo of Ground Support Equipment, spares and documentation and the Spacelab operational phase began.

As noted in Part 1* of this article, NASA is responsible for the operational phase and this responsibility started with the crane lifting of the first Pallet from the aircraft onto the waiting truck. However, for a project as complicated and sophisticated as Spacelab, one cannot simply hand over responsibility instantaneously from one Agency to another, and to ensure a smooth transition of responsibility ESA is fulfilling a 'sustaining engineering' role until the end of the Spacelab-2 mission. Before describing the details of the hardware programme in the USA, it is worth dwelling on the aspects of this post-delivery support and the various NASA centres with which there is cooperation.

Post-delivery organisation

Considering first the European contribution to the operational phase, there are three main ESA-funded elements:

(i) *ERNO Post-Delivery Support Contract:* ESA has put the major partners of the Industrial Consortium under contract to provide engineering support. This support evaluates all design changes and produces the hardware modifications for those changes, under ESA's technical and financial responsibility. It provides for repair and/or replacement for items that suffer failure during the contract period (the 'European Depot Maintenance System'), and provides general engineering support to the Resident Team at Kennedy Space Center (KSC) and the other Spacelab operations in the USA.

(ii) *The ESTEC Spacelab Project Team,* which provides backup to this industrial contract, such that there is only a technical interface between the US operations and European support, all financial matters being handled between ESTEC and industry directly.

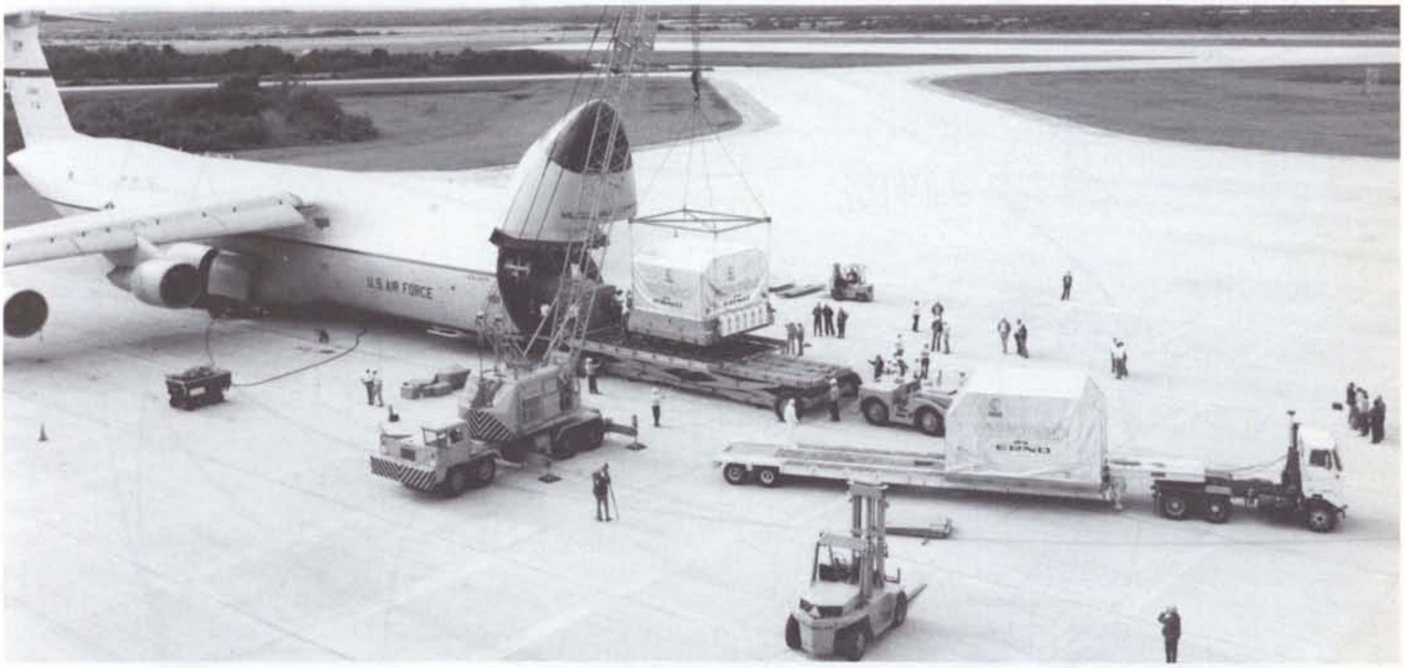
(iii) *The Spacelab European Resident Team at KSC:* this team of integrated Agency and industrial members acts as the direct interface to KSC and its contractor, the McDonnell Douglas Technical Services Company (MDTSCO). They are involved in the analysis and resolution of all the day-to-day technical problems, all urgent design changes found necessary as a result of processing, and all logistics efforts requiring European support.

All of these elements are also combined to provide on-site, real-time, support to mission operations for Spacelab-1 and -2.

Following the hardware shipments to KSC, with the back-up of this European sustaining engineering support, NASA took over responsibility for the operational phase, which involves activities at a number of NASA locations:

* See ESA Bulletin No. 38, pages 70 – 79.

Figure 10 – Arrival of Engineering-Model Pallets and Module at Kennedy Space Center (KSC), Florida



- Marshall Space Flight Center: MSFC will take over the role of ESTEC as the design agency, and this transition will be complete by the end of the Spacelab-2 mission. They are responsible for flight certification of each Spacelab mission, mission-specific design maintenance, and engineering of all improvements that they decide to incorporate. In addition, they were the procurers of the Spacelab Transfer Tunnel. Flight-operations support is provided by the Huntsville Operations Support Center (HOSC) and the Payload Operations Control Center (POCC), which is under MSFC management. Their main contractor is MDTSCO.
- Kennedy Space Center: KSC prepares the mission configuration for launch, including experiment assembly and checkout, Spacelab subsystem verification and integrated system testing. In parallel, the Shuttle External Tank, Solid-Rocket Boosters and Orbiter are readied for eventual cargo integration, checkout and launch. The main contractor for Spacelab processing at KSC is again MDTSCO, and the Shuttle contractor, originally Rockwell, is now Lockheed.
- Johnson Space Center: JSC is responsible for the technical management of the Orbiter, and also for the flight operations, taking over from KSC once the Shuttle has left the launch pad. The POCC is physically housed at JSC, in the Mission Control Center.
- Goddard Space Flight Center: GSFC provides the Spacelab Data-Processing Facility, which collects all the data transmitted from Spacelab through the Tracking and Data Relay Satellite System (TDRSS). It coordinates the network activities and distributes the resulting data to the experimenters.

These Centers are coordinated and controlled by the Spacelab Program Office in NASA Headquarters, which interfaces directly with ESA Headquarters in Paris.

Spacelab assembly and testing at KSC
After its arrival at the Shuttle Landing Facility at KSC, the Spacelab Engineering Model (EM) was unloaded and trucked to the Operations and Checkout (O&C) Building, where it went through a receiving inspection process. Although the Modules and Pallets are the largest Spacelab items, many thousands of other line items were delivered and the logistics exercise was considerable.

Figure 11 shows the overall flow of ground activities at KSC for integration of a new set of payloads into Spacelab and its processing through to launch. The flow involves assembly schedules and procedures and highly automated, software-controlled tests. The development of these tools is a long process, the more so when the project developer is not the 'on site' operational contractor.

A few KSC and MDTSCO personnel had been resident in Bremen during periods of the ERNO test programme, and from their knowledge, the project documentation and the European sustaining-engineering support, the first steps began. The EM shipping configuration was assembled into a test configuration and the Ground Support Equipment (GSE) was installed in the O&C test stands and control rooms, where it was validated for compatibility

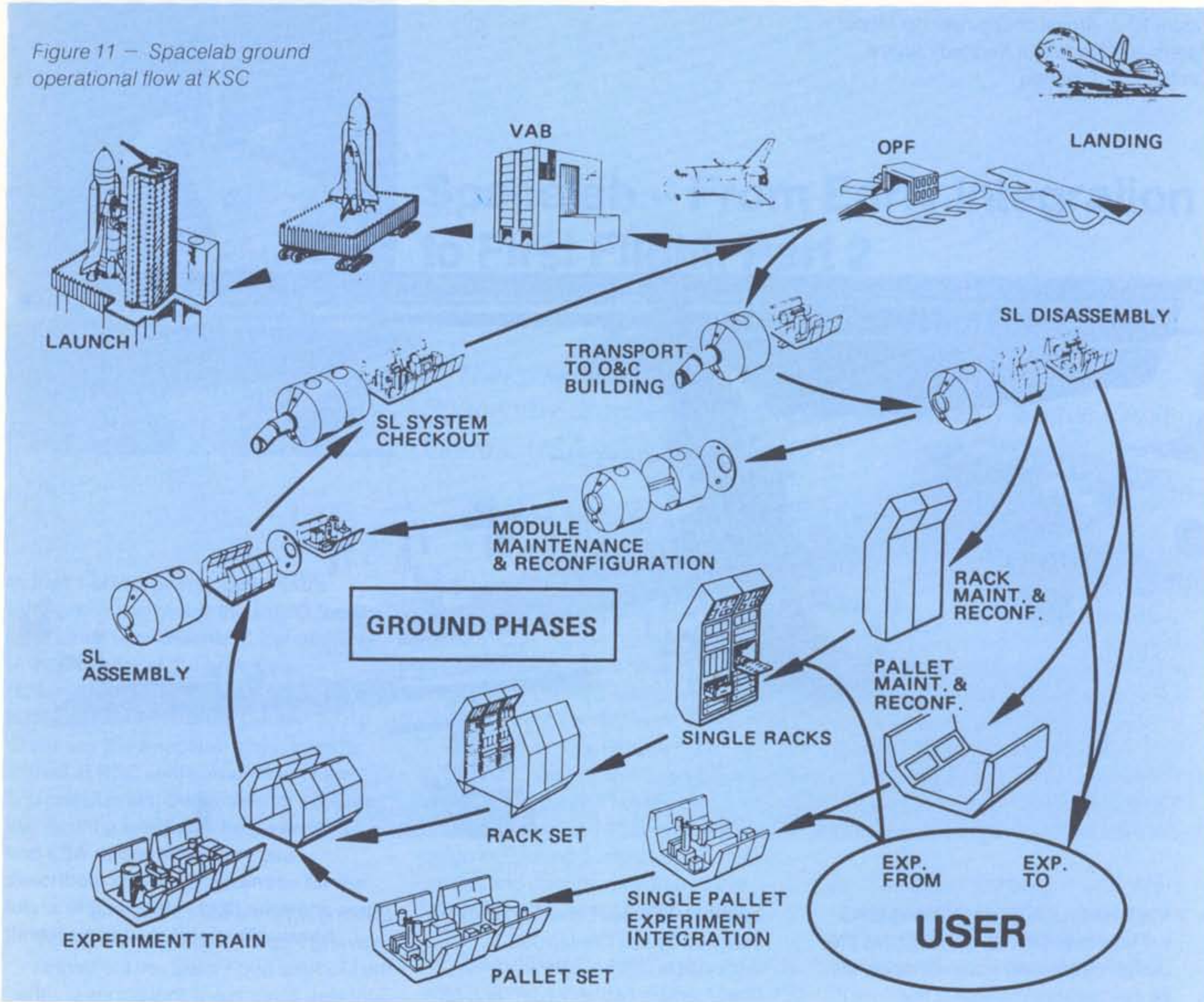


Figure 11 – Spacelab ground operational flow at KSC

with facility power (110 V, 60 Hz). The GSE was hooked up to the EM (Fig. 12) and the testing phase began. The year that elapsed between EM arrival at KSC and the first functional testing was a reflection of the amount of hardware, its complexity, and the learning curve facing NASA.

Engineering-Model processing

Having constructed the EM checkout configuration, two phases of functional testing were performed (Fig. 13), with four objectives:

- Separate validation of the two sets of Electrical Ground Support Equipment (EGSE) and servicers delivered and their compatibility with Spacelab. The first set was to be used for Spacelab-1 checkout in July/August 1982 and was therefore the first serial test in the Spacelab-1 process.
- Verification of the checkout procedures and associated software programs.
- Verification of the final delivered version of the European Subsystem and Ground Computer Operating Systems (SCOS and GCOS).
- First check of the NASA-developed Experiment Computer Operating System (ECOS).

An on-board computer fault experienced during these tests was a repeat of the failure during the last Flight-Unit (FU) test in Bremen. This had been accepted as a 'phantom' problem at ERNO, in the hurry to deliver before the end of the year, but became a clear design deficiency at KSC leading to a design change on the FU computers. Freon-114 was used in the cooling loop during these tests; in Europe freon-21 had been baselined, but NASA finally decided not to use it due to concerns about its toxicity. Freon pump performance, purity and contamination checks were all satisfactory with this new fluid.

Figure 12 – Engineering Model and Ground Support Equipment (GSE) in Operations & Checkout Building at KSC

Figure 13 – Engineering-Model flow at KSC

There were also numerous problems related to EGSE hardware failures, servicer gas line leakages, initial test configuration errors, procedural errors and hardware unfamiliarity, all of which caused test interruptions. The major achievements were the development of the activation and checkout procedures and the associated software programs, together with progress in the learning curve for the new test team. Validation of the second set of GSE later in the year proceeded much more smoothly, reflecting the experience gained during this first run.

Subsequent to these phases, EM hardware has been used for the development of new ground applications software and occasional troubleshooting of FU problems, and more recently for fit checks and personnel training for the Module Vertical Access Kit. This very complicated mechanical equipment was developed by NASA to allow access to the Spacelab Module when it is on the launch pad (e.g. for late installation of experiments).

Flight Unit/Spacelab-1

The FU hardware arriving from Bremen was subjected to extensive post-delivery inspection and then channelled along two parallel paths: Level-IV and Subsystem Verification (Fig. 14).

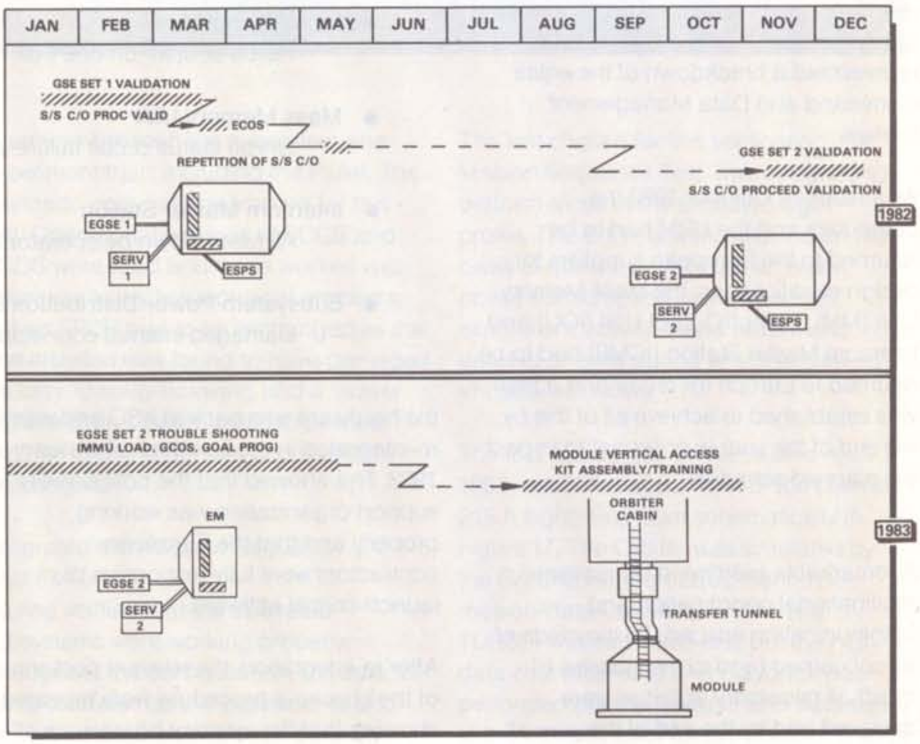
Level-IV activities

The Experiment Racks, Module floors and one Pallet were 'staged' (i.e. reconfigured in terms of harness, plumbing, rack air-flow balancing and subsystem box layout to correspond to the specific needs of Spacelab-1) and sent to the Level-IV areas for experiment integration and test. The Racks and Pallet were integrated with all the experiments (individually checked) and the assembled train tested to ensure proper interfacing to Spacelab subsystems and interpayload compatibility. A Mission Sequence Test was run to verify the operational timeline and proper data acquisition, and to check hardware/software interfaces. These activities revealed some experiment noncompliance with specified interfaces, some facility power and timing problems, which caused Remote Acquisition Unit (RAU) malfunctions, and some software errors. The test was, however, conducted to a rigorous schedule and demonstrated the basic compatibility of the experiment assembly and its software.

Subsystem verification

In parallel with the Level-IV activities, the front end of the Module – the Core Segment – was put onto the test stands and prepared for its first phase of testing. Some modifications requested by NASA were made (e.g. water and freon-loop flowmeters were installed) and integration of the Verification Flight Instrumentation (VFI) was begun. (The VFI consists of some 264 environmental, mechanical and electrical sensors needed for the first flight, and the associated control, monitoring and recording equipment). All leak paths were checked in the fluid lines, gas lines, the structural seals and all shell penetrations, to ensure that no damage had occurred during transportation.

Having completed this work, the GSE was



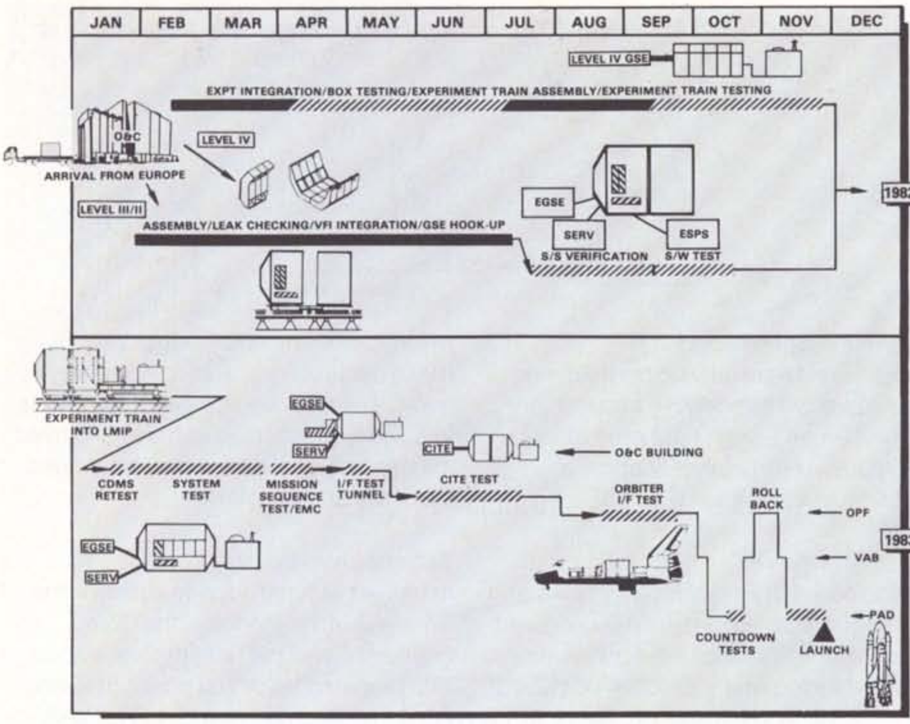


Figure 14 — Spacelab-1 flow at KSC

Figure 15 — List of major CDMS problems requiring resolution after subsystem verification

- **Flight Computers (3)**
  - General design deficiency: incompatibility between fast arithmetic operation and direct memory access
  - General design deficiency: failure of back up computer autorestart function
  - Parity error on one computer: unique box failure
- **Flight Multiplexer**
  - General design deficiency: intermittent drop out of telemetry buffer data
  - General design deficiency: incorrect multiplexing of inverted random data
  - Channel 15 problem: wide band data drop out on one box
- **Input/Output Unit**
  - Failed coupler on one box
- **Mass Memory Unit**
  - On/off status circuit failure: unique box problem
- **Intercom Master Station**
  - All fuses blown by operator error: unique box problem
- **Subsystem Power Distribution Box**
  - Damaged internal connector: unique box problem

hooked up and the Module Subsystem Verification Test was performed from July to September 1982. Procedurally, this test was a repetition of that performed in Bremen, but for the first time the avionics units, which had many design changes resulting from the European test programme, were run with the newly developed ECOS and a revised version of SCOS. The results of the test were dramatic in that, at the end of September 1982, just one year before the scheduled launch, several major problems had to be faced. Figure 15 lists these problems, a mixture of general design deficiencies and individual box failures, which in total represented a breakdown of the entire Command and Data Management System.

As a result, in October 1982 the computers and the HRM had to be returned to the European suppliers for design modifications, the Mass Memory Unit (MMU), Input/Output Unit (IOU) and Intercom Master Station (ICMS) had to be returned to Europe for repair and a plan was established to achieve all of this by the end of the year in order not to impact the planned schedule.

A remarkable exercise in transatlantic, multinational coordination and communication ensued. To the credit of all concerned (and to the surprise of most) all necessary activities were achieved and by the end of the year all the hardware was back at KSC and was re-integrated in the first week of January 1983. This showed that the post-delivery support organisation was working properly and that the European contractors were fully responsive to launch-critical activities.

After re-integration, the relevant portions of the checkout procedure were repeated, showing that the avionics boxes were all working properly. Two new problems had, however, to be solved. Firstly, the flight formats' oversampling rate had to be increased, as European test results had already shown, to avoid HRM overflow conditions. Secondly, a number of wire terminations at the subsystem/payload interface of the HRM input cabling, which had been damaged by handling errors, had to be repaired. Both problems were successfully overcome.

Figure 16 – Experiment-train transfer from Level-IV to Core Module in the Operations & Checkout Building at KSC

Throughout this period, the onboard Environmental Control Subsystem (ECS) and the ground-support equipment performed well, and the change traffic on procedures and software was not excessive. Freon-114 was used as an onboard coolant fluid, following the success on the earlier EM tests.

Spacelab-1 configuration assembly
Just prior to the retest period, with the completion of the Level-IV activities, the experiment train was moved from its test stand to that of the Module (Fig. 16) and was rolled into the shell. This was the first time that a fully integrated train had been installed, and the small but inevitable resulting structural distortions, together with a lack of task familiarity, made it a time-consuming exercise. This was compounded by the protrusion of payload equipment beneath the main floor into the envelope occupied by subfloor equipment, and some cable rerouting had to be performed. Having installed the train, the functional interfaces were made, the Aft End Cone attached and the Pallet put into place to complete the Long Module + 1 Pallet (LM1P) configuration of Spacelab-1.

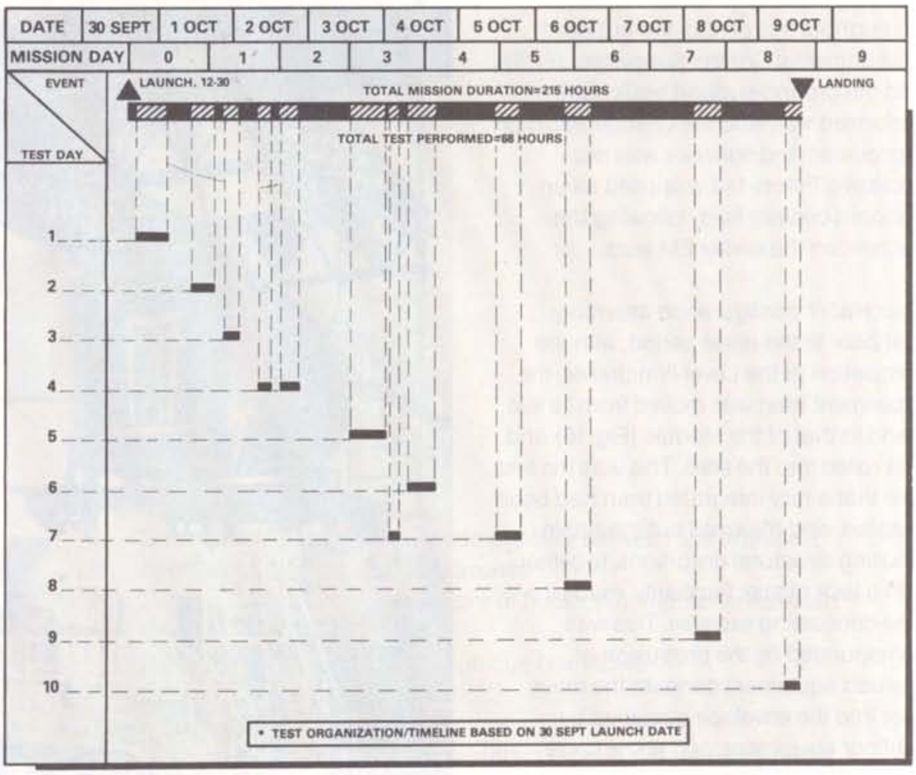
System test
With Spacelab-1 now assembled, the newly mated structure and fluid-line joints were leak-checked, and overall air flow balancing for the complete rack train was performed. This showed that more air than expected was going to the racks, and less to the underfloor area, to the point of being marginal (but acceptable) in the Shuttle's ascent and descent phases. The results differed from those experienced in Bremen, where quite the opposite problem occurred, and this difference has never been fully explained. The 'cold-case fix' diverter valve was adjusted, with some difficulty, to the mission setting.

With the cooling system operational, the first Spacelab-1 system test was carried out, from January to March 1983. The test was to verify the internal Spacelab interfaces between the subsystem and experiment train, including the Pallet. The payloads were not powered on for this test. Operational versions of SCOS and ECOS were used and these worked well. There were very few technical problems, but an SPDB had to be exchanged as the one installed was found to have damaged circuitry. Display flickering and a 'power off' of a Data Display Unit (DDU) were experienced and the unit was therefore exchanged.

Integrated test (Mission Sequence Test/EMC)
Having verified that the Spacelab subsystems were working properly throughout the configuration, the time came to power up the experiments and prove Spacelab/payload compatibility. The test chosen for this verification, the Mission Sequence Test, was designed to perform slices of the expected flight profile. The extracts were selected on the basis of maximum data transmission, power consumption, crew workload, experiment activities, and ascent and descent phases during which maximum VFI activities occur.

The test, conducted in March and April 1983, simulated about 79 h of the planned 215 h flight, as shown schematically in Figure 17. The Orbiter was simulated by the Ground Support Equipment. The mission-data-transmission link (via TDRSS) was not in the test, but the high-data-rate recording and playback was performed per the timeline, and data sent to the demultiplexer for processing. The

Figure 17 – Spacelab-1 mission-sequence test flow



software used corresponded to a 30 September 1983 launch date and a two-TDRSS data system; at the time of the test both of these were valid assumptions. Crew Mission and Payload Specialists participated in the test, working inside the Module to provide the highest fidelity of man/machine interface. At critical times during the Mission Sequence Test, the expected Orbiter-radiated emission field was produced to see if it affected Spacelab-1. The Spacelab emission was also measured to show that it did not exceed Orbiter susceptibility levels. The configuration was not shielded from the local (KSC) environment, but no values were measured that were intolerable to either side of the interface.

The whole test was very successful. The 70+ experiment instruments, the Spacelab subsystems and the control software worked very well together. The test proved that automated software control could be conducted in parallel with complex manual operations and that the mission was feasible in terms of daily activity planning. The problems of significance were:

- DDU temperatures were higher than expected (although within specification limits). This was partly due to keeping the diverter valve in the 'cold-case' position for long periods, causing the avionics air temperature to increase.
- Internal experiment problems requiring redesign and/or repair (e.g. the susceptibility to very low voltage ripples of Experiment 023, and failure of a helium-bottle valve in the Materials-Science Double Rack).
- Software timeline errors (i.e. incorrect experiment operation sequences).
- Experiment application software discrepancies requiring changes.
- A procedure error compounded by an operator error, which led to a VFI electronics box malfunction, causing part of the VFI test to be postponed.

The software changes and most experiment repairs were effected very rapidly and successfully reverified. By May 1983, the Transfer Tunnel had been integrated to the front end of the Module and its interfaces verified, and Spacelab-1 was declared ready for its first journey as a flight configuration.

Cargo Integration Test Equipment (CITE) tests

On 18 May 1983 Spacelab was disconnected from its Ground-Support Equipment and moved to the CITE stand. This journey of some 40 m took Spacelab to a high-fidelity Orbiter simulator, controlled by the KSC Launch Processing System, and utilising Orbiter General Purpose Computers. The Orbiter Aft Flight Deck (OAFD) was represented, and the Spacelab flight OAFD equipment installed (connected to Spacelab via the flight cabling). The purposes of the test were to prove Spacelab-Orbiter compatibility, verification of the flight activation/deactivation sequences, and verification of the command/control links from the POCC at JSC (via DOMSAT, not TDRSS). Whilst in the CITE stand, Spacelab's integrated configuration offgassing and pressure decay leak checks were also performed.

The ability to control and monitor Spacelab from the OAFD (including hard-wired emergency system), the timing, Pulse Code Modulation Master Unit (PCMMU) and Multiplexer-Demultiplexer (MDM) interfaces, and the correct software reporting of onboard errors were all successfully demonstrated. Overflow of IOU data in the HRM was the only significant problem. This was associated with the use of particular data formats, and a procedural workaround was established to avoid a hardware (HRM) fix.

The POCC-to-Spacelab link test was carried out to verify the command link from JSC to Spacelab and the correct reception of multiplexed telemetry at JSC from on board. Timeline software updates were sent and installed in the MMU, experiments were successfully powered on and data sent from them back to the

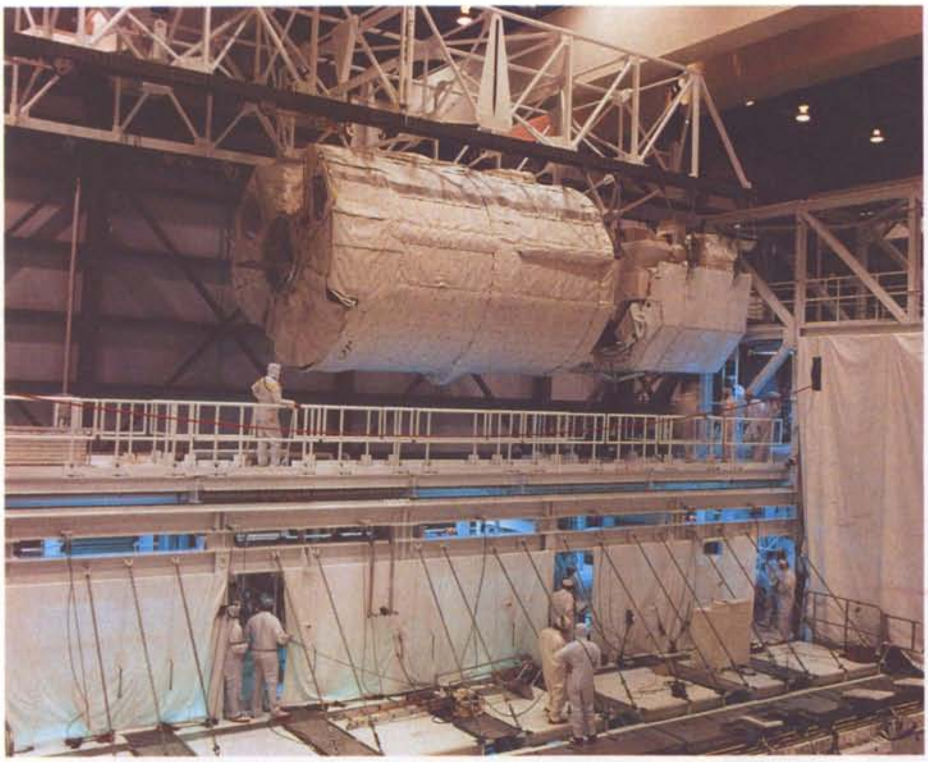


Figure 18 – Spacelab-1 being lowered into 'Columbia' in the Orbiter Processing Facility at KSC

POCC via the Ku-band system. The only onboard problem experienced in this test was a return of the flickering DDU experienced earlier. The unit was removed and replaced. A drop in the freon-pump accumulator level was also noted. This had been falling steadily for some time, but no leak could be detected. The pump was topped up with enough fluid for the mission.

An offgassing test – during which samples of cabin air were taken at regular intervals during a 6 h continuous power-up operation – was performed to demonstrate that the materials on board would not be harmful to the crew. The results showed that everything was acceptable, except for the presence of methylethylketone (MEK). This very hazardous compound resulted from the application just a week or so earlier of 'Refset' to overcome a flammability concern which existed on the sponge-like acoustic-noise-suppression material. Although the MEK would probably disperse before the mission, this could not be verified. The launch activation sequence was therefore modified to have the Tunnel fan running, thereby circulating air through the Tunnel's charcoal scrubber to extract the MEK.

The Module leakage test was conducted with an internal pressure of 16.2 psi (about 1.1 atm). The pressure decay measured corresponded to one eighth of the allowable leakage, a very satisfactory situation.

With all of the planned testing in KSC's O&C Building complete, on 18 July 1983 Spacelab-1 was ready to be transferred to the Orbiter, two weeks ahead of the schedule published on the day of FU delivery in December 1981. However, by this time the unfortunate story of the TDRS launch problems had surfaced, and there would be no operational satellite for the 30 September launch, let alone the two that had been baselined. The launch was slipped to 28 October to enable the one TDRS to be commissioned, the mission planning to be revised, the timeline software to be changed and the mission simulation schedules to be replanned. Spacelab-1 therefore stayed in the O&C Building for another month until it was transferred to the payload cannister on 15 August, transported to the Orbiter Processing Facility, and finally installed in Columbia the following day (Fig. 18).

OPF testing

Having spent years as a paper project and as hardware attached to simulators, Spacelab was now to be checked out with the real Orbiter. Three phases of testing were carried out in the Orbiter Processing Facility (OPF):

- Spacelab/Orbiter interface test: to verify power, signal, computer-to-computer, hardware/software and fluid/gas interfaces. The only interface problem was the switch-off of Spacelab IOUs when an Orbiter hydraulic circulation pump was activated using a ground-powered Spacelab power bus. Checks made using the on-board fuel cells to power Spacelab showed a much lower transient, a fact borne out during the mission. During the test, the experiment DDU again flickered and powered off, as had occurred in the earlier system and CITE tests. Yet another unit (flown in from Europe) was installed and the problem went away. An experiment RAU on the Pallet (RAU 21) failed to respond to the 'on' command. The backup command was verified and the 'off' command wiring was disconnected to prevent inadvertent relay problems (the box could not be exchanged due to inaccessibility).
- Spacelab/Tunnel/Orbiter interface test: tunnel lighting, air flow and VFI sensors were checked and no problems of significance arose.
- End-to-end command/data link test: the Spacelab – Orbiter – TDRSS – White Sands – Domsat – JSC/GSFC link was checked. Commands sent from JSC were received in Spacelab

and data transmitted over the reverse link without errors. A number of ground-link problems had to be overcome, and a faulty multiplexer bit synchroniser and computer at JSC had to be repaired. Finally, the link between Spacelab and the MCC/POCC worked continuously for several hours, including faultless performance from the TDRSS satellite.

With the functional testing over, closeout activities on Spacelab and its payloads were performed in readiness for the flight. All nonflight hardware was removed, switch positions verified, late stowage items installed and final access platforms removed. On 20 September 1983 the Orbiter payload bay doors were closed, and on 23 September the Orbiter was rolled out to the Vertical Assembly Building (VAB), rotated to the vertical position and mated to the External Tank. The Orbiter/Tank/Solids interfaces were verified and on 28 September the assembly was rolled out to the Launch Pad (Fig. 19).

Pad Operations
As per the normal Shuttle processing flow, two countdown tests were performed, one with the flight crew (fuel tanks empty) and one with all fuel loaded (using ground personnel). The entire (60 h) countdown procedure was run down to T-5 seconds to verify sequences, timelines and the hardware. At the end of the first test the countdown was recycled to T-20 minutes and rerun, this time with simulated failures to measure the ability of the launch crew to react. Spacelab was activated for both tests, which involved:
- the avionics fan (for fire/smoke detection and VFI electronics cooling)
- the freon pump (for cooling experiment RAU 21 on the Pallet)
- the water pump (for inverter cooling)
- the subsystem inverter (for supplying AC to the pumps and fan)
- the main and auxiliary DC buses
- the Tunnel fan (for continuous air circulation to remove possible contamination).

In addition, two Module lights were remotely activated. This was originally intended to be an in-orbit task, but the Subsystem Power Distribution Box (SPDB) did not allow for separate switching of lighting and pump/fan control relays from the Aft Flight Deck. The rotating machinery was needed for launch (not part of the baseline design) and so all relays had to be set to the 'on' position, thereby activating the lights as well.

There were absolutely no anomalies on board Spacelab during the countdowns, and the entire procedure was conducted without any schedule slip. This was especially significant as the launch window was only 11 minutes.

During the second countdown the newly installed fuel cells were checked for peak voltage supply to Spacelab, to ensure that the level did not exceed the 32 V limit at which Spacelab sends a command to disconnect the Orbiter-supplied main bus. The transient bus voltage during circulation-pump switching was also monitored to ensure that the problem experienced in the OPF (on ground power) did not occur.

With the fuel tanks loaded, and the countdowns successfully achieved, NASA then had to take the agonising decision to postpone the launch due to the problems in the Solid Rocket Motor ablative nozzle liners, found after the previous STS-8 flight. The problem had been known for some time, but processing had continued in the hope that the STS-9 nozzles could be cleared. Gradually, however, it became apparent that one of the SRBs was constructed from the same source material that had nearly failed on the previous flight. Therefore, on 17 October, the assembly was rolled back to the VAB, disassembled and the Orbiter sent back to the OPF.

Within the VAB, new segments of an SRB and a replacement nozzle were assembled. The problem had been isolated and the solution implemented.

Meanwhile, four major Orbiter problems suddenly surfaced and had to be resolved:
- gaseous hydrogen from the fuel cells was getting into the potable water system
- fuel-cell reactant was evaporating much faster than predicted and could not support a 9-day mission
- three engine controllers were damaged
- the Ku-band antenna deployment assembly failed a qualification test at the supplier.

Eventually all fuel cells were replaced, a modification was made to the plumbing system of the reactant supply such that the baseline capability was recovered and all three engine controllers were replaced. The antenna problem remained until later. Experiments had to be serviced/calibrated and certain onboard elements with short shelf life had to be replaced or checked. On top of all this, new flight software corresponding to a revised launch date had to be generated – but the launch date was not known because of the conflict between desire to fly as soon as possible and a potentially degraded scientific return so late in the year.

It is impossible to describe adequately the amount of ensuing activity and the atmosphere within which it was conducted. Suffice to say that 28 November was chosen by ESA and NASA as the new launch date, all modifications were implemented, the software regeneration went ahead, and Spacelab and the Orbiter were once again closed out. On 4 November the Orbiter returned to the VAB and on 8 November STS-9 returned to the pad. The Ku-band antenna deployment assembly was replaced (the payload-bay doors had to be opened for this) and Spacelab was powered up to generate 48 Mbit/s multiplexed data to be sent to the Ku-band transmitter, and thence via a fibre-optics link to the O&C Building to verify zero-error transmission. A second Spacelab activation was required, on 22

Figure 19 – STS-9 ('Columbia') being rolled out to Launch Pad 39A at KSC

Figure 20 – Lift-off of STS-9 on 28 November 1983 from KSC

November, to enable the revised flight timeline software corresponding to the 28 November launch date to be loaded into the MMU and verified. Both activities were successfully completed, and a strut between the External Tank and a Solid Rocket Booster was exchanged (there was a fault in the separation pyrotechnics). The Flight-Readiness Review was then conducted and everything was ready for countdown.

Launch countdown
The overall STS-9 countdown began at 00.00 hours on 26 November, but the Spacelab activation sequence did not start until 11.30 AM on 27 November. The activation, performed by ground personnel in the Aft Flight Deck and in Firing Room 1 of the KSC Launch Control Center, took about 40 minutes and was achieved without problem.

Thereafter the configuration stayed constant for many hours, during which the system was monitored through several major Shuttle activities:

- At 02.10 on Monday 28 November, all Launch Commit Criteria (LCCs) – a set of checks, all of which must be positive for countdown to continue – were verified and External Tank LO_2/LH_2 top-up began.
- At 05.40, a two hour 'built-in' hold began, during which the Orbiter Inertial Measuring Units were calibrated and the flight crew began to suit up.
- At 08.10, the flight crew entered the Orbiter and checked communication links with JSC and KSC. The Orbiter hatch was closed and last leak checks performed.
- At 08.29, a second LCC verification occurred. The Ground Launch Sequence (GLS) computer programs were activated and the main propulsion helium tanks, the Orbit Manoeuvre System tanks and the Reaction Control System tanks were brought to flight pressure.
- At 10.26, switching from ground to fuel-cell power was completed.
- At 10.51, at T-9 minutes to lift-off, after a 10 minute built-in hold, the count resumed with the Test Director's 'go for launch' commit. At this point, the GLS programs control all Shuttle functions, and automatically stop the count if an LCC is violated.
- At T-31 seconds, the onboard computers took over everything except the GLS control of the launch-commit criteria.
- At T-6.6 seconds, a ground command was sent to start the Orbiter main engines.
- At 11.00, the SRBs were fired and the Shuttle lifted-off and immediately started a roll manoeuvre to aim it up the East coast of the USA to enter the 57° orbit (Fig. 20).

Spacelab-1 was, at last, on its way.

The Spacelab-1 mission
Spacelab is an integral extension of the Orbiter, converting the latter into an experimental and applications laboratory in which man has the ability to conduct his scientific activities in the same way as he does on the ground, namely iteratively and reactively. It relies on the Orbiter for living quarters, for power and for heat rejection, for communications and data transmission, for certain aspects of its atmospheric control, and for its orbital positioning and attitude. As such, it is constrained by the performance abilities of the Orbiter and by the expenditure of consumables. Taking these parameters in turn, the mission demonstrated that:

- The launch, in-orbit and landing environments experienced throughout the mission were generally less harsh than expected. Preliminary results indicate that the lift-off loads were within prediction, as was the acoustic environment. The vibration response of the secondary structure and equipment to acoustic noise was much lower than predicted. Specific thermal cases (Sun and deep-space pointing) were run during the mission and the

temperature extremes experienced were more benign than calculated. The main-landing-gear impact was negligible, and the nose-landing-gear impact loads were lower than design specification requirements.

- Spacelab proved to be an efficient workshop for the crew, and the Orbiter a good home for off-duty hours. Round-the-clock activities worked well. The power, heat-rejection, command, control and data services provided all operated smoothly. The scientific airlock proved easy to operate. The day-to-day conduct of scientific work was achieved in a manner that demonstrated both the need for man in the loop and the system's flexibility. There were a number of occasions on which crew members modified hardware to enable an experiment to work. As significantly, the ground staff – the Payload Investigators – were able to react to initial results and propose procedural changes/additional tasks for the crew to carry out. It is probably impossible to quantify the percentage benefit of such iteration, but it was clear that a number of results were achieved solely because of this unique ground/crew interface. The electromagnetic environment was not quantitatively established, but no obvious interferences were experienced.
- Combined power consumption of the Spacelab systems, the experiments and the Orbiter was lower than predicted, to the point that the mission could be extended from 9 to 10 days to enable more science to be achieved. The voltage supply from the Orbiter fuel cells was very stable throughout the flight.
- In spite of the earlier TDRS problems, TV, voice communications and data transfer throughout the mission were good, and very little loss of available signal acquisition time was experienced.
- The leakage rate of Spacelab (and the Orbiter) was so low that the inflow of Orbiter-provided O_2 corresponded to only that needed for metabolic consumption. In fact early in the mission, decreasing O_2 partial pressure readings coupled with low O_2 flow rates were observed and were thought to be indicative of a problem, but were in fact a symptom of better leakage performance than expected. Lithium-hydroxide cannisters for CO_2 removal were scheduled to be exchanged every 24 hours. Although this exchange was performed (except for the first day) as planned, the CO_2 levels were so low that it was really not necessary. Towards the end of the mission the Spacelab cannisters were taken out of the system, and the air exchange through the Tunnel into the Orbiter lithium-hydroxide system was more than adequate to keep the CO_2 levels well within safety limits.
- Some 216 in-orbit manoeuvres were performed during the mission. This was more than planned, partly because one experiment (AEPI) could not be gimballed by itself and the Orbiter was used as its pointing system. The ground/air real-time planning of these maneouvres was accomplished very smoothly.

There were, of course, some problems during the flight, but even these were accommodated in a way that was encouraging. The jamming of the High-Data-Rate Recorder would, if not fixed, have resulted in loss of most of the data obtained during loss of TDRSS signal times. Following analysis on the ground, Mission Specialist Parker was able to free the obstruction (in the capstan roller assembly) and no further problem occurred. The drop out of RAU 21 for periods of the mission was found to be related to the temperature of the freon coolant loop. To minimise the Pallet freon loop temperature, a number of measures were taken in the Module to reduce the temperature of the water-loop, to which the freon loop is thermally connected via a heat exchanger. Although this was very

Figure 21 — The landing of 'Columbia' on 8 December at Dryden Flight Research Center, California

much unplanned, and the failure of RAU 21 was a considerable nuisance to the mission, the recovery attempts served to demonstrate the flexibility of the system and the depth of understanding of the ground-support personnel.

In summary, all formal detailed test objectives of the mission were fully accomplished, and as a Spacelab test flight the mission was 100% successful. As a flight for the performance of some 72 different scientific investigations, more results were achieved on this flight than have ever before been gathered on a single mission. The mission showed not only that the requirements were met but also that there is an inherent in-orbit operational flexibility built into Spacelab which has only just begun to be understood.

The landing at Dryden, (Fig. 21) followed a delayed re-entry caused by the malfunctioning of two Orbiter computers and an Inertial Measuring Unit, but these problems were soon overcome and at 3.47 PM Pacific Coast Time on 8 December 1983 the first Spacelab mission was over.

The future of Spacelab

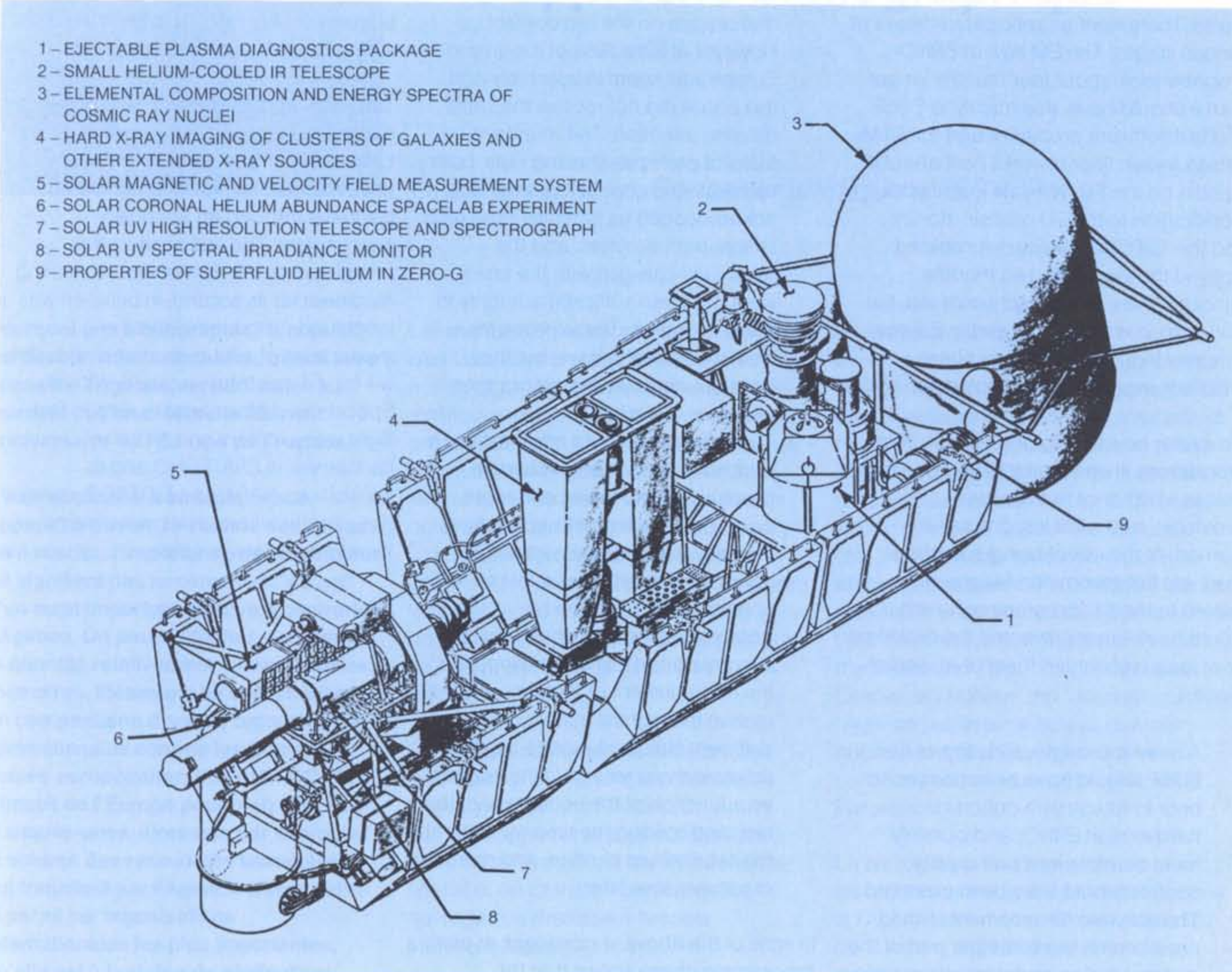
Following the return of the Spacelab-1 configuration to KSC, it has been disassembled and all the experiments removed. The subsystems in the Core Module are being set up for the next Module flight, designated Spacelab-3, currently scheduled for January 1985. The experiments for that mission, which will be a Long Module + MPESS configuration, have been checked out and overall integration and test was conducted throughout this summer (MPESS is a 0.5 m long frame structure produced by NASA which will carry a few experiments requiring direct space exposure).

In parallel with these activities, the Spacelab-2 mission ground processing is underway. This is a Pallet-only flight, using an Igloo to house the subsystems (Fig. 22). The main feature of this flight is that it will be the first use of ESA's Instrument Pointing System (IPS), a sophisticated and very accurate experiment pointing device delivered to KSC from Dornier in the middle of this year.

The NASA-procured 'Follow-on Production' Spacelab hardware is presently going through final integration at ERNO, in Bremen. It will be used for the first German Spacelab mission, D-1, experiment integration for which is also being performed by ERNO. Ground processing at KSC will begin this winter and the mission is scheduled for late 1985 (the Follow-On Production contract has been extended by NASA to include many line items of operational spares as well as the basic Spacelab flight elements set).

There are another six Spacelab missions

Figure 22 – Spacelab Mission-2 configuration



in planning, but they are not yet at the hardware stage. In addition to these 'dedicated' flights (i.e. where Spacelab is the only cargo being carried), there are a large number of missions in which Spacelab elements, such as Igloo/Pallet configurations, make up part of the total cargo complement. The latest Shuttle Manifest shows 19 such uses that have an assigned payload and Orbiter, and a further 14 uses that have been requested but not yet scheduled, all over the next four years. The Spacelab hardware will therefore be flown many times in the near future.

Meanwhile developments such as Eureca and Biorack are underway, and studies are proceeding both in Europe and the USA on a Space Station concept.

The flight of Spacelab-1 has clearly shown the benefits of man's presence for space research, and further evidence of this will undoubtedly accrue with the next flights of the laboratory. With the need for and desirability of a manned Space Station now established, the Spacelab project has shown that the European space community has the ability to contribute. Nearly all Space Station studies currently underway, both in Europe and the USA, are based on developments of the existing Spacelab design.

Conclusions

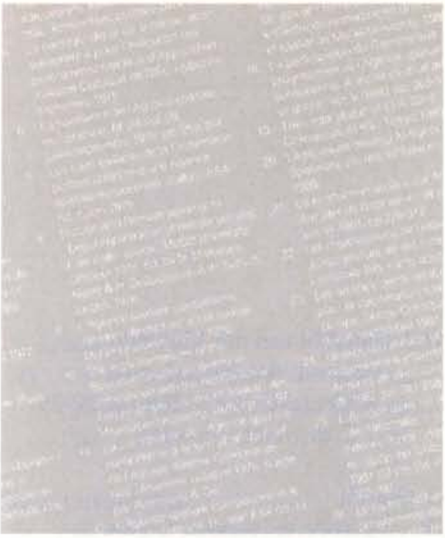
This article has described the Engineering Model and Spacelab-1 test programmes at ERNO and the ground processing at KSC between April 1978 and December 1983: $5^1/_2$ years from prototype subsystem train harness continuity checks in Bremen to the completion of the mission in California. We have dwelt on a large number of problems in both parts of this article. There were unanticipated delays at various stages. The EM flow at ERNO probably took about four months longer than it should have, due mainly to EGSE and test software problems, and the DMA cable/Module floor reworks cost about 4 months on the FU. The late load-factor modification to the FU cost six months, and the TDRSS/SRB nozzle problems delayed the launch by two months. Although there was no schedule slip, the workload, both in the US and in Europe, was very high after all the avionics problems experienced in September 1982.

No matter how strong one's loyalty to a programme, these are facts and one must assess whether or not they were avoidable, and what lessons can be learned. At the risk of being superficial, there are five recommendations, all related to the test programme, which would have either prevented the problems or at least highlighted them at an earlier stage:

- A more thorough validation of the EGSE should have been performed prior to its use with onboard hardware at ERNO, and possibly more careful piece part quality control should have been exercised.
- The software development should have been a more integral part of the system (design and) test programme rather than a reacting, isolated development which did not see the hardware until late in the flow.
- The development of a test requirements baseline should have been performed in line with the test schedule. For the EM, these requirements were not available until well into the programme, and in some cases the requirements had to be amended to reflect the existing procedure rather than driving it. For the FU programme the requirements were available in time and the procedures were therefore able to reflect them.
- The planning of the integration and test programme was dominated by discussions on the test content. However at least 50% of the time in Europe was spent in assembly and this phase did not receive the same detailed attention. The mundane tasks of progress-chasing nuts, bolts, brackets and connectors were not acknowledged as potential (and real) critical-path activities, and the personnel charged with the tasks were not given sufficient authority to obtain priorities. These problems were measured in days, but they accumulated over the programme into several weeks.
- The temptation not to troubleshoot a problem due to overall schedule pressure should have been more vigorously challenged, especially in the early test stages. Spacelab is complicated and takes a lot of understanding. Planned troubleshooting time should be an integral part of test scheduling, and the management of that time should receive the highest attention. There is sufficient historical data to be able to estimate the amount of time needed, as a function of the complexity of the test, and utilising the time will prevent the expenditure of more, and more expensive, time later.

In spite of the above, a close look at each programme phase shows that the efficiency of that phase increased as the product was better understood – which is normal – and that gradually all the objectives were met. The final 12 months of the Spacelab-1 processing at KSC were very smooth indeed on the Spacelab side. The problems experienced diminished in both number and significance, and the Orbiter processing crew were astounded at the lack of surprises and consistency that Spacelab exhibited by the time it was in the OPF and at the Pad. It performed very nearly perfectly in orbit. The mission showed that the nominal flight was in the middle of the requirements envelope and that Spacelab therefore has a lot of margin, flexibility and growth already built in. The quality of the end product is unquestionably high, from both the build standard and functional viewpoints.

Ten years ago, ESA embarked on the development of a multipurpose manned Laboratory, designed to fly in an undefined Orbiter, to carry undefined payloads through an unknown environment. The end product has completed its first mission and is nearing readiness for its second. In between was a long, hard programme and the expenditure of a lot of money. Only history will tell if it was totally justified, but Spacelab's performance during its first flight was excellent and all those concerned, in ESA, ERNO and its consortium, NASA and MDTSCO, can feel proud of the efforts that made this eventual success possible.



L'Agence spatiale européenne – une approche bibliographique

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Pourquoi une bibliographie? L'objectif est double: mieux connaître, mieux faire connaître l'Agence, en particulier au moment où l'on célèbre le 20ème anniversaire de l'Europe de l'espace.

L'intérêt attaché à un sujet donné apparaît à travers le volume des travaux qu'il suscite, l'importance de ces travaux ne signifiant pas forcément qu'il s'agit d'un sujet important. Preuve a contrario: l'Agence. On peut s'étonner, en effet, de la quantité relativement faible d'articles, mémoires, thèses qui lui sont consacrés en comparaison d'autres organisations internationales comme les Communautés européennes, l'OTAN, l'OCDE, le Conseil de l'Europe pour n'en citer que quelques-unes, alors que par exemple le volume des ressources financières qui transitent par l'Agence classe celle-ci parmi les organisations internationales les plus importantes, qu'elle est à l'origine de réalisations spectaculaires et qu'elle offre un exemple pour la conduite de grands programmes de recherche et de développement.

Les manuels et les cours de droit étudient plus volontiers le statut et les activités des autres organisations internationales 'politiques' classiques, mieux connues du grand public. On constate que les études consacrées à l'Agence sont essentiellement le fait de personnes appartenant ou ayant appartenu à son personnel. Il y a donc un effort certain à faire pour intéresser les chercheurs, ce qui suppose la mise à leur disposition du matériel documentaire nécessaire et une politique de l'information (de la saisie à la diffusion).

Cependant quelques manuels de droit international public font mention de l'Agence mais sans l'étudier. On trouve des développements plus substantiels dans certains manuels de droit aérien et spatial et on citera, en particulier, les ouvrages du Professeur Nicolas Mateesco Matte.

Un seul ouvrage est entièrement consacré à l'Agence: il s'agit de celui de M. R. Cafari Panico (II.31), qui a le mérite d'être non seulement le premier ouvrage sur l'Agence, mais aussi de présenter des développements fort intéressants. On n'hésitera pas à conseiller la lecture de cet ouvrage très documenté.

Pour une approche globale de l'Agence, on renverra également à deux articles, riches d'enseignement, mais de conceptions différentes:
- le Fascicule 195 du *Jurisclasseur de droit international* (M. Bourély) (II.22);
- l'article de M. Roy Gibson: *Aerospatial cooperation: the European Space Agency* (II.46).

La présente bibliographie est essentiellement centrée sur les aspects juridiques de l'Agence, en tant que personne de droit international public. Elle n'est pas et ne se veut pas exhaustive. Elle ne prend pas en compte les articles de la presse aérospatiale spécialisée *(Air & Cosmos, Aviation Week & Space Technology*, etc...). Ne sont pas cités non plus les articles techniques ou scientifiques sur les activités et programmes de l'Agence. Pour cela, on renverra aux Rapports annuels d'activités, aux Rapports présentés au Cospar, au *Bulletin*', au *'Journal*' que l'Agence publie ainsi qu'aux diverses publications et comptes rendus de colloques scientifiques (ESA, IAF, AIAA, Eurospace, etc...).

La bibliographie distingue deux parties: les organisations ayant précédé l'Agence et l'Agence elle-même. Elle est présentée dans l'ordre alphabétique des noms d'auteurs et pour chaque auteur dans l'ordre chronologique des travaux cités.

On donnera ci-après quelques orientations bibliographiques par thèmes de recherche:
- Origine de l'Agence: (II) 4, 6, 33, 41, 52, 53
- Aspects généraux de la Convention: (II) 7, 9, 19, 22, 46, 47, 48, 49, 64, 71
- Activités et programmes: (II) 5, 23, 26, 28, 43, 44, 57, 59, 60, 67, 72, 76
- Politique industrielle, protection des résultats: (II) 34, 35, 36, 37, 40, 68, 69
- Structure: (II) 30, 55
- Finances, contrats: (II) 38, 50, 51, 73, 74, 78, 79, 81
- Relations extérieures: (II) 1, 14, 15, 18, 25, 44, 46, 56

– Privilèges & immunités: (II) 58
– Droit de l'espace: (II) 11, 12, 20, 24, 27, 29, 75, 82

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Abréviations utilisées

AIAA:	American Institute of Aeronautics and Astronautics
AFDI:	Annuaire français de Droit international, Centre National de la Recherche Scientifique, Paris.
IAF:	Fédération Internationale Astronautique, Paris.
ICLQ:	The International and Comparative Law Quarterly, London.
IISL:	Institut International de Droit Spatial – Rapports des Colloques édités jusqu'au 21ème par: B. Rothman & Co, Littleton, Colorado, USA, puis par AIAA, New York, NY 10104.
JDI:	Journal du Droit international, Editions Techniques, Paris.
NILR:	Netherlands International Law Review.
RFDA:	Revue française de Droit aérien, Paris.
RGDIP:	Revue générale de Droit international public, Paris.
ZLW:	Zeitschrift für Luftrecht und Weltraumrechtsfragen, Carl Heymanns Verlag KG, Köln.

An Advanced Concept for the Pointing of a Spaceborne Observatory: Exosat

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The Agency's Exosat spacecraft, dedicated to the study of astronomical objects in the X-ray domain, was successfully launched on 26 May 1983. A year later, more than seven hundred observations have been performed on various X-ray emitting sources and other fascinating celestial objects. On several occasions the planned sequence of observations has had to be abruptly interrupted to redirect the instruments towards sources of unexpected phenomena detected by other space- or ground-based observatories. The ability to reorient the spacecraft at very short notice is a primary feature of the ground system developed and operated at ESOC to support the Exosat space observatory.

Introduction

Using a list of observation requests submitted by the scientific community as a starting point, we will describe the operations and the facilities needed to plan a schedule of observations, implement it and finally provide orbit and attitude information for observer evaluation of the payload data.

The flexibility of this support concept will further be demonstrated by illustrating how the system deals with unscheduled events, such as the extension, reduction or postponement of an observation, or a spontaneous request to point the spacecraft towards a 'target of opportunity'.

A description of the spacecraft and its scientific instruments can be found in ESA Bulletin No. 31, and a summary of the preliminary results from the first three months of operations in ESA Bulletins Nos. 36 and 38.

Spacecraft and constraints

To understand the constraints imposed by the satellite on attitude manoeuvring and the observation of targets, a few words are necessary on the spacecraft itself and its attitude-measurement and control system.

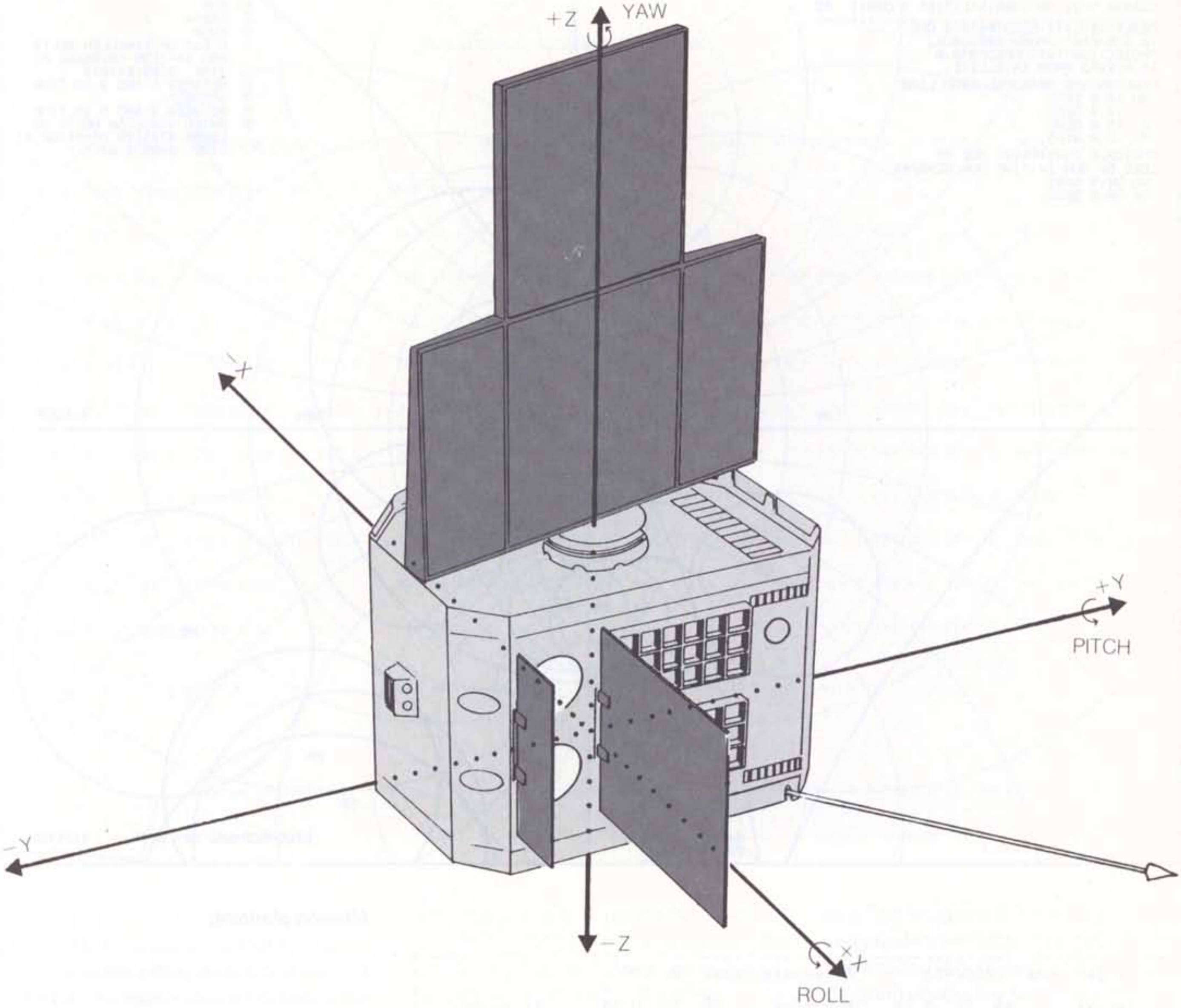
On the front panel of the spacecraft (Fig. 1), the apertures of the following instruments can be distinguished (from left to right): two redundant star sensors, two redundant low-energy X-ray imaging telescopes, four medium-energy quadrants, and the gas-scintillator proportional counter. Also visible are the front S-band antenna boom connected to the lower platform, and the rotatable solar array on top of the spacecraft.

Exosat is a three-axis-stabilised satellite. Attitude control and reorientation is provided by a propane cold-gas reaction control system. Attitude excursions are sensed in the short term by gyros and in the long term by star trackers and fine Sun sensors. The attitude-measurement and control system keeps the instruments pointed with a stability of 3 arcsec. The star sensor can track two guide stars (up to the eighth visual magnitude) simultaneously, thereby providing the attitude control system with full three-axis attitude information (roll, pitch and yaw). If only one guide star can be found in the star tracker's field of view, the roll information can be provided by one of the fine Sun sensors.

For thermal-control reasons, the spacecraft's upper and lower faces should never be exposed to direct sunlight. The Sun must therefore be kept within the spacecraft X−Y (equatorial) plane, plus or minus 3°. This constrains the manoeuvring from one target to the next.

In practice, an attitude reorientation is split into a sequence of rotations, called 'slews', about the spacecraft's geometrical axes. Three slews are usually necessary: the first around the Z-axis to bring the Y-axis along the Sun line; the second around the Y-axis, and the third around the Z-axis to bring the X-axis onto the target. This type of manoeuvre is called a 'Z-Y-Z slew'.

Figure 1 — The Exosat spacecraft



The attitude-control system can only support slews about the Y- and Z-axes. The infrequent requirement for a rotation around the X-axis is implemented as a sequence of Y and Z-slews. Small attitude-correction or trimming manoeuvres are carried out by changing the reference coordinates of the stars being tracked accordingly.

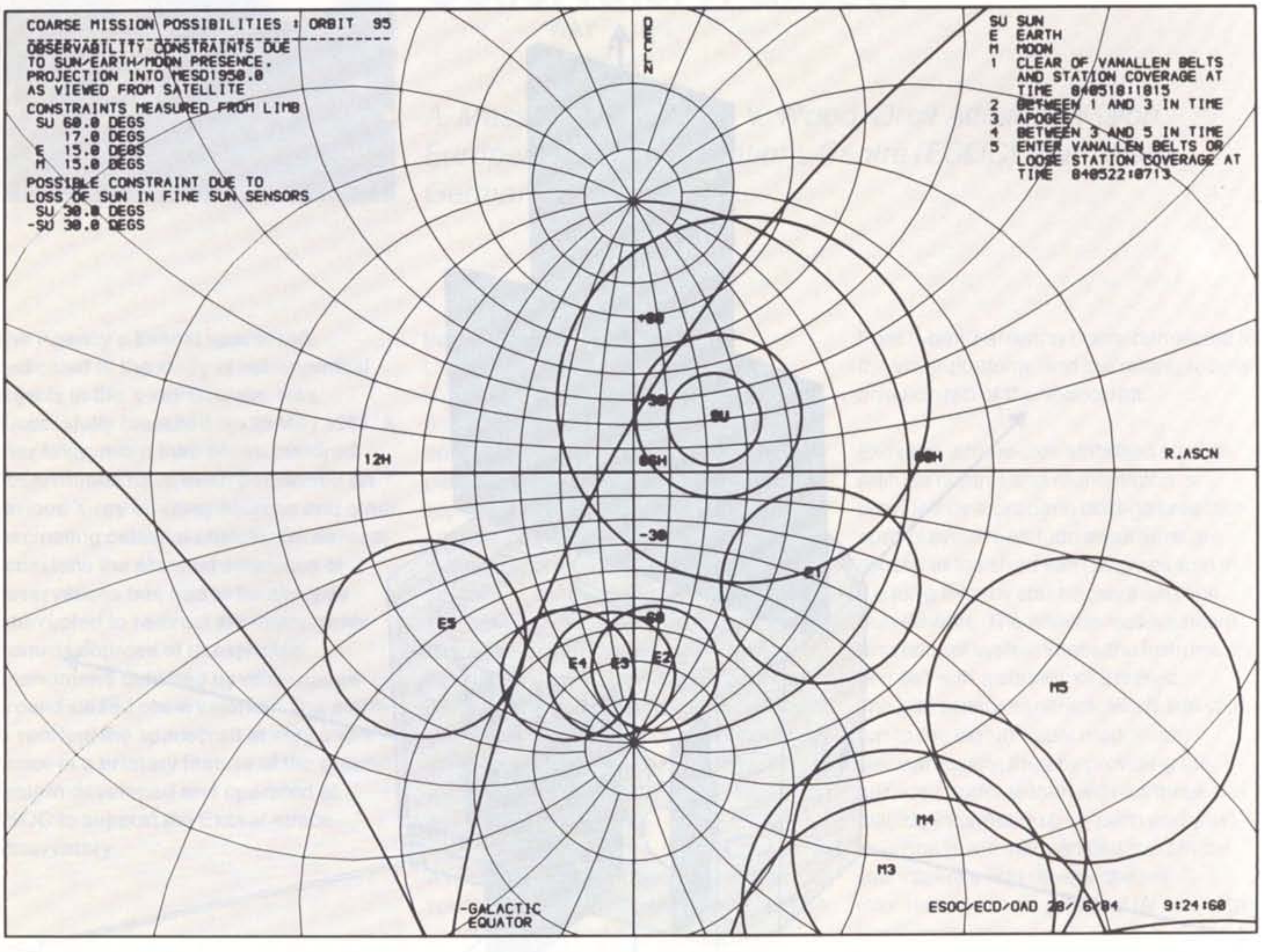
The observation of a source is also subject to constraints imposed by the scientific instruments on board. The angular distance between the source and the Earth or the Moon as seen from the spacecraft should be greater than 15°, except for observations carried out in the Moon-occultation mode. In addition, the angular distance to the Sun should be greater than 17° for the Medium-Energy, and greater than 60° for the Low-Energy Experiment. Finally, the observation of a target is constrained by the position of the spacecraft in its orbit, payload data being retrieved whilst the spacecraft is above the Earth's radiation belts and visible from the Villafranca (Spain) ground station.

These constraints are illustrated in Figure 2 on a projection that shows the Sun, Earth and Moon blinding zones over a given orbit. Two such graphs, centred 180° apart, cover the whole celestial sphere.

For each target source, the respecting of all of the above constraints defines the 'observability time slots'. The creation from a list of proposals of a feasible schedule of observations satisfying these constraints constitutes 'mission planning'.

Figure 2 — Observability constraints for orbit no. 27

Figure 3 — Example of mission-planning input




```
+------------------------------------------------------------------------+
! Target name   2200+420        Alternate names  BL LAC                  !
!                                                                        !
! Target        RA  22  0 39    Pointing    RA  22  0 39    Error box    !
! Position :                    Position :                  degrees      !
!               DEC  42  2  9               DEC +42  2  9   .1000000     !
!------------------------------------------------------------------------!
!                          OBC                      Payload              !
! Configuration #        0    0    0    0    0    0    0    0           !
! Duration in mins       0    0    0    0    0    0    0    0           !
!                                                                        !
! Observation time     3.00 units         Minimum acceptable time   3.00 !
!                                                                        !
! Start time   12393.37500000  within +/-   0.0 days                     !
!                                                                        !
! Repeat  0 times with a spacing of   0.00 days    Auto scheduling  Y    !
!                                                                        !
! Zero phase MJD      0.00000000  Period   0.000000000  Phase  0.00000   !
!                                                                        !
! Grouped obs.    0  Sequential obs.    Occultation     Strong source    !
!------------------------------------------------------------------------!
! Coordinated observations :  Spacecraft  0      Ground observatory  0   !
+------------------------------------------------------------------------+
```

Mission planning

Proposals for the observation of sources by the Exosat observatory are first submitted to the Committee on Proposal Selection for evaluation. Once a proposal is agreed by that Committee, it is encoded in a special form for further processing via the Mission Planning System (Fig. 3). In some cases, observations have to be time-correlated with observations of the same source by other ground-based or space observatories; such an observation is then labelled 'coordinated'. For the study of a periodic source (pulsar, binary object), the astronomer may require that the Exosat observation takes place at specific phases of the cycle. He may also require repetition of the observation on a regular basis or that the source be

Figure 4 — An optimised sequence of observations

EXOSAT ORBIT 96

#	DATE	TIME	MJD 1950	MAN	BETA	UNIQID	SOURCE	RA	DEC	EXPOS	*	PROP#	TARG#	P CODE	OBSERVER
1	84/ 5/18	19:41	12556.8202	30		8096	Reacquisition								
2	84/ 5/19	1: 1	12557.0424		107.3	261	AY LYR	18 42 43	+39 33 30	50	2	P 307	T 922	LLX G12	J. HEISE
3	84/ 5/19	5: 1	12557.2091		103.5	262	1418+546	14 18 6	+54 36 57	242	3	P 270	T 865	AGN F26	A. WILLMORE
4	84/ 5/19	12:31	12557.5216		90.8	41	HD 193793	20 18 47	+43 41 43	334	4	P 129	T 331	LLX F10	A. POLLOCK
5	84/ 5/19	21:31	12557.8966		97.3	263	PKS2135-147*	21 35 1	-14 46 27	334	5	P 49	T 115	AGN F21	J. BERGERON
6	84/ 5/20	6: 1	12558.2508		103.1	264	1418+546	14 18 6	+54 36 57	242	6	P 270	T 864	AGN F26	A. WILLMORE
7	84/ 5/20	13: 1	12558.5424		129.4	265	NGC5548	14 15 42	+25 22 0	501	7	P 309	T 928	AGN G7	G. BRANDUARDI-RAYMONT
8	84/ 5/21	1: 1	12559.0424		108.0	266	AY LYR	18 42 43	+39 33 30	50	8	P 307	T 923	LLX G12	J. HEISE
9	84/ 5/21	5: 1	12559.2091		99.8	267	CYGNUS X-1	19 56 29	+35 3 55	501	9	P 310	T 929	HLX G9	C. PAGE
10	84/ 5/21	16: 1	12559.6674		91.3	268	4U2030+40	20 30 38	+40 47 13	334	10	P 311	T 930	HLX F24	M. VAN DER KLIS
11	84/ 5/22	0:31	12560.0216		107.3	22	NGC5055	13 13 35	+42 17 55	109	11	P 74	T 241	EXG F14	I. GIOIA
	84/ 5/22	5:16	12560.2195			9096	Perigee Passage	---	Perform IFTs for LE1 & GS						

Orbit Fuel Cost is 4.510 units.

Please note that only a source whose name is followed by a "*" should be performed with the PSD.

eventually occulted by the Moon.

For each candidate source, the Mission Planning Program produces time intervals of observability over a period of about one month. A scheduling of those observations subjected to timing constraints is then attempted. This scheduling process is iterated until a solution can be agreed by all parties involved. The task of coordination between the Exosat Observatory and other observatories is handled by the Exosat Observatory Group at ESOC.

The second step in the preparation of the final sequence is the insertion of observations that are free of timing constraints. These observations are arranged so as to minimise the overall manoeuvring time. This optimisation often results in the generation of one-or two-legged slews (instead of the classical Z-Y-Z three-legged slews), thereby minimising fuel consumption.

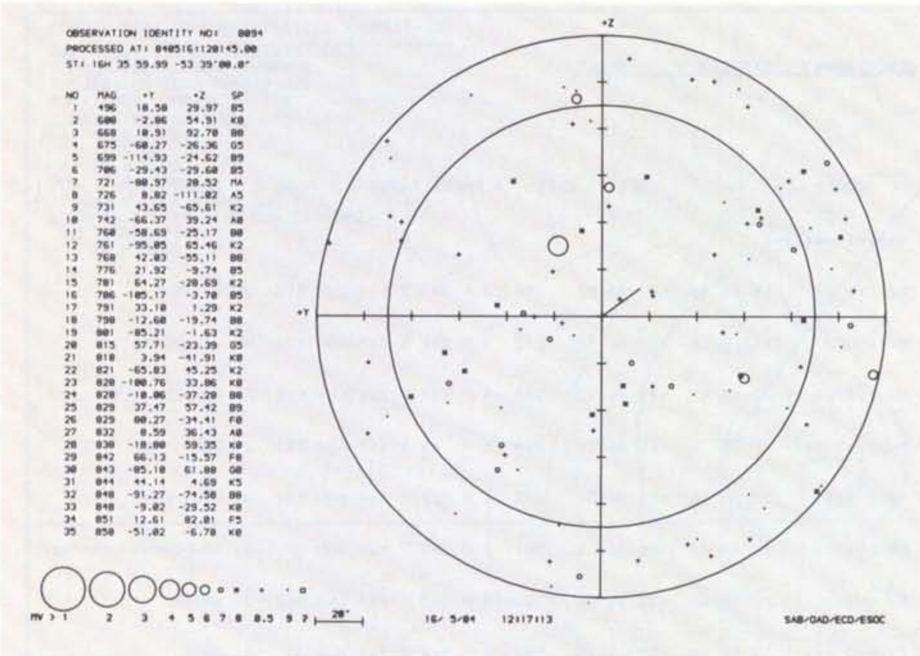
Figure 4 shows an optimised sequence of observations for one orbital revolution (about four days).

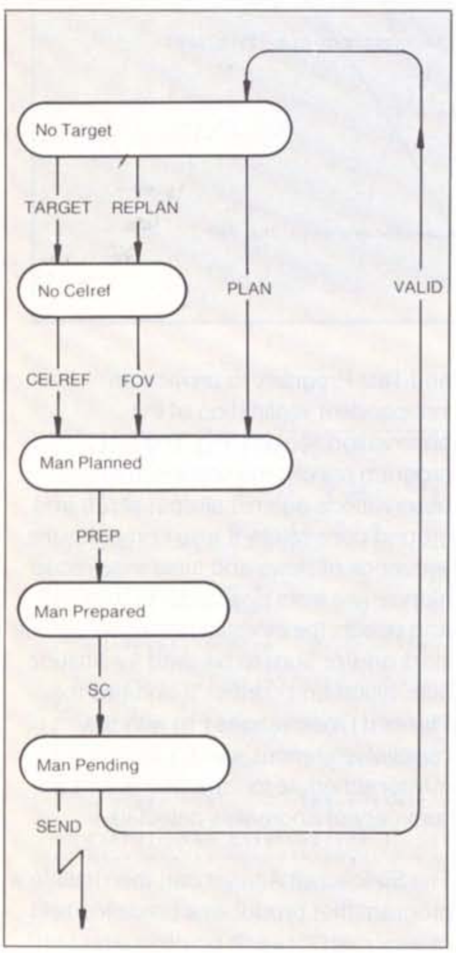
The sequence of observations set up by the Exosat Observatory Group is transferred on a magnetic tape, called the 'Planned Observation Tape', to the Operations Division on a monthly basis for implementation. This tape is processed by the Spacecraft Analyst with the help of a menu-driven, interactive Scheduling and Test Program, to provide an independent verification of the observation sequencing. The test program checks the sequence of observations against all spacecraft and ground constraints. It also computes the sequence of slews and trims required to manoeuvre from one target to the next and selects the celestial references (guide stars and/or Sun) to be used for attitude acquisition and control. It updates the Planned Observations File with the celestial references and finally prints a master schedule for operations and a summary of anomalies detected.

The Spacecraft Analyst can then initiate a program that produces a predicted field-of-view map for each pointing direction,

Figure 5 — Predicted Field-of-View map generated at the mission-planning stage

Figure 6 — Normal transitions in manoeuvre status





showing stars, planets or other extended objects as they should be seen by the star tracker at the time of the observation (Fig. 5). A detailed description of the Exosat Star Catalogue can be found in the ESA Bulletin No. 37.

When any anomalies revealed by the test program have been resolved, the updated Planned Observation File can serve as input to the Manoeuvre Support System for the actual preparation of attitude manoeuvres.

Preparation of attitude manoeuvres

The attitude manoeuvres are prepared by the Spacecraft Controller with the help of the Manoeuvre Support System (MAN). This menu-driven software package consists of a set of programs, each dedicated to a particular task. The programs are run interactively and all driving parameters are retrieved and displayed to the user. They can be changed by the operator in the case of contingencies, such as the preparation of a manoeuvre to an unplanned target (target of opportunity), or a switch to redundant spacecraft equipment. This concept provides great system versatility whilst retaining extreme simplicity for routine operations.

Internally, the MAN system (Fig. 6) recognises five different manoeuvre states:

- *No target:* The previous manoeuvre has been reported as executed, but the new target attitude is not yet specified
- *No celref:* The target attitude is specified, but the celestial references for attitude control are not yet defined
- *Man planned:* The target attitude is specified and the celestial references are selected
- *Man prepared:* The sequence of slews and trims necessary to reorient the spacecraft is available as well as spacecraft antenna switching times.
- *Man pending:* All commands required for the reorientation of the spacecraft and the subsequent acquisition of the specified celestial references have been generated. The manoeuvre can physically start.

The transitions from one status to the next are realised by running the appropriate MAN programs on the task flows presented in Figure 6.

A central 'Manoeuvre Status File', which holds all the data relating to the manoeuvre being considered, is used to communicate between the programs.

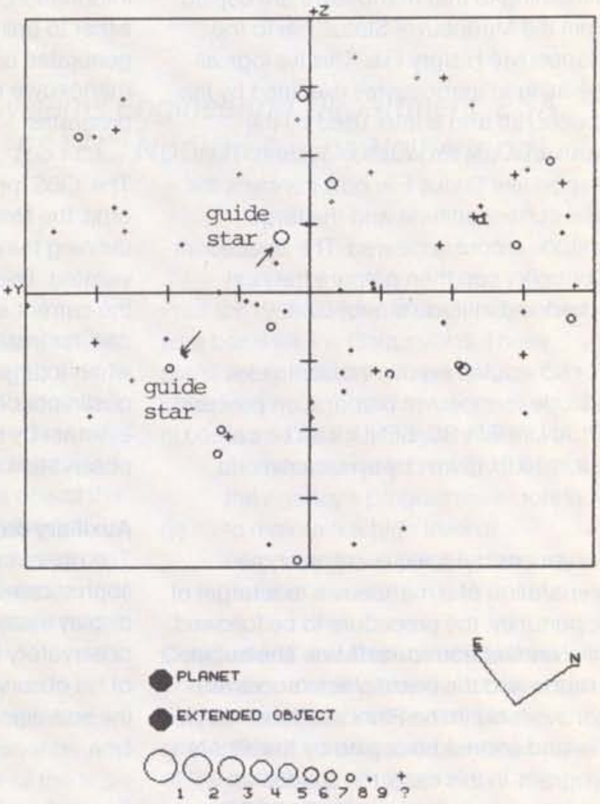
To prepare the next manoeuvre, the Spacecraft Controller first runs the 'PLAN' program, which copies the next planned observation from the Planned Observation File to the Manoeuvre Status File. The Controller next runs the 'PREP' program, which calculates the best slew sequence that satisfies both the spacecraft constraints and the prescribed limits on manoeuvre duration. Other manoeuvre-related information, such as times of spacecraft antenna switching and settling times of the attitude control system, are also computed, displayed to the operator for approval, and then stored in the Manoeuvre Status File.

Figure 7 — Predicted Field-of-View map generated by the MAN system

Figure 8 — Stars detected by the Exosat star tracker

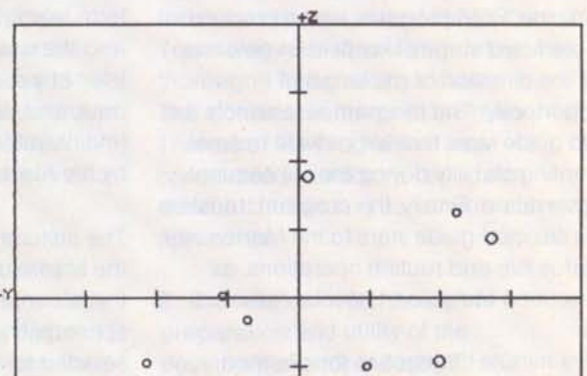
SOURCE: 16H 36, -53 39'
TIME: 84 130:1100.
STAR COUNT: 71

NO	MAG	Y	Z
1	5.06	+ 12.36	+ 24.13
2	6.18	- 9.55	+ 48.61
3	6.78	+ 3.41	+ 86.68
4	6.85	- 65.30	- 33.80
5	7.16	- 34.38	- 36.38
6	7.31	- 87.10	+ 20.63
7	7.36	+ 5.50	-117.01
8	7.41	+ 39.38	- 70.90
9	7.52	- 72.73	+ 31.65
10	7.68	+ 97.66	+ 68.46
11	7.70	- 63.73	- 32.56
12	7.71	-101.93	+ 57.28
13	7.78	+ 37.55	- 60.43
14	7.86	+ 16.51	- 15.48
15	7.91	+ 59.26	- 33.55
16	7.96	-110.65	- 12.06
17	8.01	+ 27.46	- 4.23
18	8.02	+ 91.41	+ 68.93
19	8.08	- 17.76	- 26.20
20	8.11	- 90.73	- 9.58
21	8.25	+ 52.58	- 28.40
22	8.28	+ 0.76	- 48.01
23	8.31	- 72.31	+ 37.66
24	8.38	- 14.86	- 43.68
25	8.38	-107.00	+ 25.56
26	8.39	+ 75.36	- 38.96
27	8.39	+ 30.70	+ 51.95
28	8.42	+ 2.23	+ 30.38
29	8.48	- 25.58	+ 52.73
30	8.52	+ 60.85	- 20.40
31	8.53	- 91.91	+ 53.90
32	8.54	+ 38.45	+ 0.60
33	8.58	- 13.98	- 35.90
34	8.61	+ 5.33	+ 76.03
35	8.68	- 56.45	- 14.01
36	8.69	+ 78.98	+ 84.75
37	8.71	- 13.21	+ 1.01
38	8.72	+119.78	- 5.33
39	8.73	- 9.30	+ 40.48
40	8.74	+ 78.03	+ 35.45



SOURCE: STAR TRACKER
TIME: 84 129:0940.
STAR COUNT: 11

NO	MAG	Y	Z
1	6.30	- 4.11	+ 53.91
2	7.60	- 67.38	+ 37.65
3	6.99	- 81.85	+ 26.83
4	7.82	+ 32.78	+ 0.91
5	7.91	+ 21.85	- 10.20
6	6.63	- 59.81	- 27.88
7	7.73	+ 64.80	- 28.65
8	7.19	- 28.90	- 30.60
9	7.96	+ 4.61	- 42.43
10	7.69	+ 43.08	- 55.30
11	7.41	+ 45.00	- 65.81



PLANET

EXTENDED OBJECT

1 2 3 4 5 6 7 8 9 ?

The Controller may now request computation of spacecraft commands, by initiating the 'SC' program. In addition to the commands required to slew the spacecraft to the target attitude, this program also computes the command sequences needed by the star tracker to acquire and track the new guide stars and the parameters to be used by the ground software for real-time monitoring of spacecraft attitude during the subsequent observation. The computed commands and parameters are stored in the Command Interface File and a printout generated.

By running the 'SEND' program, the Spacecraft Controller transmits the Command Interface File to the Real-Time Command System, which uses Automatic Commanding Programs (ACPs) to uplink the commands to the appropriate spacecraft subsystem according to predefined procedures (command frequency, verification, conditional commanding, etc.). These ACPs, initiated by the Spacecraft Controller, are very effective in reducing the load on the operator, since some 150 attitude commands and 30 attitude-monitoring parameters are generated by the MAN system for a typical reorientation manoeuvre.

When the manoeuvre has been executed, the Spacecraft Controller must 'inform' the MAN system by running the 'VALID' program and reporting the time at which the manoeuvre was actually started and the time at which the required pointing accuracy was reached on the new target (latter provided by the real-time attitude-monitoring system).

If, at the end of the manoeuvre, the guide stars are not found, the Controller commands the star tracker to perform a field-of-view mapping. This map (Fig. 8) is then displayed in a format identical to the predicted one (Fig. 7), allowing the 'VALID' program to calculate the current spacecraft attitude.

Upon validation the parameters pertaining to that manoeuvre are copied from the Manoeuvre Status File to the Manoeuvre History File. This file logs all the attitude manoeuvres executed by the spacecraft and is later used by the Auxiliary Data Production System. The Manoeuvre Status File now contains the new current attitude and the target attitude record is cleared. The Spacecraft Controller can then prepare the next scheduled attitude manoeuvre.

For scheduled events, the complete attitude-manoeuvre preparation process (PLAN, PREP, SC, SEND) can be carried out in 10 to 15 min by an experienced operator.

For an unscheduled event, such as preparation of a manoeuvre to a target of opportunity, the procedure to be followed involves two additional tasks. The target attitude and the celestial references are not available in the Planned Observation File and cannot be copied by the 'PLAN' program. In this case, the spacecraft controller must first use the 'TARGET' program to enter the target attitude, desired time and duration of the manoeuvre, and duration of the observation. The Controller subsequently runs the 'FOV' program, which produces a predicted star-tracker field-of-view map for the direction of the target of opportunity. The program also selects the two guide stars that will provide optimal pointing stability during the subsequent observation. Finally, the program transfers the selected guide stars to the Manoeuvre Status File and routine operations, as described above, can now be resumed.

Last-minute changes to the planned schedule are supported by further facilities of the MAN system, such as the 'WINDOW' and 'OBS' programs. The 'WINDOW' program is particularly useful when a pending manoeuvre has to be either brought forward or postponed. It provides the earliest and latest times at which a manoeuvre may be started without violating any manoeuvre or observability constraint. With this information, the operator can decide either to uplink the commands already generated or to reschedule the manoeuvre by using the 'PREP' and 'SC' programs.

The 'OBS' program displays, over a full orbit, the times at which the constraints defining the observability of a source are violated. This program, applicable to both the current and the next planned target, can, for instance, be used to check if and when a target of opportunity is observable. It may also be used to estimate by how much the current observation can be prolonged.

Auxiliary data production

The observer can make use of a sophisticated real-time analysis and display system at ESOC to tune the observatory to the specific characteristics of his observations, thereby maximising the scientific return from his allocated time.

For end analysis of the data, ESOC provides the observer with a Final Observation Tape. This tape, delivered within four weeks of the observation, contains not only the scientific data in a form readily accessible to the user, but also the spacecraft housekeeping telemetry data, the instrument-calibration data, and the so-called 'Auxiliary Data' (mainly attitude and orbit data) generated by the Auxiliary Data Production System.

The attitude information is extracted from the Manoeuvre History File and provides the nominal three-axis attitude of the spacecraft and the parameter values selected for onboard attitude control. Deviations from nominal attitude are usually so small (<3 arcsec) that they can be neglected. If necessary, the attitude offsets, computed in real time and appended to the housekeeping telemetry data, can be used by the observer to reconstruct the instantaneous attitude.

To aid the observer in establishing the identity of any serendipitous X-ray source detected, a list of astronomical objects falling inside a 2.2° cone around the pointing direction is also supplied. These objects are extracted from the Exosat Star Catalogue (435 000 stars), an X-ray database (about 1000 sources), and more than twenty other catalogues of nonstellar objects (40 000 sources).

The orbit information is supplied as a set of coefficients from which the spacecraft position and velocity can be computed as a function of time.

Conclusion

The reliability and overall flexibility of the above concept has been successfully proven by an extremely rewarding first year of Exosat operation. Moreover, the experience gained so far should be of considerable value in the design and implementation of ground systems for the support of future ESA spaceborne observatories.

Results of the ESA/Industry Symposium on Space Technology

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On 10-12 April 1984, the Agency met with European industry to discuss the content of and future orientation for the Agency's Technology Research Programme. This Symposium, attended by a large number of technologists, mission planners and managers, proved extremely fruitful.

Introduction

The Agency consults with a large number of internal and external users and other parties who can make a contribution to the proper orientation and the efficiency of implementation of its technological developments. This dialogue is one of the most important tools at the Agency's disposal for preparing for future projects and for enabling industry and user groups to prepare for the Agency's next spacecraft projects.

Industry particularly plays an important role in the ESA Technology Research Programme. The largest share of the Programme is executed through industry and it must largely develop the competences and specialisations needed for designing new spacecraft. To allow the Agency to benefit to the maximum extent from this reservoir of industrial expertise in space-technology matters throughout Europe, it was decided to organise a Symposium which would both provide an open forum and allow a collective dialogue between industry and ESA representatives.

The Symposium was structured on the basis of the Agency's major 'Technology Themes', shown for reference in Figure 1. In addition to these theme sessions, there was a plenary session, covering the overall orientation of the Agency's programme, a round table on management implementation and policy aspects, and a special session on in-orbit technology demonstration.

The Agency's Technology Research Programme for 1984 and Medium-Term Plan for 1985/86 (the 'Blue Book') served as a basis for the discussions. These plans are guided by two primary objectives:

(i) to ensure the timely availability of the necessary technology for all of the Agency's programmes

(ii) to maintain a high level of competence in space technology in Europe.

Conclusions and Recommendations

The final outcome of the Symposium can best be described in terms of the responses to seven basic questions asked at the outset:

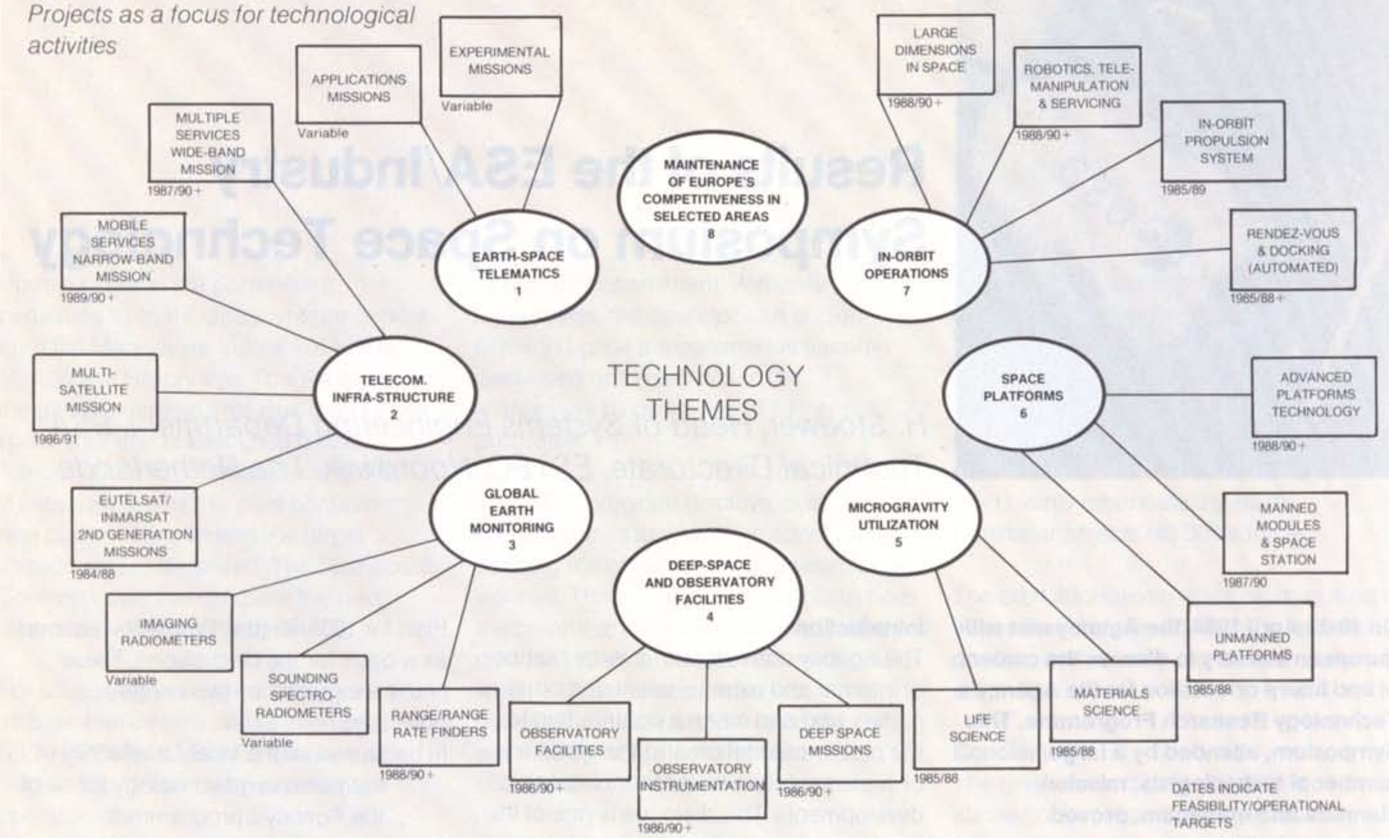
1. Appropriateness of the technical orientation to expected future programme needs?

In general, the Agency's approach to the technical orientation and content of the Technology Research Programme was thoroughly endorsed by industry. The technical contents of the major Themes of the Programme were considered satisfactory, taking into account the funding constraints currently applicable.

2. Importance of technological preparation and utility of the developments for industry?

The overall importance of a sound programme of technology research and development for European space industry was heavily stressed. This feeling was especially strong in view of the emphasis placed on advanced space technologies in the USA and Japan, and the need for competitivity of European space products in the World market.

Figure 1 — Technology Themes and Projects as a focus for technological activities



3. Proposed additional subjects not presently addressed by ESA?
There were a great number of additional subjects proposed by industry for inclusion in the Agency's programme of technological research and development. The most important ones related to the manned systems technologies, launch vehicles and re-entry-system technologies, which should be covered more extensively.

4. Subjects that could be eliminated?
Essentially no activities were felt to be unnecessary or proposed for elimination. It was, however, felt that improved harmonisation of ESA and national technologies could yield further benefits.

5. Timing and schedule for bringing the technologies on-line?
The overall schedule and planning was considered adequate, given the extent to which mission requirements can currently be identified. However, when compared with the presently available funding provisions, the goals were considered unrealistic in many instances.

6. Appropriateness of funding allocation (Basic and Supporting Technology Programmes)?
The overall funding provisions were considered inadequate for the achievement of the objectives and the needs for achieving/maintaining the competences necessary to ensure industrial competitivity in the appropriate fields of space technology in the World market.

Industry endorsed the Agency's goal of allocating 10% of the ESA budget to technology activities. As part of this goal, the proposed in-orbit Technology Demonstration Flights, together with Supporting Technology Programmes for each of the Agency's major programme areas, were welcomed and supported.

7. Need for in-orbit technology demonstration?
The Agency's initiative in introducing more frequent opportunities for in-orbit testing and qualification of European technologies was very much appreciated by industry. The prospects of a much shorter 'proof of technology demonstration' cycle, together with the associated reductions in risk in the main development phases (Phases C/D) of Agency projects and for commercial satellite developments, were considered important and were strongly endorsed.

The two general questions raised during the opening sessions were:

- Has ESA optimised its programme of technology R&D within the given resource constraints?
- What should be the volume, technical character and content of the Agency's future Technology Programme?

The consensus in response to the first of these questions was a definite 'yes'. In answer to the second, the Agency's existing planning was endorsed and many constructive contributions were received from industry during the course of the Symposium for its further enhancement.

Copies of the Symposium summary report are available from the Systems Engineering Department (Code TF), at ESTEC.

Acknowledgement
The Agency is grateful for the organisational support provided to the Symposium by Eurospace, and its Director General Mr. Y. Demerliac.

In Brief

ESA Astronaut in Space Shuttle Crew for Flight 51H

The composition of the crew for the STS-51H mission, planned for November 1985, has recently been announced by NASA. ESA astronaut Claude Nicollier will be one of the Mission Specialists on this flight. A Swiss national and an astronomer by training, Claude Nicollier is also a reserve-list pilot with the Swiss Air Force.

The other crew members will include Vance D. Brand (Shuttle Commander), Michael J. Smith (Pilot), Robert C. Springer and Owen K. Garriott (Mission Specialists), Michael L. Lampton and Byron K. Lichtenberg (Payload Specialists).

Two European experiments carried on Spacelab-1, the Grille Spectrometer and the Metric Camera, are to be reflown on this mission as part of the nine-experiment payload.

Claude Nicollier

Meteosat Industrial Contract Signed

The contract for the procurement of a series of satellites of the operational Meteosat type was signed at ESA Headquarters on 15 May 1984 by Mr. E. Mallett, Director of the Agency's Application Programmes, in the presence of Mr. P. Madon, Director of Civil Programmes for the French Société Nationale Industrielle Aérospatiale (Aérospatiale).

This contract, worth some 1100 million French francs, provides for the delivery of three satellites, to be launched by Arianespace in June 1987, September 1988 and November 1990. It results from the decision taken by the Signatories of the Eumetsat Convention on 24 May 1983 to undertake the Meteosat Operational Programme and to entrust its management to the European Space Agency (see ESA Bulletin No. 35, page 90).

The construction of the Meteosat satellites is being entrusted to a European industrial consortium under the prime contractorship of Aérospatiale, most of whose members have already taken part in the development of the two preoperational Meteosat spacecraft currently in orbit. The co-contractors are ANT and MBB (Germany), ETCA (Belgium), Matra (France), Selenia (Italy) and IGG and MSDS (United Kingdom). Other firms in various European countries are associated with the work as subcontractors.

Signature of the operational Meteosat industrial contract by Mr. P. Madon (left) and Mr. E. Mallett

From Spacelab to Space Stations

ESA and NASA Experimenters involved in the First Spacelab Mission met together in an Investigators Working Group Meeting on Capri from 13 to 15 June to review the first results of their experiments. The Meeting, conducted in the form of a round-table, addressed each of the five major disciplines of the First Spacelab Payload: space plasma physics; materials and fluid sciences; life sciences; astronomy and solar physics; atmospheric physics and Earth observation.

This IWG Meeting was preceded on 12 June by a Forum, chaired by Sen. Luigi Granelli, Italian Minister for Scientific Research and Technology, titled 'From Spacelab to Space Stations'. Three main topics were addressed during this Forum:

- the Spacelab-1 mission: scientific objectives, summary of preliminary results, lessons learned
- space stations: European involvement and NASA scenarios
- the Italian contribution (Columbus project, tethered satellites, IRIS).

A second Forum titled 'Space Systems Utilisation and the Legal/Economic Aspects' followed the IWG meeting on 16 June.

The participants at the Capri meeting included the Spacelab-1 astronauts Cap. John W. Young, Dr. Byron K. Lichtenberg, Dr. Ulf Merbold (ESA), Dr. Owen Garriott and Dr. Robert Parker.

New Chairman of ESA Council Elected

At its meeting on 27 – 28 June 1984, the ESA Council elected Dr. H.H. Atkinson (United Kingdom) as its new Chairman. He succeeds Prof. H. Curien (France) at the end of his term. Mr. J. Stiernstedt (Sweden) and Dr. H. Strub (Germany) have been elected Vice-Chairmen.

Dr. Atkinson, born in New Zealand, is 54 years of age. He has a BSc and MSc with first class honours in physics, and was awarded a PhD by Cambridge University in 1958. In 1969 he was seconded to the staff of the Government's Chief Scientific Advisor in the Cabinet Office. In 1972, he became Head of the Astronomy, Space and Radio Division of the UK Science Research Council. He was promoted to Under-Secretary in 1979. In 1983, he became Director of Science at the Science and Engineering Research Council (SERC), where he also has responsibility for International Affairs.

Closely connected with ESA activities since 1973, Dr. Atkinson has been UK Delegate to and, since 1981, Vice-Chairman of the ESA Council.

European Workshop on Laser Applications and Technology in Space

An International Workshop on Space Laser Applications and Technology (SPLAT), organised jointly by ESA's Directorate of Applications Programmes and ESA's Technical Directorate, was held in Les Diablerets, in Switzerland, from 26 to 30 March 1984.

The SPLAT Workshop brought together specialists in laser techniques, the manufacturers of space hardware and the potential users, with more than 100 participants from some ten countries, including the United States. Discussion topics included the present state of laser technology and the prospects for developing and using these techniques in fields as varied as space telecommunications, geophysics, study of the atmosphere and space navigation.

Lasers have features that make it possible today to envisage improving the performance of space telecommunications, and ESA is currently developing a laser transponder suitable for linking one satellite with another. Such links would make it possible to reduce the level of errors in transmission and increase the amount of data passed. Laser intersatellite links can also be expected to play a leading role in data-relay systems, by providing direct communication on a worldwide scale between satellites in low Earth orbit, or space stations, and a relay satellite in geostationary orbit.

Opening address by Prof. M. Trella, ESA's Technical Director

With its high emission frequency and precisely-aimed beam, the laser allows extremely accurate measurement of range, velocity and angle between various points in space. It is therefore already being seen as an essential element of a number of space systems to be used for space geophysics (e.g. for topographical mapping of the Earth's surface, measuring the deformation and movements of tectonic plates, etc.).

One of the most important areas of application for space-based laser systems is climatological studies. As it passes through the various layers of the atmosphere, the laser beam makes it possible to measure such parameters as atmospheric temperature, humidity, pressure and composition, which are essential for weather forecasting. Such measurements at different altitudes would provide a great improvement over the broad photographic information currently employed.

It is also planned to use laser systems as tools for measuring and communicating during the construction of orbital stations. The rendezvous and automatic docking of two spacecraft, for example, can be controlled by laser detectors, acting as precise and fast-responding optical radars. Laser systems can also be used for coordination and formation-keeping for individual spacecraft or clusters of spacecraft.

One goal of the SPLAT Workshop was to establish, with the help of the assembled experts, what re-targeting may be needed in the research and development programmes currently under way. Another was to seek recommendations regarding fresh action to be taken in respect of the systems needed for preparing and developing future civilian space projects involving lasers.

The complete Proceedings of the Workshop were published in June as ESA Special Publication SP-202. These Proceedings (price 65 Dutch guilders, or equivalent) are available from ESA Scientific & Technical Publications Branch, Postbox 299, Noordwijk, The Netherlands.

Exosat Completes First Year in Orbit

On 26 May, the Agency's X-ray observatory satellite Exosat completed its first year in orbit, a year in which it has provided astronomers the World over with exciting new information in the field of X-ray astronomy.

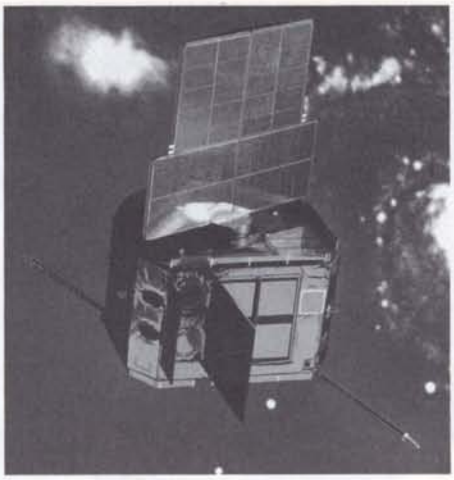
The scientific results from the mission to date have been extremely exciting. In particular, the observation of stars in our own galaxy has been especially rewarding. Such exotic objects as neutron stars and black holes – dead stars less than 20 km in diameter but heavier than our own Sun – have provided detailed information on the physics involved in objects where extreme gravitational conditions exist (see ESA Bulletin No. 36, page 21 and No. 38, page 17).

Observations of the temporal and spectral characteristics of galactic binary X-ray sources using the Exosat experiments have already determined the orbital periods of a number of binary systems and measured the rotation rates and changes in rotation of the neutron stars which are believed to power these binary systems. Data from such dying stars has provided information on the mechanisms whereby the neutron star or black-hole devours material from the primary normal star. The bulk of the energy released is radiated at X-ray wavelengths and is

many thousands of times greater than the Sun's total energy output.

The Exosat telescopes have provided detailed images in a number of wavebands of the remnants of dead stars. The study of these images and their spectra has provided results on the energy involved in the original explosion and the physical conditions in space in the vicinity of the explosion.

Exosat has also probed deeper into space, outside our own galaxy, to study the energy output of active galaxies, quasars, and clusters of galaxies. The X-ray output of active galaxies and quasars is far larger than that of our own and results from energetic phenomena operating at the very core of the galaxy. Studies of the spectra and time variability of the X-ray emission from such objects has been carried out to determine the size and physics of the central engine which is powering the core. Finally, observation of clusters of galaxies has provided data on the temperature of the tenuous gas now known to exist between galaxies and the interaction of individual galaxies with this gas. Such gas, only observed at X-ray wavelengths due to its high temperature of 100 million degrees, may represent the so-called 'missing mass' of the Universe, which is required to 'close' the Universe and is therefore of major cosmological significance.



Exosat

In spite of the problems encountered by the detectors, mentioned previously, Exosat's first year in orbit has already provided a wealth of scientific results which will keep astronomers engaged for many years to come. It is hoped that the next two to three years of the mission will see many astrophysical questions answered and the future observations will build on the results obtained from this exciting first year.

ESA at the Barcelona International Fair

A major event in the Agency's 1984 calendar was its attendance at COSMO '84, the Barcelona Fair, from 2 to 10 June.

Part of the accent was on recent achievements, with full-sized models of Exosat, the European Scientific X-ray observation satellite launched on 26 May 1983, and of Marecs, the European maritime communications satellite, the second flight model of which (Marecs-B2) is to be launched by Ariane at the end of 1984.

The outstanding success of the first Spacelab mission was also featured, with giant-screen projection of films and video clips.

Future activities in telecommunications were highlighted too, with a full-sized model of the large pre-operational Olympus platform, which will be the forerunner of a family of geostationary satellites able to carry a variety of telecommunications payloads, particularly for direct television broadcasting.

Also on the ESA stand was a direct reception station linked to the Meteosat-2 satellite, automatically providing screen images and printouts of the satellite's half-hourly images of the Earth's disc.

Press interview given by Dr. W. Brado (second from right), ESA's Head of Cabinet

The ESA stand

and twenty years ago . . .

N° 5

EUROPEAN SPACE RESEARCH ORGANISATION

CERS-ESRO 36, rue La Pérouse, Tel. 225.24.02 15 September 1964

NEWS IN BRIEF

I. ESRO NEWS

FIRST LAUNCHINGS : The two first launchings undertaken by ESRO took place on 6 and 8 July from the Salto-di-Quirra range (Sardinia). Skylark rockets carried experiments intended for the study of ejection phenomena and photo-ionisation in the atmosphere. The experiments had been planned by the Max Planck Institute in Munich and the Institut d'Astrophysique de l'Université de Liège, which are both concerned with the study of comets. ESTEC had assembled the payload.

During these two launchings, baryum and strontium as well as ammonia were relased at altitudes of approximately 150 and 200 km respectively (the expected altitude was not reached during the second launching, due to strong wind). The ejected clouds were observed from the ground by means of a number of cine-cameras, 1 television camera, photo-electric equipment and spectro-graphs.

The clouds were visible for 1½ hours and not only from Sardinia, but also from Italy, Sicily and even Africa. The results are at present being examined and the scientific groups hope that the experiments will enable them to learn more, both about the upper atmosphere and of some of the physical phenomena occurring in comets.

SUMMER SCHOOL - A summer school on space technology, organised by ESRO was held in Oxford from 10 August to 4 September 1964. The Summer School comprised a series of lectures intended for junior engineers and physicists who envisage a career in research and development work in the space field.

The lectures dealt with the following subjects: instrumentation, launching vehicles, satellite orbits, control and stabilisation, power supplies, space environment.

Furthermore, a series of seminaries took place during which the main European space projects were discussed, such as the ELDO launcher, the French launcher, Diamant, NASA's orbiting astronomical observatory (OAO), the United Kingdom family of satellites, the French satellites FR-1 and D-1, the Italian San Marco project, etc.

Professor AUGER, Director-General of ESRO, opened the Summer School by a talk on space science. Dr. A. W. LINES, Technical Director, and about 15 other lecturers gave a total of 50 lectures and were in charge of 10 seminaries. These seminaries were attended by

P/1191.

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55 junior engineers and physicists from 10 Members States (United Kingdom 12, France 10, Spain 3, Italy 2, Sweden 3, Denmark 2, Switzerland 5, Belgium 6, Netherlands 4, Federal Republic of Germany 8).

PRINCIPAL MEETINGS (since 15 May 1964)

- COUNCIL ; 2nd Session, 15/17 June; 3rd Session, 28/29 July.
- 1st meeting of the Scientific and Technical Committee 10/11 September (Chairman: Dr. R. LÜST, RFA; Vice-Chairman: Prof. B. PETERS; Denmark).
- 1st meeting of the Administrative and Finance Committee 16/17 July (Chairman:M.M. SASSOT, Spain; Vice-Chairman: Mr. O. OBLING, Denmark)

The following interim groups, now dissolved, held their last meeting on the following dates : Interim Scientific and Technical Working Group, 25/26 May; Interim Administrative Working Group, 20/21 May and 2/4 June; Appointments Commission, 19 May and 28 July; Interim Structure Group 23/24 June.

AGREEMENTS :

- Agreement with SWEDEN signed on 29 July 1964 for the establishment of a launching range for sounding rockets at Kiruna.
- Agreement with ITALY, by an exchange of letters (which entered into force on 15.6.1964) concerning two launching campaigns with Skylark rockets to be undertaken from the Salto-di-Quirra range during summer and autumn 1964.
- Agreement with NASA signed on 8.7.1964, confirming the intention of the two bodies to co-operate with a view to launching two first ESRO satellites, ESRO I and ESRO II. ESRO will supply the satellites and the scientific instruments; NASA will launch the satellites on a polar orbit by means of Scout rockets. The launchings are due to take place in 1967.
- Agreement by an exchange of letters with FRANCE (entered into force on 15.8.1964) concerning the two launching campaigns with Centaure rockets, to be undertaken from the Ile du Levant range during autumn 1964 and spring 1965.
- (Furthermore, an agreement with the NORWEGIAN Government is under preparation, concerning the use of the Andoya range for ESRO experiments with Centaure rockets during autumn 1965).

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STAFF MATTERS

At its second and third Sessions, the COUNCIL adopted the Staff Regulations, the Rules governing the Provident Fund (with a reservation in respect of the articles concerning the management of the Fund) and an autonomous Social Security Scheme (applicable from 15.6.1964).

The Council granted to the staff at ESDAC the cost-of-living allowance of 5.5% recommended by the Co-ordinating Committee of the Four International Organisations with Headquarters in Paris; prolonged until the end of 1964 the authorisation to grant a double residence allowance and an education allowance to staff members working in Delft, Darmstadt and Kiruna; agreed the proposal on loans to be granted to staff members at a low rate of interest.

As regards Headquarters staff at the end of 1964, the proposed figure of 167 was approved.

NEWS OF THE ESTABLISHMENTS

ESTEC : On 28 and 29 July, the Council discussed the question of the final site of ESTEC and asked for a supplementary report on the possible effects of the proximity to the sea of the Noordwijk site, proposed by the Netherlands Government as a more suitable site. The report will be circulated to the members of the Council at the beginning of October. ESTEC will remain in Delft until the final buildings are completed on the new site. The temporary premises comprise several workshops (design, engineering, vibration tests, etc...). ESTEC is at present preparing the payloads to be launched by Centaure and Skylark rockets in October and November. The numerical strength foreseen at the end of 1964 is 276.

Staff having joined ESTEC since 1 July (Category A)

- Satellite Projects Division : M. PACAULT (France), Assistant Director ; Mr. GRENSEMANN (Fed. Rep. of Germany); Mr. SWIFT (U.K.); Mr. NOYES (U.K.), Deputy Head of the "Programmes" Section in the Control Centre.
- Applied Research Division : Mr. Van CAKENBERGHE (Belgium), Assistant Director, Power Supplies; Mr. ROWLES (U.K.) and Mr. PREUKSCHAFT (Fed. Rep. of Germany), Instrumentation Section;
- Administration : Mr. SCHUSTER (Fed. Rep. of Germany), temporarily in charge of "General Services"; Mr. Van REETH (Belgium), Contracts Officer; Mr. Van WORT (Netherlands), Accounting Officer.

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ESDAC : is at present working on computations for ESTEC, and prepares the data handling system for the next sounding rocket launching and the programme of orbit computation. ESDAC is using the IBM 7080 computer belonging to the Deutsches Rechenzentrum, situated in the vicinity of its temporary offices

Staff having joined ESDAC since 1 July (Category A)

Miss W. LLOYD, British mathematician, Head of the Programming Section of the Data Handling Division; Dr. Klaus LENHART, Austrian mathematician. Mr. TAYLOR, British mathematician, is due to take up duties in the Data Analysis Division in September.

KIRUNA : The preliminary studies having been completed, the Swedish firm AB. Gravmaskiner is now proceeding with the site preparation (roads). Another Swedish firm, Paul Anderson, has been asked to undertake the construction of the principal buildings of the launching platform and the work has begun.

The site engineer, Mr. HEMRE (Norway) has taken up his duties at Kiruna.

ESRIN : At its meeting of 28 July, the Appointments Commission agreed to offer the post of Director of ESRIN to Dr. JORDAN, German physicist.

LAUNCHING PROGRAMME

SOUNDING ROCKETS

- Payload VI, under preparation at Sud-Aviation, will be launched from the Ile du Levant range at the beginning of November 1964.
- Payload II is due to be launched from Sardinia by Skylark rockets at the beginning of December 1964, if the work to be carried out on the launcher (Gigli Tower) is completed by that date.

SATELLITES

- ESRO I : Preliminary studies of ESRO I are still in progress at SAAB in Sweden and at the Centro delle Ricerche Aerospaziali in Italy.
- ESRO II : On the basis of the preliminary studies carried out by ACEC (Belgium) and ETH (Switzerland) a specification for tender action was sent to 31 European firms on 26 June 1964.
- Large Astronomical Satellite : The preliminary design studies carried out by the firm DVL (Deutsche Versuchsanstalt für Luft und Raumfahrt, Fed. Rep. of Germany), CNES, (Comité National de Recherches Spatiales, France) and RAE (Royal Aircraft Establishment, U.K.) are completed. ESTEC is preparing further proposals which will form the basis for a tender action.
- Small Stabilised Satellite : The preliminary design study carried out by the RAE (U.K.) is completed and is now being examined by ESRO's Scientific and Technical Committee.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 8, No. 2:

THE SEMI-TRANSPARENCY CORRECTION AS APPLIED OPERATIONALLY TO METEOSAT INFRARED DATA: A REMOTE-SENSING PROBLEM
BOWEN R A & SAUNDERS R W

RANGE MEASUREMENTS TO THE OTS-2 SATELLITE BY MEANS OF A STELLA TERMINAL
KIRCHNER D ET AL

SIMULATION OF SYNCHRONOUS DATA SOURCES AND ASSOCIATED DATA SYSTEMS
CHAPUIS C ET AL

A TST/SS-TDMA TELECOMMUNICATIONS SYSTEM: FROM CABLE TO SWITCHBOARD IN THE SKY
PENNONI G

AN IMPROVED MATERIAL FOR SPACECRAFT THERMAL AND CHARGING PROTECTION – TCC KAPTON
BOUCHEZ J P & LEVADOU F

NEW DESIGN CONCEPTS FOR SWITCHING REGULATORS
MEULDIJK D

Special Publications

ESA SP-202 // 325 PAGES
SPLAT – SPACE LASER APPLICATIONS AND TECHNOLOGY, PROC. ESA WORKSHOP, LES DIABLERETS, SWITZERLAND, 25-30 MARCH 1984
BATTRICK B & ROLFE E J (EDS)

ESA SP-208 // 520 PAGES
NOWCASTING II – MESOSCALE OBSERVATIONS AND VERY-SHORT-RANGE WEATHER FORECASTING, PROC. IAMAP/WMO/ESA/SMHI INTERNATIONAL SYMPOSIUM, 3-7 SEPTEMBER 1984, NORRKÖPING, SWEDEN
BATTRICK B & ROLFE E J (EDS)

ESA SP-218 // 518 PAGES
FOURTH EUROPEAN IUE SYMPOSIUM, PROC INTERNATIONAL SYMPOSIUM, ROME, ITALY, 15-18 MAY 1984
ROLFE E J & BATTRICK B (EDS)

ESA SP-219 // 100 PAGES
THE EFFECT OF GRAVITY ON THE SOLIDIFICATION OF IMMISCIBLE ALLOYS, PROC. OF AN RIT/ESA/SSC WORKSHOP AT JARVA KROG, SWEDEN, 18-20 JANUARY 1984 (MARCH 1984)
ROLFE E J & BATTRICK B (EDS)

ESA SP-1061 // 309 PAGES
REPORT PRESENTED BY THE EUROPEAN SPACE AGENCY TO THE 25TH COSPAR MEETING, GRAZ, AUSTRIA, JUNE 1984 (MAY 1984)
BURKE W R & ANDRESEN R D (EDS)

ESA SP-1062 // 87 PAGES
REPORT ON THE ACTIVITIES OF SPACE SCIENCE DEPARTMENT IN 1982-1983 (FEB 1984)
PAGE D E ET AL

Brochures

ESA BR-12 // 24 PAGES
EUROPEAN SPACE TRIBOLOGY LABORATORY (MARCH 1984)
BURKE W R (ED)

ESA BR-17 // 25 PAGES
A SURVEY OF SPACE BIOLOGY AND SPACE MEDICINE (FEBRUARY 1984)
PLANEL P H & OSER H (ED. BURKE W R)

ESA BR-19 // 21 PAGES
THE TUD-ESA SPHERICAL NEAR-FIELD ANTENNA TEST FACILITY, LYNGBY, DENMARK (APRIL 1984)
HANSEN J E (ED. BATTRICK B)

Contractor Reports

ESA CR(P)-1859 // 232 PAGES
EVALUATION DE MATERIEL DE REPONSE THERMIQUE – RAPPORT DE SYNTHESE (OCT 1983)
AVIONS MARCEL DASSAULT/BREGUET AVIATION, FRANCE

ESA CR(P)-1861 // 134 PAGES
INDUSTRIALISATION OF EMITTER MODULES – PHASE 2 – FINAL REPORT (NOV 1983)
SEP, FRANCE

ESA CR(P)-1862 // 114 PAGES / 63 PAGES / 315 PAGES
MATHEMATICAL MODELLING OF A CONTINUUM: RELATED MODAL ANALYSIS – VOLUME 1: PROBLEM ANALYSIS – VOLUME 2: USER'S MANUAL – VOLUME 3: PROGRAMMERS' MANUAL (NOV 1983)
UNIVERSITY OF SURREY, UK

ESA CR(P)-1864 // 17 PAGES
ETUDE ENREGISTREURS FUTURS DE L'ASE – RAPPORT FINAL (UNDATED)
ENERTEC/SCHLUMBERGER, FRANCE

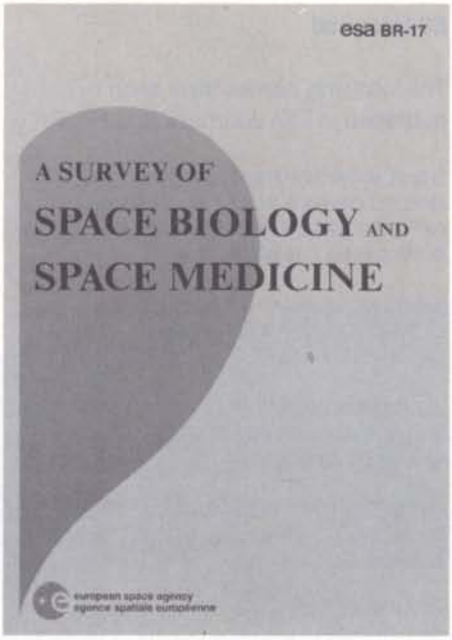
ESA CR(P)-1866 // 357 PAGES
ASSESSMENT OF DATA HANDLING CONFIGURATION FOR ON-BOARD OPERATION SYSTEM DEFINITION – PHASE 1 FINAL REPORT (UNDATED)
MATRA, FRANCE

ESA CR(P)-1867 // 82 PAGES
ETUDE SUR LA COMPARAISON DES DONNEES IMAGES PRODUITES PAR DES SATELLITES DE CARACTERISTIQUES DIFFERENTES (OCT 1983)
SODETEG, FRANCE

ESA CR(P)-1868 // 361 PAGES
APPLICATION OF LASERS FOR CLIMATOLOGY AND ATMOSPHERIC RESEARCH (OCT 1983)
BATTELLE, GERMANY

ESA CR(P)-1869 // 434 PAGES
DESIGN OF A CARBON DIOXIDE LASER TRANSCEIVER PACKAGE FOR SPACE-TO-SPACE OPTICAL COMMUNICATION – FINAL REPORT (JUL 1983)
BATTELLE, GERMANY

ESA CR(P)-1870 // 131 PAGES / 130 PAGES / 260 PAGES
ESSAIS DE SIMULATION D'ENVIRONNEMENT SPATIAL SUR REVETEMENTS DE CONTROLE THERMIQUE DE SATELLITES (AUG 1983)
ONERA, FRANCE



ESA CR(P)-1871 // 32 PAGES
SIMULATION ALGORITHMS FOR PARALLEL PROCESSES (NOV 1983)
SALFORD UNIVERSITY, UK

ESA CR(P)-1872 // 23 PAGES
STUDY FOR CONCENTRATION FOR SPACE PHOTOVOLTAIC GENERATOR – EXECUTIVE SUMMARY (DEC 1983)
AEROSPATIALE, FRANCE

ESA CR(P)-1873 // 145 PAGES
TWO-PHASE HEAT TRANSPORT SYSTEM – CONCEPTUAL STUDIES (AUG 1983)
SABCA, BELGIUM

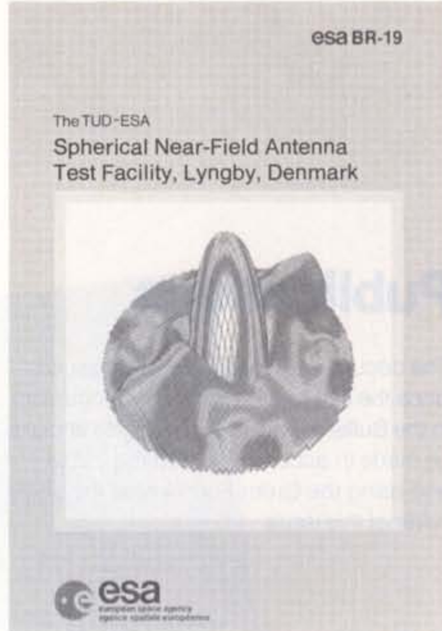
ESA CR(P)-1877 // 38 PAGES
LASER RANGING TECHNOLOGY FOR SPACE APPLICATIONS – VOL II: HIGH STABILITY CARBON DIOXIDE LASER FOR RANGE RATE FINDER – DEVELOPMENT OF CRITICAL TECHNOLOGIES (JULY 1984)
MBB, GERMANY

ESA CR(P)-1881 // 176 PAGES
STUDY ON CRITICAL ASSESSMENT OF IR CCD ARRAYS FOR SPACEBORNE REFLECTED AND THERMAL IR IMAGERS – FINAL REPORT (DEC 1983)
MBB, GERMANY

ESA CR(P)-1882 // 415 PAGES / 33 PAGES
POPSAT – A CANDIDATE SATELLITE SYSTEM FOR SOLID EARTH APPLICATIONS AND SCIENCES – PRELIMINARY FEASIBILITY STUDY – FINAL REPORT VOL I: SUMMARY; VOL II: DEVELOPMENT PROGRAMME (NOV 1983)
DORNIER, GERMANY

ESA CR(P)-1883 // 104 PAGES
ANALYSIS OF POPSAT GRAVITY MODEL ERRORS (NOV 1983)
THD, THE NETHERLANDS

ESA CR(P)-1884 // 103 PAGES
EXPERIMENTAL EXHAUST PLUME INVESTIGATION WITH MBB 10 N BIPROPELLANT THRUSTER – FINAL REPORT (DEC 1983)
MBB, GERMANY



ESA CR(X)-1857 // 44 PAGES
STUDY OF CONCEPTS FOR TV FEEDER LINK STATION – SUMMARY REPORT (OCT 1983)
MARCONI, UK

ESA CR(X)-1858 // 190 PAGES
BRITISH AEROSPACE MAST (BAM) – FINAL REPORT (APR 1983)
BADG, UK

ESA CR(X)-1860 // 64 PAGES
SINGLE CELL BATTERY, VACUUM CHAMBER TEST AND MODEL VERIFICATION – FINAL REPORT (DEC 1983)
ELEKTRONIKCENTRALEN, DENMARK

ESA CR(X)-1863 // 55 PAGES
VOLUME, DISTRIBUTION ET AMPLITUDE DES TELECOMMUNICATIONS EN VOL A USAGE PROPRE DES COMPAGNIES (DEC 1983)
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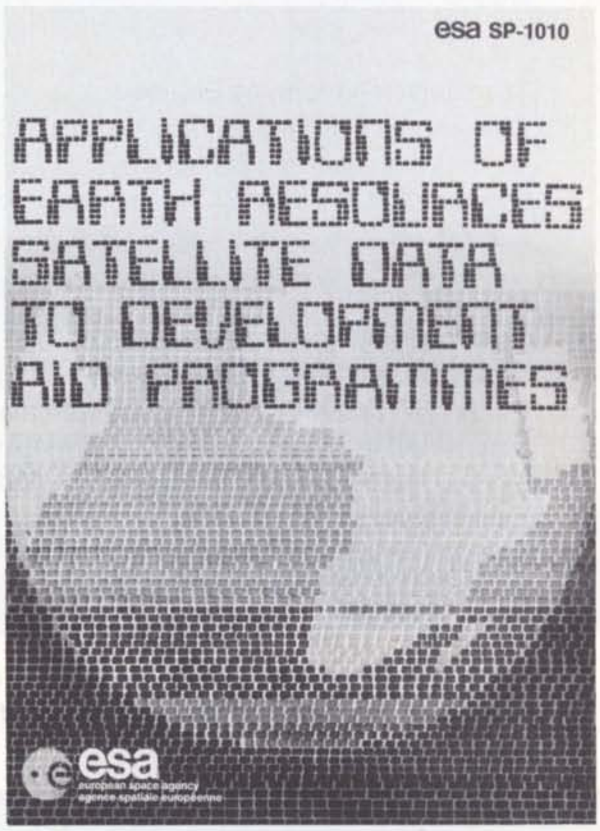

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