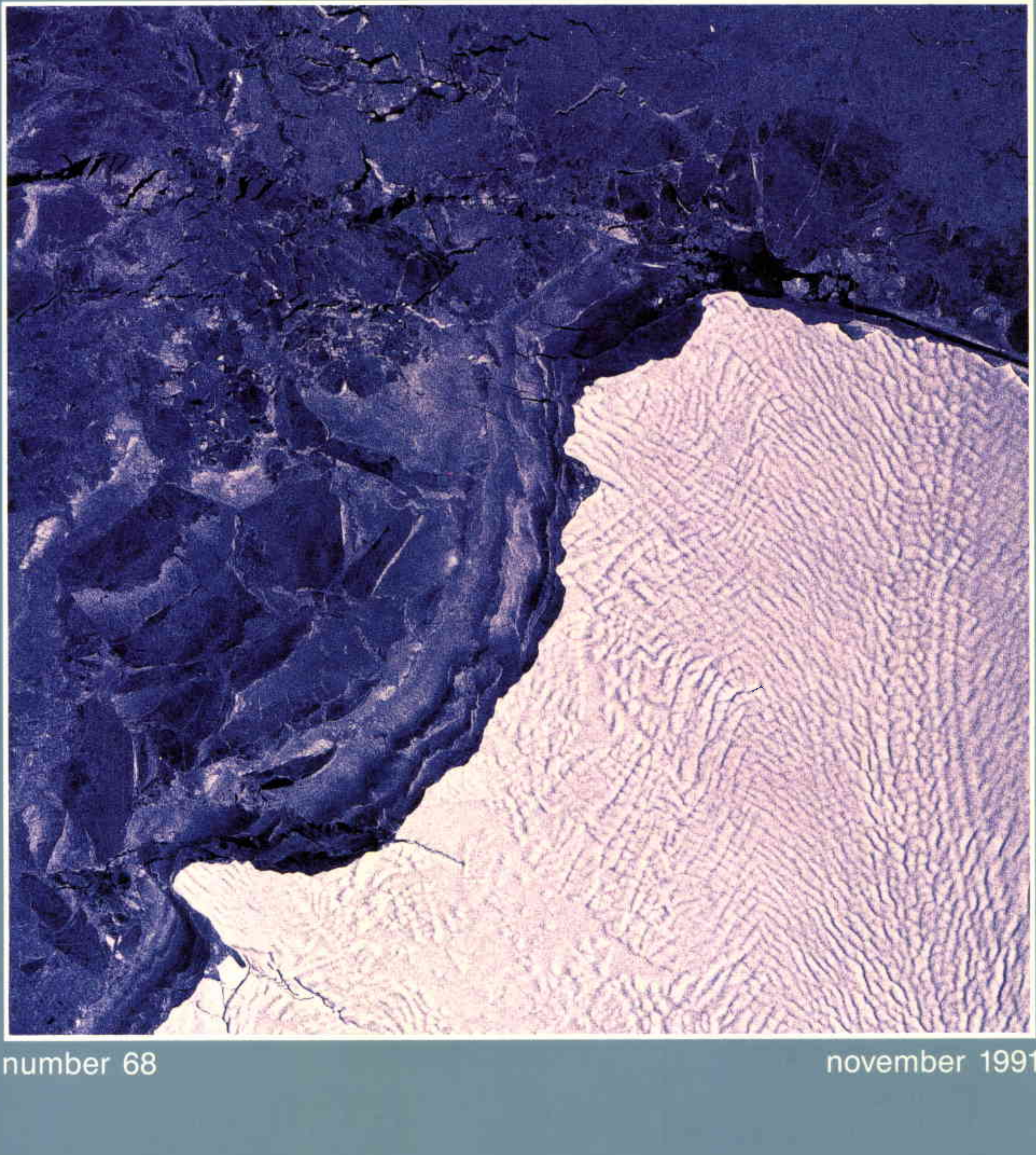
european space agency

esa bulletin

agence spatiale européenne



number 68

november 1991

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Prof. F. Carassa

Director General: J.-M. Luton.

agence spatiale européenne

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

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

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

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

Le Directoire de l'Agence est composé du Directeu général; de l'Inspecteur général; du Directeur de Programmes scientifiques; du Directeur de Programmes d'Observation de la Terre et de so Environnement; du Directeur du Programme d Télécommunications; du Directeur des Systèmes d Transport spatial; du Directeur du Programme Statio spatiale et Microgravité; du Directeur de l'ESTEC, d Directeur des Opérations et du Directeur d l'Administration.

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence sont:

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

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

ESRIN, Frascati, Italie

Président du Conseil: Prof. F. Carassa

Directeur général: J.-M. Luton.

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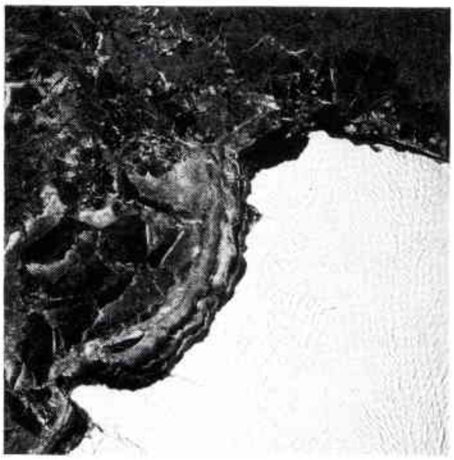

Cover: ERS-1 SAR image of the Weddell Sea near the Caird Coast (Antarctica); processed at DLR, Oberpfaffenhofen (Germany)

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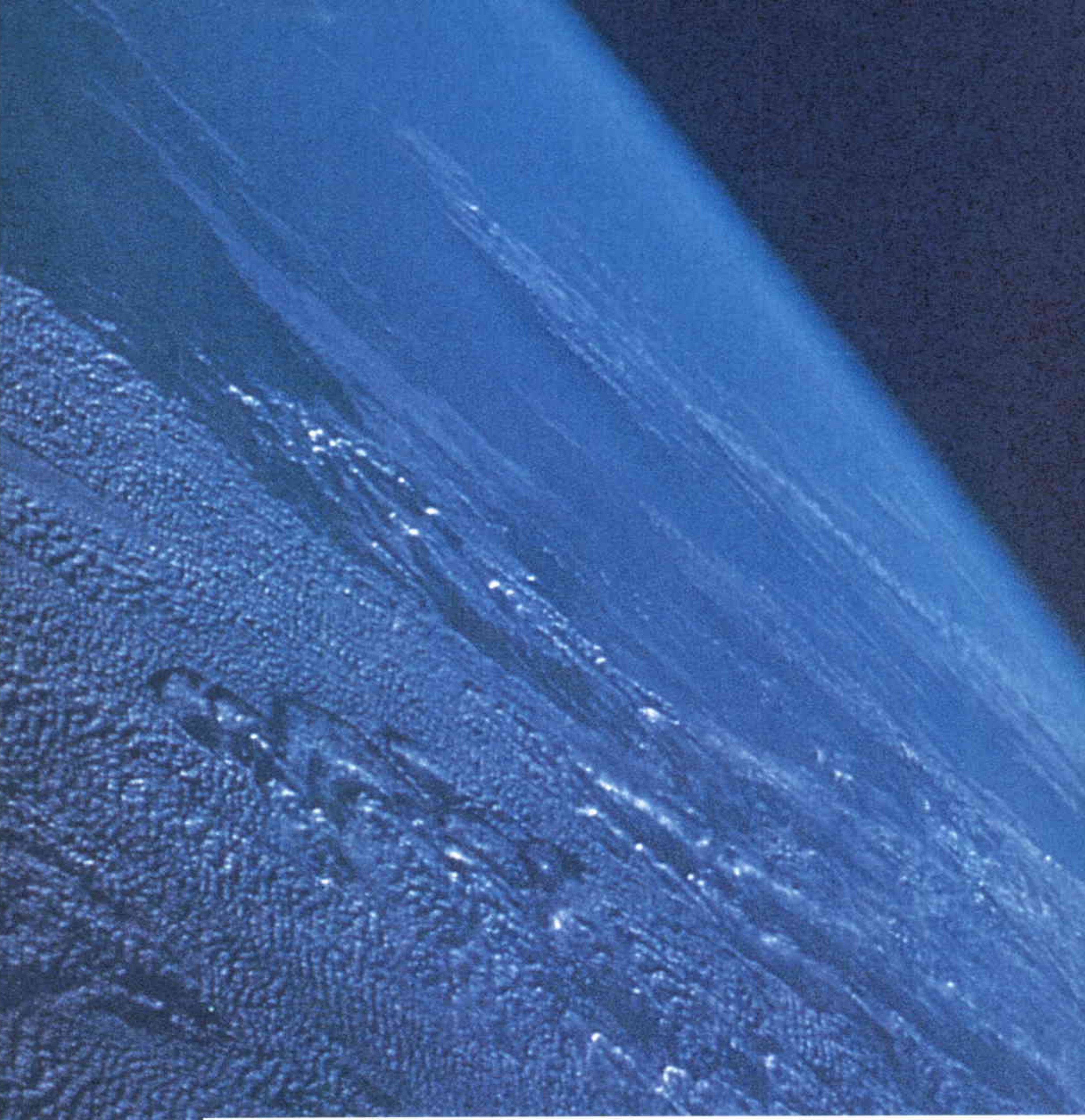
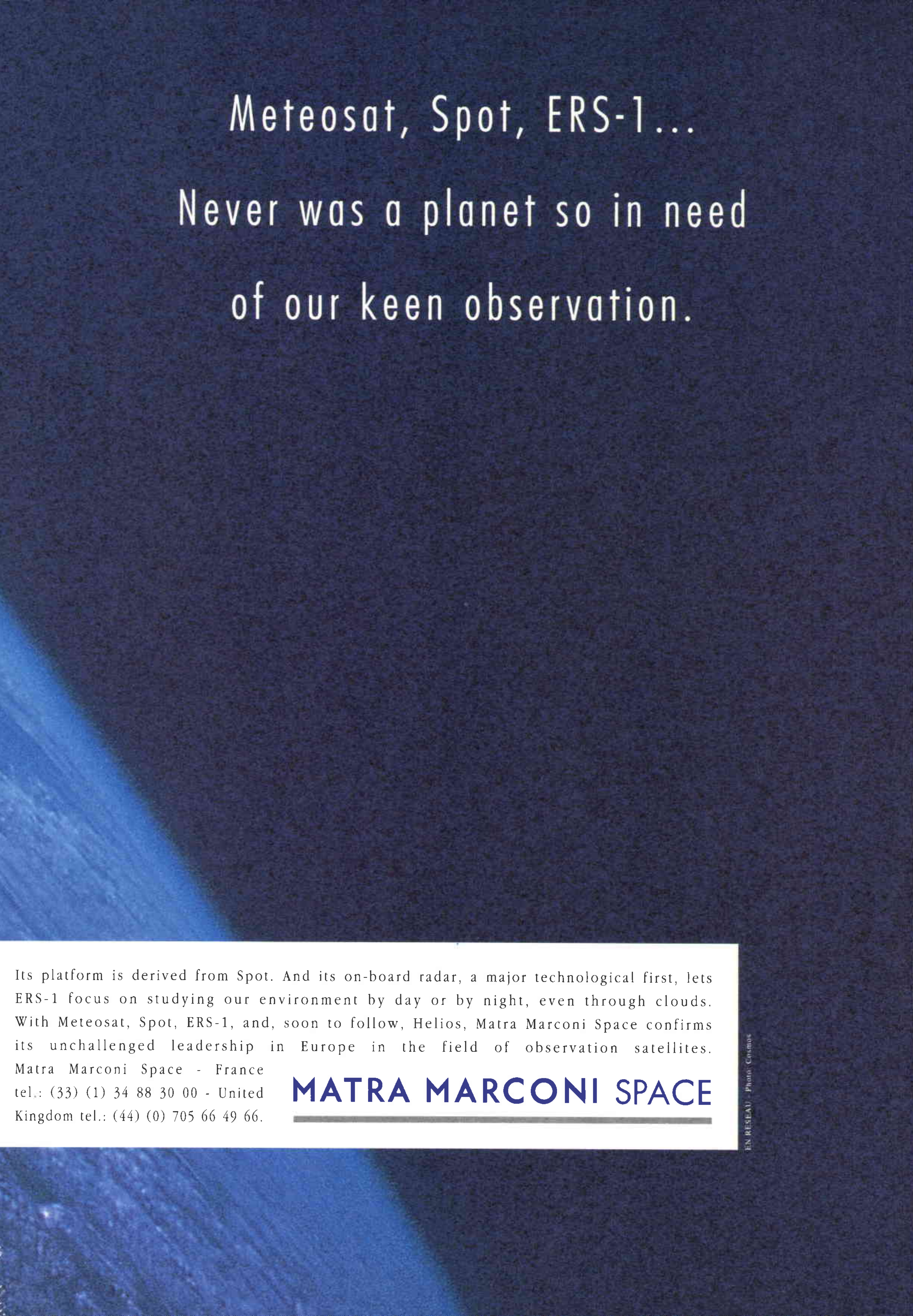


The disintegrating ozone layer, rising greenhouse effect, changing climates... Never has the Earth been more in need of our attention. Thanks to the European Space Agency and following the successful launch of ERS-1, we now have the means to better understand our planet, and therefore protect it. In cooperation with Dornier, Matra Marconi Space provided the satellite's vital elements.



Meteosat, Spot, ERS-1...
Never was a planet so in need
of our keen observation.
Its platform is derived from Spot. And its on-board radar, a major technological first, lets ERS-1 focus on studying our environment by day or by night, even through clouds. With Meteosat, Spot, ERS-1, and, soon to follow, Helios, Matra Marconi Space confirms its unchallenged leadership in Europe in the field of observation satellites.
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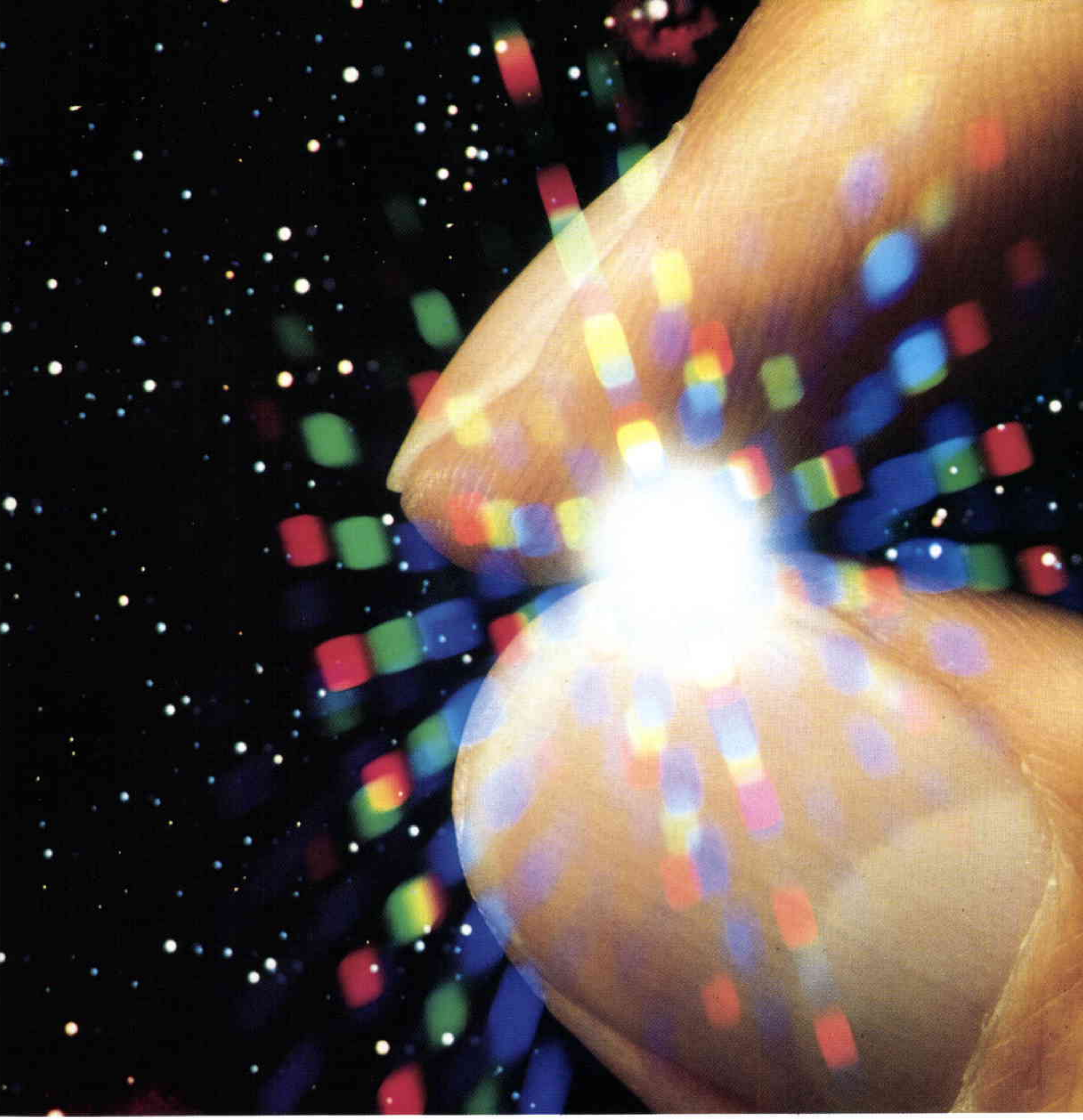
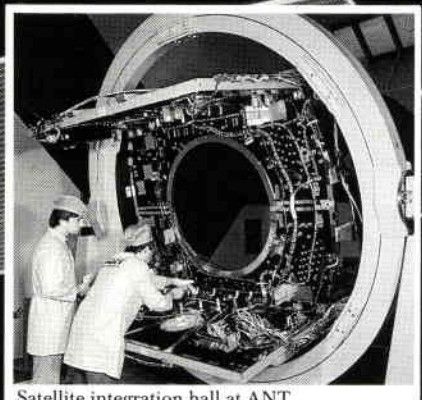
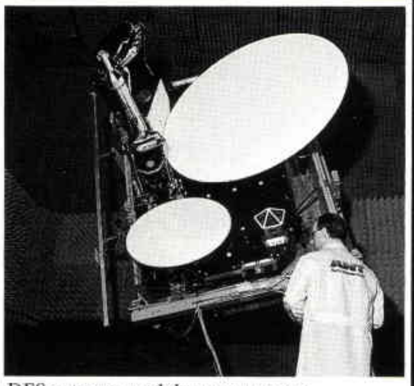


Satellite Technology from ANT:

DFS Kopernikus – The German Telecommunications Satellite



Satellite integration hall at ANT



DFS antenna module measurement

ANT 8927 E Schr.

DFS Kopernikus, the first German telecommunications satellite, has gone into orbit. The satellite programme was designed and manufactured by the ANT/MBB consortium. The system consists of two spacecraft and a ground spare. ANT supplies the entire telecommunications payload.

Kopernikus is equipped with eleven transponders which can be simultaneously operated for the transmission of speech, text, data and TV programmes in the 11/14, 12/14 and 20/30 GHz frequency ranges. Six further transponders are mounted onto the satellite for redundancy operation.

Furthermore, ANT supplied the receiver systems for 32 small DFS earth stations and was the main contractor for the 11/14 GHz DFS earth station in Berlin as well as for the conversion to DFS operation of an earth station in Usingen.

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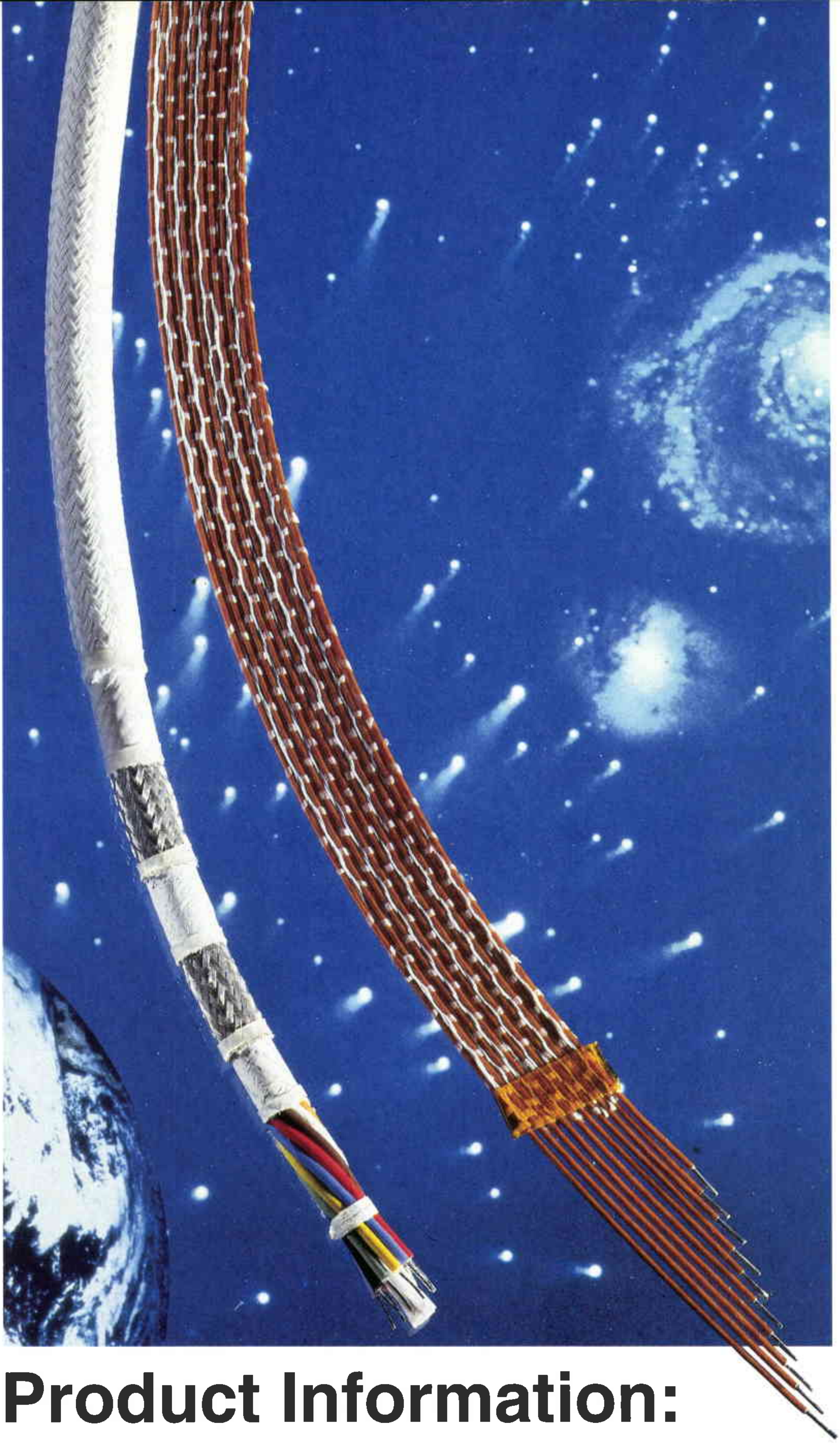

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- Dielectric waveguides from 26.5 to 110 GHz
- Highly flexible, low-attenuation coaxial cables
- Round and flat conductor ribbon cables
- Data lines
- Round cables
- High voltage wires and cables

Product Information: Power Supply Cable Assemblies for Space Technology

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The process, developed by MBB-ERNO in co-operation with Sulzer, Switzerland, provides a hydrazine purity which exceeds the MIL specification.

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Outcome of the Ministerial Conference

J.-M. Luton
Director General, ESA, Paris

Background
The fact that there is a strong political interest in European space activities is reflected in the coming together, at significant moments, of the Ministers responsible for space matters in the ESA Member States, to encourage and guide the next steps forward. While several previous Council Meetings at Ministerial Level have indeed taken place at critical moments, there has always been an overriding will to find a positive way to continue the long-term aim of ensuring that Europe first rose to, and then enhanced its standing as a world-class space power.

Thus in the seventies, application satellites were welcomed, ESA was born out of ESRO and ELDO, an independent European launcher was undertaken, a European contribution to the post-Apollo programme was agreed, and far-reaching decisions were taken on communications and remote-sensing programmes.

The last two such meetings, in Rome in 1985 and in The Hague in 1987, spelled out the political intention that Europe should have a cogent and influential space policy, supported by a coherent, complete and balanced set of programmes. To make a significant contribution to the International Space Station 'Freedom', the first phases of the Columbus Programme, and the Hermes spaceplane development were approved. This was also part of the policy to achieve autonomous European facilities for the transportation and support of humans in space, and to increase the competitiveness of European industry in the World markets.

Since the last Ministerial Meeting in The Hague, momentous changes both within Europe, and beyond, of a political and economic nature, have affected short-term considerations in space matters. It was against this background that the ESA Council again met at Ministerial Level in Munich on 18, 19 and 20 November.

Nevertheless, Europe's standing as a space power rests not on its excellent past achievements, but on its ability and willingness to take its place alongside existing and growing space powers in the future. To do so, Europe must have a dynamic and vibrant set of programmes that will maintain and increase European industry's ability to prosper in a highly competitive market. The programmes that were under discussion in Munich are intended to give Europe the essential drive and confidence politically, technically, and commercially, to succeed over the coming decade and beyond.

The decisions taken

I am pleased to report that all the hard work invested by the Agency in preparation for the Munich Council reaped a positive result in the form of two Resolutions adopted by the Ministers. The texts of these Resolutions is reproduced in full in this Bulletin, together with the Press Release issued at the conclusion of the Meeting.

In essence, the Ministers gave the go-ahead to continue the major programmes of the Agency, and to prepare a detailed evaluation of these programmes ready for a further meeting at Ministerial Level in Spain before the end of 1992.

The rapidly changing political scene and the economic situation prevailing in much of Europe were very much on the Ministers' minds, and so there will be two underlying themes to our work in the near-term. In looking at the execution of the programmes, we must bear in mind, and investigate new scenarios for collaboration beyond the Member States, and particularly with potential European partners. Secondly, we must respect the financial constraints under which Member States find themselves, and distribute any shortfalls against programmes in a balanced way.

In agreeing that we should continue the Columbus, Hermes and Data-Relay System (DRS) Programmes in 1992, the Ministers have shown a positive attitude and, provided that we can show that we have sought the most cost-effective ways of executing these programmes, I am confident that the Meeting in 1992 will give us the final authority to complete these programmes.

The Ministers, in a separate Resolution, approved the execution of the first Polar-orbiting Earth-Observation Mission (POEM-1) in two phases using the Columbus Polar Platform as a technical basis, and exploiting the Data-Relay System (DRS) in order to acquire global data coverage.

The excellent results achieved by ERS-1 have already played their part in persuading Member States of the major contribution that ESA is making, and can continue to make, towards the better understanding of our global environment.

The Ministers are well aware of the successes that have paved ESA's path in the past, and there was unanimous reaffirmation of the objectives of the Agency's tasks. This they did by accepting the Long-Term Space Plan for 1992–2005 as a strategic framework for ESA's activities and programmes. We must now elaborate detailed programme proposals before the end of 1992. We therefore have a busy year ahead, but knowing what our objectives are, I am confident that we will be able to secure the long-term future of the Agency's programmes.

Les résultats de la Conférence ministérielle

J.-M. Luton
Directeur général, ESA, Paris

Bref historique
Les activités de l'Europe spatiale suscitent un vif intérêt de la part des responsables politiques. C'est pourquoi les ministres chargés des questions spatiales dans les Etats membres de l'ESA se réunissent, lorsque le moment l'exige, afin de donner l'élan et la voie à suivre pour franchir les étapes suivantes. Il est à noter qu'en dépit du fait que plusieurs sessions du Conseil au niveau ministériel ont eu lieu, dans le passé, à des moments critiques, les débats ont toujours été dominés par la volonté de trouver des solutions positives pour poursuivre l'objectif à long terme grâce auquel l'Europe a pu conquérir, puis affirmer son statut en tant que puissance spatiale de rang mondial.

Ainsi, au cours des années 1970, le feu vert a été donné à des satellites d'application, l'ESA a été créée à partir de l'ESRO et de l'ELDO, un lanceur européen indépendant a été mis en chantier, une contribution européenne au programme successeur d'Apollo a été approuvée et des décisions de grande portée ont été prises sur des programmes de télécommunications et de télédétection.

Les deux dernières réunions au niveau ministériel, qui se sont tenues à Rome en 1985 et à La Haye en 1987, ont clairement affirmé l'intention politique de l'Europe de se doter d'une politique spatiale crédible et ambitieuse, s'appuyant sur un ensemble de programmes cohérent, complet et équilibré. Les premières phases du programme Columbus ont été approuvées, ainsi que le développement de l'avion spatial Hermès, pour assurer une contribution significative à la station spatiale internationale Freedom. Ces décisions s'inscrivaient également dans la politique ayant pour objectif de doter l'Europe de moyens autonomes pour assurer le transport et le séjour de l'homme dans l'espace et accroître la compétitivité de l'industrie européenne sur les marchés mondiaux.

Depuis la réunion de La Haye, l'Europe et les autres pays du monde ont connu des changements politiques et économiques considérables, qui ont eu des répercussions sur les aspects à court terme des affaires spatiales. Tel est le contexte de la nouvelle session du Conseil de l'ESA au niveau ministeriel qui s'est tenue à Munich du 18 au 20 novembre 1991.

Pour conserver son rang de grande puissance spatiale, l'Europe ne doit pas uniquement s'en remettre à ses remarquables succès passés, mais apporter la preuve de sa capacité et de sa détermination à tenir sa place à l'avenir parmi les puissances spatiales existantes et celles qui commencent à apparaître. A cet effet, l'Europe a besoin d'un ensemble de programmes dynamique, propre à susciter l'enthousiasme et à permettre à l'industrie européenne de préserver et d'accroître ses chances de réussite sur un marché hautement concurrentiel. Les programmes proposés à Munich ont pour objectif de donner à l'Europe l'élan et la confiance indispensables, sur le triple plan politique, technique et commercial, pour assurer son succès au cours de la décennie à venir et au-delà.

Les décisions prises
J'ai le plaisir de vous informer que les efforts investis dans les travaux préparatoires ont porté leurs fruits sous la forme de deux Résolutions adoptées par les Ministres. Vous pouvez en lire le texte complet dans ce Bulletin, ainsi que le communiqué de presse publié à la fin de la session; mais l'essentiel est de savoir que nous avons obtenu le feu vert pour poursuivre les grands programmes de l'Agence et pour préparer leur évaluation détaillée en vue d'une

nouvelle réunion ministérielle qui aura lieu en Espagne avant la fin de 1992.

L'évolution rapide du contexte politique ainsi que la situation économique dans laquelle se trouve une grande partie de l'Europe ont constitué la toile de fond de la réflexion des Ministres; deux thèmes sous-tendront ainsi nos activités à court terme. En ce qui concerne tout d'abord l'exécution des programmes, il nous faut envisager et étudier de nouveaux scénarios de collaboration avec des pays autres que les Etats membres, et notamment avec des partenaires européens potentiels. Deuxièmement, nous devrons tenir compte des contraintes financières que connaissent les Etats membres et répartir les déficits éventuels dans le cadre des programmes de façon équilibrée.

Les Ministres ont adopté une position constructive en convenant qu'il fallait poursuivre les programmes Columbus, Hermès et DRS en 1992 et, à condition que nous puissions prouver que nous nous sommes attachés à exécuter ces programmes avec le meilleur rapport coût/efficacité, je suis convaincu que la réunion de 1992 nous donnera le coup d'envoi définitif pour mener à terme ces programmes.

Dans une Résolution distincte, les Ministres ont approuvé l'exécution en deux phases de la première mission d'observation de la Terre sur orbite polaire (POEM-1), en utilisant la plate-forme polaire Columbus comme base technique et en faisant appel au Système de Relais de Données (DRS) afin d'obtenir une couverture à l'échelle du globe.

Les excellents résultats d'ERS-1 ont déjà, parmi d'autres facteurs, convaincu les Etats membres de la contribution majeure que l'Agence apporte, et pourra continuer d'apporter, à l'approfondissement de notre compréhension de l'environnement terrestre.

Les Ministres sont pleinement conscients des réussites qui jalonnent le chemin déjà parcouru par l'Agence, et ont réaffirmé à l'unanimité les objectifs fixés à ses activités en entérinant le Plan spatial à long terme 1992–2005 comme cadre stratégique des activités et des programmes de l'ESA. Il nous faut maintenant élaborer des propositions de programme détaillées d'ici la fin de 1992. Une année très chargée nous attend, mais nous connaissons nos objectifs et j'ai toute confiance que nous sommes en mesure d'assurer l'avenir à long terme des programmes de l'Agence.

Bavarian Minister President, Dr. Max Streibl, hosting the official dinner

Le Ministre-Président de Bavière, Dr. Max Streibl, s'adressant à ses invités lors du diner de gala

The Ministers of the ESA Member States, with Bavarian Minister President Dr. Max Streibl and ESA's Director General Mr Jean-Marie Luton

From left to right: Dr. Streibl, Mr Luton, Mr Bertel Haarder (Denmark), Lord Reay (United Kingdom), Dr. Jo Ritzen (The Netherlands), Mr William Winegard (Canada), Mr Claudio Aranzadi (Spain), Dr. Heinz Riesenhuber (Germany), Mr Ole Knapp (Norway), Mrs Wivina Demeester-De Meyer (Belgium), Mr Paul Quilès (France), Mr Per Westerberg (Sweden), Prof. Antonio Ruberti (Italy) and Mr René Felber (Switzerland)

Les Ministres des Etats membres de l'Agence spatiale européenne en compagnie du Ministre-président de Bavière, Dr. Max Streibl, et du Directeur général de l'ESA, M. Jean-Marie Luton

De gauche à droite: Dr. Streibl, M. Luton, M. Bertel Haarder (Danemark), Lord Reay (Royaume-Uni), Dr. Jo Ritzen (Pays-Bas), M. William Winegard (Canada), M. Claudio Aranzadi (Espagne), Dr. Heinz Riesenhuber (Allemagne), M. Ole Knapp (Norvège), Mme Wivina Demeester-De Meyer (Belgique), M. Paul Quilès (France), M. Per Westerberg (Suède), Prof. Antonio Ruberti (Italie) et M. René Felber (Suisse)

Resolution on the European Long-Term Space Plan 1992–2005 and Programmmes

adopted on 20 November 1991

The Council meeting at Ministerial Level

RECALLING Resolution ESA/C-M/LXVII/Res. 1 (Final) on the European long-term space plan adopted on 31 January 1985 and Resolution ESA/C-M/LXXX/Res. 1 (Final) on the European long-term space plan and programmes adopted on 10 November 1987,

CONSCIOUS of the need for a careful ongoing analysis of the changing geopolitical context in order to assess its impact on European space activities,

RECOGNISING the need to achieve the best possible relationship between cost and effectiveness requirements, in particular through a widened and strengthened cooperation with States that have already developed advanced space technologies, while keeping European efforts within an acceptable financial framework,

RECALLING the mission of the Agency to formulate and implement a long-term European space policy as part of the European drive to develop high technology and to further space activities for the benefit of science and applications,

CONSCIOUS of the need to ensure synergy between the Agency and the European Communities and between the Agency and other European organisations concerned while taking due account of their respective memberships and areas of responsibility,

RECOGNISING the successful development of cooperation with the United States of America on the International Space Station,

WELCOMING the renewal of the Association Agreement with Finland and Finland's stated intention to become a full member of the Agency on 1 January 1995,

WELCOMING the continuation of cooperation with Canada on the basis of the renewed close cooperation Agreement,

CONSIDERING that the European science programme has yielded remarkable results over a number of years and that Resolution ESA/C/XCIII/Res. 2 (Final) of 13 December 1990 has confirmed the increase in the level of resources allocated to that programme while proposing that measures be taken to increase the purchasing power of its annual budgets,

RECOGNISING that exploitation of the elements developed under the programmes making up the in-orbit infrastructure will give Europe mastery of the basic technologies for crewed spaceflight and provide exceptional resources with a view to multidisciplinary scientific use,

NOTING that the implementation of the Agency's Earth-observation programmes contributes to the formulation of a European long-term policy in this field,

WELCOMING the launch and operation since the 1987 Meeting in The Hague of Olympus, Giotto, Hipparcos, Meteosat, the Space Telescope, Ulysses and ERS-1,

Résolution sur le Plan spatial européen à long terme 1992–2005 et les programmes

adoptée le 20 novembre 1991

Le Conseil, siégeant au niveau ministériel,

RAPPELANT la Résolution ESA/C-M/LXVII/Rés. 1 (final) sur le Plan spatial européen à long terme adoptée le 31 janvier 1985 et la Résolution ESA/C-M/LXXX/Rés. 1 (final) sur le Plan spatial européen à long terme et les programmes adoptée le 10 novembre 1987,

CONSCIENT de la nécessité d'une analyse continue et attentive de l'évolution du contexte géopolitique afin d'évaluer ses incidences sur les activités spatiales européennes,

RECONNAISSANT la nécessité d'atteindre le meilleur rapport possible entre les impératifs de coût et d'efficacité, en particulier grâce à un élargissement et à un renforcement de la coopération avec des Etats ayant déjà développé des technologies spatiales avancées, tout en maintenant les efforts européens dans un cadre financier acceptable,

RAPPELANT que l'Agence a pour mission de formuler et mettre en oeuvre une politique spatiale européenne à long terme s'inscrivant dans la dynamique européenne pour la mise au point de technologies de pointe et le développement des activités spatiales au bénéfice de la science et des applications,

CONSCIENT de la nécessité d'assurer la synergie entre l'Agence et les Communautés européennes, ainsi qu'entre l'Agence et les autres organisations européennes intéressées compte dûment tenu de leurs Etats membres et de leurs domaines de responsabilité respectifs,

RECONNAISSANT le développement fructueux de la coopération avec les Etats-Unis d'Amérique au sujet de la Station spatiale internationale,

SE FELICITANT du renouvellement de l'accord d'association avec la Finlande et de l'intention exprimée par le Finlance de devenir membre de plein exercice de l'Agence à compter du 1er janvier 1995,

SE FELICITANT de la poursuite de la coopération avec la Canada sur la base du renouvellement de l'accord de coopération étroite,

CONSIDERANT que le programme scientifique européen a produit des résultats remarquables depuis plusieurs années et que la Résolution ESA/C/XCIII/Rés. 2 (final) du 13 décembre 1990 a confirmé l'accroissement du niveau de ressources alloué à ce programme tout en proposant que des mesures soient prises pour accroître le pouvoir d'achat de ses budgets annuels,

RECONNAISSANT que l'exploitation des éléments développés dans le cadre des programmes constituant l'infrastructure orbitale donnera à l'Europe la maîtrise des technologies fondamentales en matière de vols avec équipage et fournira des ressources exceptionnelles en vue d'une utilisation scientifique pluridisciplinaire, NOTING with satisfaction the continuing success of the Ariane-4 operational launches following successful qualification tests and the progress made on Ariane-5 development, while RECOGNISING the need for a European launcher system, for continuing support to the corresponding production programmes and for preferential use of this system by European user programmes,

EXPRESSING its satisfaction at the outcome of the work done by the Council Working Group on the preparation of this Ministerial Meeting, in particular the draft Resolutions, which it regards as the basis for further progress in optimising the Agency's programmes,

HAVING REGARD to the level of resources adopted for the period 1990–1995 (ESA/C/XCIII/Res. 3 (Final) of 13 December 1990),

HAVING REGARD to the Director General's proposal for a European long-term space programme (ESA/C-M(91)2) and the European long-term space plan 1992–2005 (ESA/C(91)38),

CHAPTER I
Objectives

1. REAFFIRMS in their entirety the agreed objectives referred to in Chapter I of Resolution ESA/C-M/LXXX/Res. 1 (Final) of 10 November 1987, which are reproduced for reference in the Annex to this Resolution, stressing that those objectives were designed to further the principles contained in the Convention and represented a comprehensive undertaking touching upon all fields of space activity pursued by the Agency.

2. RECOGNISES that the extensive and valuable experience gained in carrying out the programmes undertaken since 1987 has confirmed the relevance of the objectives referred to above, and has provided sound and reasonable guidelines for those programmes, as well as a suitable basis for their better evaluation.

3. REAFFIRMS the need to intensify international cooperation, both among the Member States and with other European and non-European partners, with a view to achieving fully the objectives of the European long-term space plan with the best possible relationship between the cost and effectiveness requirements, while optimising the use of European space resources available within the Agency and the Member States.

4. INVITES the Director General to continue to improve the balance between the infrastructure, scientific research and applications programmes, such as telecommunications and Earth observation, that will match the expectations of the Member States, while ensuring a proper relationship between technology, research and development, exploitation and utilisation activities.

CHAPTER II
European Long-Term Space Plan 1992–2005

1. WELCOMES the Director General's proposal for a European long-term space programme and the European long-term space plan 1992–2005 referred to in the preamble.

2. ACCEPTS the European long-term space plan 1992–2005 as a strategic framework for the Agency's planning, activities and programmes, and RECOGNISES that the Director General's proposal mentioned above provides the guidance needed for satisfactory implementation of this plan.

NOTANT que la mise en oeuvre des programmes d'observation de la Terre de l'Agence contribue à l'établissement d'une politique européenne à long terme dans ce domaine,

SE FELICITANT du lancement et de l'exploitation, depuis la réunion de 1987 à La Haye, d'Olympus, de Giotto, d'Hipparcos, de Météosat, du Télescope spatial, d'Ulysse et d'ERS-1,

NOTANT avec satisfaction la poursuite du succès des lancements opérationnels d'Ariane-4 après des essais de qualification réussis et les progrès du développement d'Ariane-5, tout en RECONNAISSANT la nécessité de disposer d'un système de lancement européen, d'obtenir un appui constant de la part des programmes de production correspondants et de faire en sorte que des programmes utilisateurs européens se servent en priorité de ce système,

EXPRIMANT sa satisfaction à l'issue des travaux menés par le Groupe de travail du Conseil chargé de préparer la présente session au niveau ministériel, et en particulier les projets de Résolutions, travaux qu'il considère comme la base de futures avancées dans l'optimisation des programmes de l'Agence,

VU le niveau de ressources adopté pour la période 1990–1995 (ESA/C/XCIII/Rés. 3 (final) du 13 décembre 1990),

VU la proposition du Directeur général relative au programme spatial européen à long terme [ESA/C-M(91)2] et le Plan spatial européen à long terme 1992–2005 [ESA/C(91)38],

CHAPITRE I
Objectifs

1. REAFFIRME dans leur intégralité les objectifs approuvés tels qu'ils ressortent du Chapitre premier de la Résolution ESA/C-M/LXXX/Rés. 1 (final) du 10 novembre 1987 et qui sont reproduits en référence dans l'Annexe de la présente Résolution, en soulignant que ces objectifs, définis pour promouvoir les principes énoncés dans la Convention, traçaient le cadre d'une action englobant tous les domaines des activités spatiales de l'Agence.

2. RECONNAîT que la vaste et précieuse expérience apportée par l'exécution des programmes qui ont été entrepris depuis 1987 a confirmé le bien-fondé des objectifs précités et a fourni des lignes directrices solides et raisonnables pour ces programmes, ainsi qu'une base propre à mieux les évaluer.

3. REAFFIRME la nécessité d'intensifier la coopération internationale, aussi bien entre les Etats membres qu'avec d'autres partenaires européens et non européens, en vue de réaliser pleinement les objectifs du Plan spatial européen à long terme avec le meilleur rapport possible entre les impératifs de coût et d'efficacité, tout en optimisant l'utilisation des ressources spatiales européennes disponibles au sein de l'Agence et dans les Etats membres.

4. INVITE le Directeur général à continuer d'améliorer l'équilibre entre les programmes d'infrastructure, de recherche scientifique et d'applications, notamment les télécommunications et l'observation de la Terre, équilibre qui corresponde aux attentes des Etats membres, tout en assurant un rapport adéquat entre les activités technologiques, de recherche et de développement, d'exploitation et d'utilisation.

3. CONSIDERING the strategic importance for Europe of the above-mentioned plan and the duration of the corresponding commitments, AGREES in principle to meet each year at Ministerial Level, on the next occasion before the end of 1992; and INTENDS, at those meetings, to evaluate the progress made by the programmes under way, to consider the impact on these programmes of changes in the world political context, to evaluate the possibilities for widened international cooperation with other space powers, in the first instance in Europe, and to consider the future direction to be taken by the programmes.

4. RECOGNISES that the said plan allows the Member States concerned to take part in other programmes such as the GSTP (General Support Technology Programme), for which the Director General is invited to submit an enabling Resolution, as well as in any further programmes that he may propose with a view to complete achievement of the objectives of the plan.

CHAPTER III
In-Orbit Infrastructure Programmes

CONSIDERING the progress made since the Council meeting at Ministerial Level in The Hague in 1987 in defining the technical, timetable and cost element objectives of the Hermes, Columbus and Data-Relay System (DRS) in-orbit infrastructure development programmes,

RECOGNISING nonetheless that the pursuit of activities relating to these programmes must take account of changes since that meeting in factors that are likely to affect their execution, such as the changes that have taken place in the overall political environment in Europe and the new financial constraints within the Member States,

CONSIDERING, without prejudice to the evaluation provided for in Chapter IV of this Resolution, the need to maintain the objectives of the overall coherence of these programmes and in particular the dates for launching their respective elements,

WELCOMING the will shown by the States participating in the said programmes to continue with their execution within the framework of the Director General's proposal for a European long-term space programme and of the European long-term space plan 1992–2005 referred to in the preamble,

1. AGREES that, bearing in mind the evaluation provided for in Chapter IV of this Resolution, the Agency shall carry out these programmes in 1992 within an overall budgetary envelope reduced by 120 MAU in contributions from the amount proposed by the Director General (2427 MAU), to give revised contributions totalling 2307 MAU (at 1990 economic conditions), and REQUESTS the Director General to allocate the reduced budgets in accordance with programme needs and to distribute the work to be performed in 1992 in an equitable manner, taking due account of those firms that are not assuming prime contractorship responsibilities for those programmes.

2. AGREES to continue work in 1992 under the Hermes and Columbus development programmes and the Data-Relay System programme element within the framework of the proposals for those programmes and the European long-term space plan 1992–2005 referred to in the preamble, taking into account the evaluation due to take place in late 1992, and to do so in accordance with the respective contribution percentages agreed to by the States participating in those programmes and with the new levels of contribution to the Data-Relay System programme element declared by France and Germany at this Meeting;

CHAPITRE II
Plan spatial européen à long terme 1992–2005

1. ACCUEILLE FAVORABLEMENT la proposition du Directeur général relative au programme spatial européen à long terme et le Plan spatial européen à long terme 1992–2005 visés au préambule.

2. ACCEPTE le Plan spatial européen à long terme 1992–2005 comme cadre stratégique de la planification, des activités et des programmes de l'Agence, et RECONNAIT que la proposition du Directeur général mentionnée ci-dessus donne les orientations nécessaires pour une mise en oeuvre satisfaisante de ce plan.

3. CONSIDERANT l'importance stratégique pour l'Europe du plan mentionné ci-dessus et la durée des engagements correspondants, CONVIENT en principe de se réunir au niveau ministériel chaque année, la prochaine fois avant la fin de 1992; et SE PROPOSE, au cours de ces réunions, d'évaluer les progrès atteints par les programmes en cours, de considérer l'impact sur ces programmes de l'évolution du contexte politique mondial, d'évaluer les possibilités de coopération internationale élargie avec d'autres puissances spatiales, en premier lieu en Europe, et d'envisager l'orientation que devront prendre les programmes à l'avenir.

4. RECONNAIT que ledit plan permet aux Etats membres intéressés de participer à d'autres programmes, comme le GSTP (Programme général de technologie de soutien), au sujet desquels le Directeur général est invité à soumettre une résolution habilitante, ainsi qu'à d'autres programmes qu'il pourra proposer en vue de parfaire la réalisation des objectifs du plan.

CHAPITRE III
Programme d'infrastructure orbitale

CONSIDERANT les progrès accomplis depuis la réunion du Conseil au niveau ministériel à La Haye en 1987 dans la définition des objectifs techniques, de calendrier et des éléments de coût des programmes de développement d'infrastructure orbitale Hermes, Columbus et système de relais de données (DRS),

RECONNAISSANT néanmoins que la poursuite des activités relatives à ces programmes doit prendre en compte l'évolution, depuis ladite réunion, des facteurs susceptibles d'affecter leur exécution, tels que les modifications intervenues dans l'environnement politique global de l'Europe ou les nouvelles contraintes financières dans les Etats membres,

CONSIDERANT, sans préjudice de l'évaluation visée au Chapitre IV de la présente Résolution, la nécessité de maintenir les objectifs de cohérence de l'ensemble de ces programmes et en particulier les dates de lancement de leurs éléments respectifs,

SE FELICITANT de la volonté marquée par les Etats participant auxdits programmes de poursuivre leur exécution dans le cadre de la proposition du Directeur général relative à un programme spatial européen à long terme et du Plan spatial européen à long terme 1992–2005 visé au préambule,

1. CONVIENT, compte tenu de l'évaluation prévue au Chapitre IV de la présente Résolution, que l'Agence devra exécuter ces programmes en 1992 à l'intérieur d'une enveloppe budgétaire globale réduite de 120 MUC en contributions par rapport au montant proposé par le Directeur général (2427 MUC), pour obtenir des contributions révisées d'un

NOTES further that the work to be undertaken under the programmes referred to in this paragraph shall be organised in such a way as to ensure continuity of activities and adherence to the development timetables.

3. INVITES the States participating in these programmes to adopt the corresponding draft budgets by the end of 1991 and AGREES that the present Resolutions shall constitute the legal basis for their adoption and execution.

4. INVITES the Director General to present the terms of a proposal for an optional programme of Columbus precursor flights in order to prepare for utilisation of the Columbus in-orbit infrastructure, seeking a balance between the infrastructure and utilisation programmes, and INVITES the States concerned to draw up the legal instruments that will enable these activities to be started before mid-1992.

5. AGREES to assess the situation of those in-orbit infrastructure programmes in the light of the report drawn up by the Director General in accordance with the provisions of Chapter IV below.

6. INVITES the Director General to further pursue, in time for the Council Meeting at Ministerial Level in late 1992, optimisation of the costs of the validation and exploitation of the in-orbit infrastructure programmes and submit proposals for the sharing of these costs among the Member States.

7. NOTES the proposals made on the decentralised ground infrastructure given in ESA/C-WG(91)WP/49 Rev. 1, which is an Annex to the European long-term space plan and which was submitted by the Council Working Group to Council for adoption (ESA/C(91)95).

CHAPTER IV
Evaluation and Confirmation of the In-Orbit Infrastructure and Earth-Observation Programmes

1. INVITES the Director General to submit, in time for the Council Meeting at Ministerial Level in late 1992, a report on the situation of the in-orbit infrastructure and Earth-observation programmes being carried out within the Agency. The said report shall show in particular the impact on the Agency's objectives and programmes as a whole of the possibilities for international cooperation, in the first instance in Europe, with a view to improving the overall cost-effectiveness of the Agency's activities. Finally, the report shall describe the status of the various programmes in terms of their final development objectives, their technical and time-scheduling coherence, and their estimated cost-at-completion.

   STRESSES its intention to set up, at a subsequent meeting at delegate level, a working group to consider on an ad hoc basis the international aspects of such cooperation and to report to Council so that the Director General can take its findings into account in his report referred to in this paragraph.

2. INVITES the Director General to formulate such proposals for adjustment of those programmes as may be judged necessary in order to ensure their proper execution and an equitable industrial involvement, while keeping the balance between development and user programmes.

montant total de 2307 MUC (aux conditions économiques de 1990), et DEMANDE au Directeur général de répartir les budgets réduits selon les besoins des programmes et de distribuer de manière équitable les travaux à exécuter en 1992, en prenant dûment en compte les entreprises qui n'assument pas une responsabilité majeure de maîtrise d'oeuvre dans ces programmes.

2. MARQUE SON ACCORD sur la poursuite en 1992 des travaux relatifs aux programmes de développement Hermes, Columbus et de l'élément de programme système de relais de données (DRS) suivant les propositions relatives à ces programmes et au Plan spatial européen à long terme 1992–2005 visé au préambule, compte tenu de l'évaluation qui aura lieu fin 1992, selon les pourcentages de contribution respectifs agréés par les Etats participant auxdits programmes et selon les nouveaux niveaux de contribution à l'élément programme de système de relais de données qui ont été déclarés par l'Allemagne et la France au cours de la présente session;

   NOTE également que les travaux à engager au titre des programmes visés au présent paragraphe seront programmés pour assurer la continuité des activités et le respect des calendriers de développement.

3. INVITE les Etats participant auxdits programmes à adopter, avant la fin de l'année 1991, les projets de budgets correspondants et convient que la présente Résolution constitue la base juridique de leur adoption et de leur exécution.

4. INVITE le Directeur général à présenter les termes d'une proposition de programme facultatif de vols précurseurs Columbus afin de préparer les utilisations de l'infrastructure orbitale Columbus pour rechercher un équilibre entre les programmes d'infrastructure et d'utilisation, et INVITE les Etats intéressés à établir les instruments juridiques permettant un démarrage de ces activités avant la mi-1992.

5. CONVIENT d'évaluer la situation de ces programmes d'infrastructure orbitale à la lumière du rapport préparé par le Directeur général conformément aux dispositions du Chapitre IV ci-après.

6. INVITE le Directeur général à affiner, en temps opportun pour la session du Conseil au niveau ministériel fin 1992, l'optimisation des coûts des programmes de validation et d'exploitation de l'infrastructure orbitale et à présenter des propositions relatives au partage de ces coûts entre les Etats membres.

7. NOTE les propositions faites au sujet de l'infrastructure au sol décentralisée, telles qu'elles figurent dans le document ESA/C-WG/(91)WP/49, Rév. 1, document qui constitue une Annexe au Plan spatial européen à long terme et qui a été soumis au Conseil pour adoption par le Groupe de travail du Conseil [ESA/C(91)95].

CHAPITRE IV
Evaluation et confirmation des programmes d'infrastructure orbitale et d'observation de la Terre

1. INVITE le Directeur général à présenter, en temps opportun pour la session du Conseil au niveau ministériel fin 1992, un rapport sur la situation des programmes d'infrastructure orbitale et d'observation de la Terre en cours d'exécution au sein de l'Agence. Ce rapport s'attachera à montrer en particulier l'incidence sur l'ensemble des objectifs et programmes de l'Agence des possibilités de coopération internationale, en premier lieu

3. INVITES the States participating in the in-orbit infrastructure and Earth-observation programmes to take, in the light of the report and of any adjustment proposals as referred to above, such decisions as are necessary to permit their continuation, in accordance with the relevant provisions of Annex III to the Convention; and

   AGREES that the decisions in question shall be taken at the Meeting of Council at Ministerial Level due to be held in late 1992.

CHAPTER V
Industrial Policy

1. RECALLS that the objectives of the Agency's industrial policy defined in Article VII of the Convention and Annex V thereto determine the rules and procedures for implementing that policy.

2. REAFFIRMS the objective, when distributing contracts, of achieving a return coefficient as near as possible to the ideal value of 1 for all countries and that this must be achieved on the basis of all the Agency's programmes as provided for in Article IV paragraph 3 of Annex V to the Convention.

3. TAKES NOTE of the results of the formal review of the geographical distribution of contracts and associated return coefficients for the period 1988–1990 that was held in January 1991 and RECALLS that, pursuant to Article IV paragraph 5 and Article V of Annex V to the Convention, such a formal review must take place every three years.

4. DECIDES as a measure of conservation that the lower limit referred to in Article IV paragraph 6 of Annex V to the Convention, below which special measures are to be taken, shall be kept at 0.95 for the present three-year period (1991–1993);

   AGREES to consider, at the Meeting of Council at Ministerial Level scheduled for late 1992, increasing the said limit to 0.96 with retroactive effect over the period 1991–1993 and applying it also to the following three-year period (1994–1996); and

   DECIDES that, in addition to this limit, the ratio between the deficit observed at the end of each period covered by the formal review and the annual contributions for the last year of that period shall be taken into account in determining whether special measures are to be taken.

5. CONFIRMS the guidelines and measures concerning the Agency's industrial policy which were decided upon by the Council Meeting at Ministerial Level at The Hague and are described in Chapter IV of Resolution ESA/C-M/LXXX/Res. 1 (Final), including the guarantee for all participating States of a return coefficient above 0.9 at the end of each optional programme.

6. ACCEPTS that special measures be applied in favour of Italy, in accordance with the procedures in force, for an amount corresponding to the figure that would have been necessary to bring its return coefficient to 0.95 at the end of September 1991, on the understanding that the said measures shall be applied progressively within the framework of implementation of the long-term plan in the period 1992–1995.

7. INVITES the Director General to provide in future, in addition to the information relating to the geographical distribution of contracts already provided, a predicted overall return coefficient with the aim of assessing the trend in the industrial return situation of each country more accurately.

en Europe, afin d'améliorer le rapport entre les impératifs de coût et d'efficacité des activités de l'Agence. Ce rapport devra également traiter de l'état d'avancement des différents programmes par rapport à leurs objectifs ultimes de développement, de leur cohérence sur le plan technique et calendaire et de leur coût à achèvement estimé.

SOULIGNE qu'il a l'intention de créer, lors d'une future session au niveau des délégués, un groupe de travail chargé d'étudier au cas par cas les aspects internationaux d'une telle coopération et de faire rapport au Conseil afin que le Directeur général puisse tenir compte de ses conclusions dans son rapport visé au présent paragraphe.

2. INVITE le Directeur général à formuler toutes propositions d'ajustement de ces programmes jugées nécessaires pour assurer leur exécution satisfaisante et une participation industrielle équitable, tout en maintenant l'équilibre entre programmes de développement et programmes utilisateurs.

3. INVITE les Etats participant aux programmes d'infrastructure orbitale et d'observation de la Terre à prendre, au vu du rapport et des éventuelles propositions d'ajustement précités, les décisions nécessaires afin d'assurer leur poursuite conformément aux dispositions pertinentes de l'Annexe III de la Convention; et

   CONVIENT que les décisions en question seront prises à la session du Conseil ministériel qui doit se tenir fin 1992.

CHAPITRE V
Politique industrielle

1. RAPPELLE que les objectifs de la politique industrielle de l'Agence définie dans l'Article VII de la Convention et son Annexe V fixent les règles et procédures de mise en oeuvre de cette politique.

2. REAFFIRME que l'objectif visé lors de la répartition des contrats est de faire bénéficier tous les pays d'un coefficient de retour aussi proche que possible de la valeur idéale égale à l'unité et que ce résultat doit être obtenu sur l'ensemble des programmes de l'Agence, conformément à l'Article IV, paragraphe 3, de l'Annexe V de la Convention.

3. PREND NOTE des résultats obtenus au cours de l'examen formel qui s'est tenu en janvier 1991 de la répartition géographique des contrats et des coefficients de retour correspondants pour la période 1988–1990, et RAPPELLE qu'en application de l'Article IV, paragraphe 5, et de l'Article V de l'Annexe V de la Convention un tel examen formel doit avoir lieu tous les trois ans.

4. DECIDE de maintenir à 0,95, à titre de mesure conservatoire pour la présente période triennale (1991–1993), la limite inférieure mentionnée à l'Article IV, paragraphe 6 de l'Annexe V de la Convention en-deçà de laquelle des mesures spéciales doivent être prises;

   ACCEPTE de considérer, à l'occasion de la session du Conseil au niveau ministériel prévue à la fin de 1992, que cette limite soit portée, avec effet rétroactif sur la période 1991–1993, à 0,96 et qu'elle soit appliquée également à la période triennale suivante (1994–1996); et

8. RECOMMENDS that all necessary measures be taken in accordance with Article VII of the Convention to improve the competitiveness of European space industry and increase its share of the world market.

9. CONSIDERS that the involvement of the private sector in the use of available capacities, and in financing and operating responsibilities, should be encouraged.

ANNEX

Council Resolution on the European Long-Term Space Plan and Programmes (ESA/C-M/LXXX/Res. 1 (Final))

adopted on 10 November 1987 in The Hague

Chapter I

1. REAFFIRMS the agreed objectives as described in Chapter I of the Resolution ESA/C-M/LXVII/Res. 1 (Final) adopted on 31 January 1985, these being in particular:

   - to pursue a European space programme as a coherent whole, with the spending on the tools needed for space activities and on the activities themselves appropriately balanced;
   - to expand the horizons of space research and exploitation in Europe;
   - to enable the European scientific community, via an expansion of the scientific programme, to remain in the vanguard of space research;
   - to develop further the potential of space in the areas of telecommunications and meteorology;
   - to prepare a substantial contribution of space and ground techniques to Earth-observation sciences and applications and, if so required, prepare for the setting-up of operational systems and of user-oriented organisations to operate them;
   - to improve the competitiveness of European industry in applications areas by means of advanced development of space systems and technology;
   - to promote, via a substantial microgravity research programme (e.g. materials sciences, life sciences and fluid physics) practical applications in space;
   - to strengthen the European space transportation capability, meeting foreseeable future user requirements both inside and outside Europe, and remaining competitive with space transportation systems that exist or are planned elsewhere;
   - to prepare autonomous European facilities for the support of man in space, for the transport of equipment and crews and for making use of low Earth orbits;
   - to enhance international cooperation and in particular aim at a partnership with the United States through a significant participation in an international space station.

2. NOTES the advent of new space capabilities and new techniques and the emergence of further promising applications.

3. CONSIDERS that an additional effort is needed to ensure that Europe keeps up with other space powers beyond the year 2000 and to ensure that Europe is capable of all space applications.

DECIDE qu'en plus de cette limite, le rapport existant entre le déficit observé à la fin de chaque période couverte par l'examen formel et les contributions annuelles portant sur la dernière année de ladite période doit être pris en compte lors de la décision quant à l'opportunité de prendre des mesures spéciales.

5. CONFIRME les lignes directrices et les mesures relatives à la politique industrielle de l'Agence, qui ont été arrêtées par le Conseil siégeant au niveau ministériel à La Haye et qui figurent au Chapitre IV de la Résolution ESA/C-M/LXXX/Rés. 1 (final), y compris la garantie, pour tous les Etats participants, d'un coefficient de retour supérieur à 0,9 à la fin de chaque programme facultatif.

6. ACCEPTE que l'Italie bénéficie, selon les procédures en vigueur, de mesures spéciales pour un montant corespondant à la somme qui aurait été nécessaire pour porter son coefficient de retour à 0,95 à fin septembre 1991, étant entendu que ces mesures seront appliquées progressivement, au cours de la période 1992–1995, dans le cadre de la mise en oeuvre du plan à long terme.

7. INVITE le Directeur général à fournir dorénavant, en plus des informations sur la répartition géographique des contrats qui doivent être communiquées, une prévision de coefficient de retour global en vue d'évaluer plus précisément l'évolution de la situation du retour industriel dans chaque pays.

8. RECOMMANDE que toutes les mesures nécessaires soient prises, en application de l'Article VII de la Convention, pour améliorer la compétitivité de l'industrie spatiale européenne et renforcer sa part sur du marché mondial.

9. ESTIME qu'il convient d'encourager la participation du secteur privé à l'utilisation des capacités disponibles, ainsi qu'à l'exercice de responsabilités en matières du financement et d'exploitation.

ANNEXE

Résolution du Conseil sur le Plan européen à long terme et ses programmes (ESA/C-M/LXXX/Rés. 1 (Final))

adoptée le 10 novembre 1987 à La Haye

Chapitre 1

1. REAFFIRME les objectifs approuvés tels qu'ils sont décrits au premier chapitre de la Résolution ESA/C-M/LXVII/Rés. 1 (final) adoptée le 31 janvier 1985, et qui consistent plus spécifiquement:

   – à poursuivre un programme spatial européen qui soit un ensemble cohérent dans lequel les dépenses entre les instruments nécesaires aux activités spatiales et ces activités elles-mêmes soient correctement équilibrées;
   – à élargir les horizons de la recherche et de l'exploitation spatiales en Europe;
   – à permettre à la communauté scientifique européenne, par le biais d'un élargissement du programme scientifique, de rester à l'avant-garde de la recherche spatiale;
   – à renforcer le potentiel spatial dans les domaines des télécommunications et de la météorologie;

4. APPROVES the objective of reinforcing the current European capability in order to achieve as far as possible by the end of this century the capability needed for access to and return from space for manned missions and for servicing payloads, and in order to provide for men living and working in space; NOTES the importance of continuing studies and technology programmes concerning future European space transportation systems which will take into account studies carried out in Member States nationally and concerning the expansion of the European in-orbit infrastructure in order to render it fully autonomous;

5. SEES it as important for Europe to be able to respond to new scientific and applications prospects of space, to acquire new scientific and high-technology knowledge and to be able to remain competitive in new markets and to increase its ability as a valuable partner in international cooperation in exploring and making use of space.

6. SEES these efforts as a source of new opportunities offered to the private sector, which should be encouraged to make use of the available capacity, participate in the investment and take over operating responsibilities. WELCOMES the fact that the Director General is actively pursuing in particular the studies on the possibility of the private sector taking part in the funding of the Data-Relay Satellite.

- à prévoir un apport substantiel des techniques spatiales et terrestres aux sciences de l'observation de la Terre et à leurs applications, et à préparer en tant que de besoin la mise sur pied de systèmes opérationnels et d'organisations axées sur les utilisateurs pour l'exploitation de ces systèmes;
- à améliorer la compétitivité de l'industrie européenne dans les secteurs des applications par des développements de pointe dans le domaine des systèmes spatiaux et de la technologie correspondante;
- à promouvoir, par le biais d'un important programme de recherche en microgravité (par exemple sciences des matériaux, sciences de la vie et physique des fluides), des applications pratiques dans l'espace;
- à renforcer le potentiel européen en matière de transport spatial pour que celui-ci réponde aux besoins prévisibles des utilisateurs en Europe et hors d'Europe et demeure compétitif par rapport aux systèmes de transport spatial existants ou prévus ailleurs;
- à préparer des moyens européens autonomes pour le soutien de l'homme dans l'espace, pour le transport des équipements et des équipages et pour l'utilisation des orbites terrestres basses;
- à intensifier la coopération internationale et en particulier à rechercher une association avec les Etats-Unis sous forme d'une participation importante à une station spatiale internationale.

2. NOTE l'émergence de nouvelles possibilités spatiales, de nouvelles techniques et de nouvelles applications prometteuses.

3. CONSIDERE qu'un effort supplémentaire est nécessaire pour faire en sorte que l'Europe se maintienne au niveau des autres puissances spatiales au-delà de l'an 2000 et qu'elle soit en mesure de maîtriser toutes les applications spatiales.

4. APPROUVE l'objectif visant à renforcer le potentiel actuel de l'Europe pour qu'elle acquière dans toute la mesure possible d'ici la fin du siècle les moyens voulus d'accès à l'espace et de retour pour des missions de type habité, le service de charges utiles et la vie et le travail de l'homme dans l'espace; NOTE l'importance que revêt la poursuite de programmes d'étude et de technologie portant d'une part sur les futurs systèmes européens de transport spatial, qui tiendront compte des études effectuées au plan national dans les Etats membres, et d'autre part sur l'expansion de l'infrastructure orbitale européenne pour la rendre pleinement autonome.

5. ESTIME important que l'Europe soit capable d'exploiter les nouvelles perspectives de la science et des applications dans l'espace, d'acquérir de nouvelles connaissances dans le domaine de la science et de la haute technologie, de rester compétitive sur de nouveaux marchés et de s'affirmer encore davantage comme partenaire valable dans la coopération internationale pour l'exploration et l'utilisation de l'espace.

6. VOIT dans ces efforts une source de possibilités nouvelles pour le secteur privé qui devrait être incité à utiliser le potentiel disponible, à participer aux investissements et à prendre des responsabilités en matière d'exploitation. SE FELICITE que le Directeur général poursuive activement les études portant notamment sur la possibilité d'associer le secteur privé au financement du satellite de relais de données.

Resolution on Programmes for Observation of the Earth and Its Environment

adopted on 20 November 1991

The Council meeting at Ministerial Level

WHEREAS by Resolution ESA/C-M/LXXX/Res. 1 (Final), approved on 10 November 1987, it welcomed and endorsed pursuance of the Agency's activities and programmes in the field of Earth observation,

EXPRESSING satisfaction at the successful launch and operation of the ERS-1 satellite, and the approval of the ERS-2 Programme; and NOTING that such missions will make a major contribution to the understanding of the global environment and a significant European contribution to International Space Year,

HAVING REGARD to the successful co-operation between the Agency and Eumetsat in developing and operating the geostationary Meteosat satellites,

WELCOMING the continuation of research and development work within the Agency on new generations of space systems such as future missions in polar orbit designed to study the Earth and its environment, as part of the European long-term space policy entrusted to the Agency.

HAVING REGARD to the preparatory programme for the first Earth-observation mission in polar orbit (POEM-1) and to the Director General's proposal for a POEM-1 programme (ESA/PB-EO(91)68) and a preparatory programme for follow-on POEM missions (ESA/PB-EO(91)69), and to the Aristoteles programme proposal (ESA/PB-EO(91)1, Rev. 1),

CONSIDERING that these activities and programmes of the Agency foster the successful implementation of a coherent and effective European long-term Earth observation policy, as well as forming part of the international action being taken on studying the Earth and its environment and laying the foundation for independent operational systems in the future,

HAVING REGARD to the Resolution on the European long-term space plan 1992–2005 and programmes (ESA/C-M/XCVII/Res. 1 (Final) of 20 November 1991),

HAVING REGARD to Articles V.1(b) and XI.5(c) of the ESA Convention, and Annex III thereto,

CHAPTER I
International Dimension of Earth Observation

1. RECOGNISES the growing awareness of the need to protect the environment and the various initiatives being taken in this area and the crucial role for satellite observations in understanding, monitoring and managing the Earth's resources.

2. NOTES that satellite measurements are essential to the success of global environmental monitoring and research programmes, including the World Climate Research Programme, the International Geosphere Biosphere Programme and the proposal for a Global Climate Observing System,

Résolution sur les programmes d'observation de la Terre et de son environnement

adoptée le 20 novembre 1991

Le Conseil, siégeant au niveau ministériel,

RAPPELLANT que, par la Résolution ESA/C-M/LXXX/Rés. 1 (final) adoptée le 10 novembre 1987, il avait accueilli favorablement et entériné la poursuite des activités et programmes de l'Agence dans le domaine de l'observation de la Terre,

SE FELICITANT du succès du lancement et du fonctionnement du satellite ERS-1, ainsi que de l'approbation donnée au programme ERS-2; et NOTANT que ces missions apporteront une contribution majeure à la compréhension de l'environnement du globe et représenteront une importante contribution de l'Europe à l'Année internationale de l'espace,

VU le succès de la coopération entre l'Agence et Eumetsat dans la réalisation et l'exploitation des satellites géostationnaires Météosat,

ACCUEILLANT FAVORABLEMENT la poursuite des travaux de recherche et de développement dans le cadre de l'Agence portant sur de nouvelles générations de systèmes spatiaux, comme les futures missions sur orbite polaire visant à étudier la Terre et son environnement dans le cadre d'une politique spatiale européenne à long terme dont l'Agence a la charge,

VU le programme préparatoire de la première mission d'observation de la Terre sur orbite polaire (POEM-1) et la proposition du Directeur général portant sur un programme POEM-1 (ESA/PB-EO(91)68) et sur un programme préparatoire relatif aux missions POEM ultérieures (ESA/PB-EO(91)69), ainsi que la proposition relative au programme Aristoteles (ESA/PB-EO(91)1, Rév. 1),

CONSIDERANT que ces activités et programmes de l'Agence favorisent le succès de la mise en oeuvre d'une politique européenne à long terme cohérente et efficace en matière d'observation de la Terre, qui s'inscrit également dans le cadre de l'action internationale entreprise pour l'étude de la Terre et de son environnement et jette les bases de futurs systèmes opérationnels indépendants,

VU la Résolution sur le Plan spatial européen à long terme 1992–2005 et les programmes (ESA/C-M/XCVII/Rés. 1 (Final) du 20 novembre 1991),

VU l'Article V.1(b), l'Article XI.5(c) et l'Annexe III de la Convention de l'Agence,

CHAPITRE I
Dimension internationale de l'observation de la Terre

1. RECONNAIT la prise de conscience croissante de la nécessité de protéger l'environnement et les diverses initiatives prises dans ce domaine, ainsi que le rôle crucial que jouent les observations par satellite dans la compréhension, la surveillance et la gestion des ressources terrestres.

3. NOTES that the crucial importance of Earth-observation programmes, with guaranteed continuity, for understanding and systematically observing the climate system was emphasised by the Second World Climate Conference in Geneva in November 1990, by the Intergovernmental Panel on Climate Change in its First Assessment Report in 1990, and again during the ongoing negotiations under the auspices of the United Nations on a future Climate Convention,

4. NOTES that the importance of monitoring and understanding the environment through Earth-observation programmes will be considered at the United Nations Conference on Environment and Development in June 1992,

5. RECOGNISES the importance of remote-sensing data from space for socioeconomic development in Member States and throughout the World including the Developing Countries, and the need for the Agency to contribute to the development of user communities in close coordination with other European organisations.

6. RECOMMENDS all Member States actively to pursue consistent implementation of the objectives of a European long-term Earth-observation policy in the framework of other international organisations and institutions, and to establish an effective European contribution to an international programme of long-term climate monitoring.

7. INVITES the Director General to establish fruitful cooperation with Eumetsat, with the European Communities and their Environmental Agency, as well as with other European organisations, and to seek appropriate international arrangements for involving such organisations in the development of the future European Earth-observation systems.

8. UNDERLINES that the programmes referred to in this Resolution constitute a significant European contribution to international efforts to develop space-based observation of the Earth's resources, and to an international Earth-observation system.

CHAPTER II
The European Earth-Observation Policy

1. RECOGNISES that the Agency has successfully developed and run Earth-observation systems in the course of its activities and programmes and has thereby demonstrated the knowledge and expertise needed for cooperation among European States in research and development work on future space systems intended for scientific and operational purposes.

2. CONSIDERS that the Agency's activities and programmes in the field of observation of the Earth and its environment should be given high priority for the successful implementation of a coherent and effective European Earth-observation policy.

3. ENDORSES the Agency's contribution to the development of a European Earth-observation policy aimed at increasing Europe's capability to monitor both regional and global environmental phenomena and at furthering the understanding of such matters as global warming, climate change and ozone depletion.

2. NOTE que les mesures par satellite conditionnent le succès des programmes de surveillance et de recherche sur l'environnement à l'échelle du globe, notamment le programme mondial de recherche sur le climat, le programme international sur la géosphère et la biosphère et la proposition relative à un système d'observation du climnat à l'échelle du globe.

3. NOTE que l'importance capitale des programmes d'observation de la Terre offrant les assurances de continuité voulues pour la compréhension et l'observation systématique du système climatique a été soulignée par les participants à la deuxième Conférence mondiale sur le climat, qui s'est tenue à Genève en novembre 1990, par la Commission intergouvernementale sur les modifications du climat dans son premier rapport d'évaluation remis en 1990, puis à nouveau lors des négociations en cours sous les auspices des Nations Unies pour une future Convention sur le climat.

4. NOTE que la Conférence des Nations Unies sur l'environnement et le développement, qui doit se tenir en juin 1992, examinera l'importance que revêtent la surveillance et la compréhension de l'environnement au moyen de programmes d'observation de la Terre.

5. RECONNAIT l'importance des données de télédétection par satellite pour le développement socio-économique des Etats membres et des autres pays du monde, notamment les pays en développement, ainsi que la nécessité pour l'Agence de contribuer au développement des communautés d'utilisateurs en étroite coordination avec d'autres organisations européennes.

6. RECOMMANDE à tous les Etats membres de travailler activement à la mise en oeuvre cohérente des objectifs d'une politique européenne à long terme d'observation de la Terre dans le cadre d'autres institutions et organisations internationales et d'apporter une contribution européenne efficace à un programme international de surveillance du climat à long terme.

7. INVITE le Directeur général à établir une coopération fructueuse avec Eumetsat, les Communautés européennes et l'Agence européenne de l'environnement, ainsi qu'avec d'autres organisations européennes, et à rechercher des accords internationaux adéquats pour que ces organisations participent à la réalisation des futurs systèmes européens d'observation de la Terre.

8. SOULIGNE que les programmes visés par la présente Résolution constituent une contribution significative de l'Europe aux efforts internationaux visant à développer l'observation des ressources terrestres à partir de l'espace et à l'édification d'un système international d'observation de la Terre.

CHAPITRE II
Politique européenne d'observation de la Terre

1. RECONNAIT que l'Agence a mené à bien la mise au point et l'exploitation de systèmes d'observation de la Terre dans le cadre de ses activités et programmes et a ainsi prouvé qu'elle avait acquis l'expérience et le savoir-faire nécessaires à la coopération entre Etats européens en matière de recherche et de développement touchant les futurs systèmes spatiaux destinés à des applications scientifiques et opérationnelles.

2. ESTIME qu'il convient d'accorder un haut degré de priorité aux activités et programmes de l'Agence dans le domaine de l'observation de la Terre et de son environnement pour assurer le succès de la mise en oeuvre d'une politique européenne d'observation de la Terre cohérente et efficace.

4. STRESSES that the Agency's Earth-observation programmes will address the requirements of the user communities, which call for a European segment of a global environmental data network. STRESSES further that this policy should be closely coordinated with the appropriate national and European bodies such as the Commission of the European Communities, and be such as to encourage private commercial users' enterprises and to ensure the widest availability, in the proper formats, of remote-sensing data from space from all sources for the various user entities, with particular regard to the environmental needs of regional, national and European entities.

5. RECOGNISES that the experience already gained by means of the Earthnet system can be regarded as a foundation on which such a network can be built, and INVITES the Director General, at the appropriate time, to propose an optional Earthet programme to ensure the continuity of existing activities to meet this expanding requirement in accordance with the Agency's long-term space plan.

6. RECOGNISES the maturity of the ARISTOTELES programme proposal and notes the intention to fly a package of instruments selected for precise mapping of the Earth's gravitational and magnetic fields under cooperative ESA/NASA arrangements. ENCOURAGES the Director General to explore further the possibilities of continuing ongoing activities with a view to ultimately presenting the programme proposal to Member States for their consideration on a timescale consistent with scientific requirements.

7. RECOGNISES the successful co-operation with Eumetsat and INVITES the Director General to continue this co-operation in the context of the future use of the First Polar Platform; INVITES the Director General to continue to cooperate closely with Eumetsat on the further definition and development of the second-generation Meteosat system, taking into due account the Resolution of the Eumetsat Council of 30 October 1991; and further INVITES the Director General to present in due time to Council a programme proposal within the financial provisions of the European Long-Term Space Plan and consistent with the continuing operational responsibilities of Eumetsat.

8. SEEKS the Director General's guidance in exploring the possibility of adding the science and research part of the Earth-observation programmes to the mandatory activities of the Agency.

9. INVITES all Member States and Associate States to participate in the activities and programmes designed to implement and further develop a coherent European Earth-observation policy.

CHAPTER III
POEM-1 Programme

1. APPROVES execution of the first Polar-Orbiting Earth Observation Mission (POEM-1) programme within the framework of the Agency, on the basis of the Director General's proposal referred to above, using the Columbus Polar Platform as a technical basis, and exploiting the Data-Relay System (DRS), in order to acquire global data coverage. This programme will be carried out in two phases in accordance with Annex III to the Convention.

3. ENTERINE la contribution de l'Agence à la définition d'une politique européenne d'observation de la Terre visant à accroître les capacités de l'Europe en ce qui concerne la surveillance des processus qui régissent l'environnement, tant au niveau régional que global, et à développer les connaissances sur des questions telles que le réchauffement de la planète, les modifications du climat et la diminution de la couche d'ozone.

4. SOULIGNE que les programmes d'observation de la Terre de l'Agence seront axés sur les impératifs des communautés d'utilisateurs, qui appellent une composante européenne d'un réseau de données sur l'environnement à l'échelle du globe. SOULIGNE également que cette politique doit être étroitement coordonnée avec les entités nationales et européennes compétentes, comme la Commission des Communautés européennes, et être conçue de manière à encourager les entreprises des utilisateurs commerciaux privés et à assurer la plus large disponibilité, sous les formes appropriées, des données de télédétection par satellite, quelle qu'en soit l'origine, aux différentes entités utilisatrices en accordant une attention particulière aux besoins des entités régionales, nationales et européennes en matière d'environnement.

5. RECONNAIT que l'expérience déjà acquise au moyen du système Earthnet peut constituer une base pour l'édification d'un réseau de ce type et INVITE le Directeur général à proposer en temps opportun un programme facultatif Earthnet pour assurer la poursuite des activités existantes et répondre à l'accroissement des besoins conformément au plan spatial à long terme de l'Agence.

6. RECONNAIT que la proposition de programme Aristoteles est arrivée à maturité et prend note du projet consistant à embarquer un groupe d'instruments choisis pour établir une cartographie précise des champs gravitationnel et magnétique de la Terre en coopération entre l'ESA et la NASA; ENCOURAGE le Directeur général à étudier plus avant les possibilités de poursuivre les activités en cours, l'objectif étant de soumettre la proposition de programme aux Etats membres pour examen à une date compatible avec les impératifs scientifiques.

7. RECONNAIT le succès de la coopération avec Eumetsat et INVITE le Directeur général à poursuivre cette coopération dans le cadre de l'utilisation future de la première plate-forme polaire; INVITE le Directeur général à continuer de coopérer étroitement avec Eumetsat à la poursuite de la définition et du développement du système Météosat de deuxième génération, compte dûment tenu de la Résolution adoptée par le Conseil d'Eumetsat le 30 octobre 1991; INVITE également le Directeur général à présenter au Conseil en temps opportun une proposition de programme s'inscrivant dans les limites des dispositions financières du plan spatial européen à long terme et compatible avec la poursuite des activités opérationnelles dont Eumetsat a la charge.

8. FAIT APPEL au Directeur général pour étudier la possibilité d'ajouter aux activités obligatoires de l'Agence la partie des programmes d'observation de la Terre consacrée à la science et à la recherche.

9. INVITE tous les Etats membres et Etats associés à participer aux activités et programmes visant à mettre en oeuvre et à développer une politique européenne cohérente d'observation de la Terre.

CHAPITRE III
Programme POEM-1

1. APPROUVE l'exécution du programme de la première mission d'observation de la Terre sur orbite polaire (POEM-1) dans le cadre de l'Agence, sur la base de la proposition du Directeur général précitée, qui utilise la plate-forme polaire Columbus comme base technique et fait appel au système de relais de données (DRS) afin d'obtenir une

2. NOTES that this first mission has the following primary objectives:

   (a) to provide for continuity of the observations started with the ERS satellites, including those obtained from radar-based observations;

   (b) to extend the range of parameters observed to meet the need to increase knowledge of the factors determining the environment;

   (c) to provide a demonstration flight opportunity for a polar operational meteorological payload package provided by Eumetsat;

and further NOTES that those will be achieved by developing

   (d) a package of instruments selected via the ongoing POEM-1 preparatory programme, aimed at meeting the need to observe the Earth and its atmosphere from space in synergetic fashion, addressing such matters as global warming, climate change, operational meteorology, ozone depletion and ocean and ice monitoring;

   (e) a ground segment including a mission management and planning centre, an operation control centre and a reception, archiving, cataloguing and user access system taking also into account the model of the present ESA ground infrastructure serving inter alia ERS-1.

3. AGREES that the first phase will run until end 1992. The decision to move to Phase 2 will be taken in the light of the report drawn up by the Director General in accordance with the provisions of Chapter IV of the resolution on the European long-term space plan 1992–2005 and programmes adopted on 20 November 1991. This report will include the proposal of the Director General for the final platform decision taking into account aspects of international cooperation and the most effective means to meet the mission objectives.

4. NOTES that the cost of the POEM-1 programme, including its exploitation and the associated ground segment, is estimated at 929 MAU (at 1990 economic conditions), assuming inclusion in the payload of a SAR/AMI instrument. However, if it is technically feasible in the light of studies under the POEM-1 Preparatory Programme to include an advanced SAR in the payload of POEM-1 while maintaining the schedule of the mission, the Director General will present a technical and financial proposal for such an inclusion;

   RECORDS the statements on intended participation contained in the Annex to this Resolution.

5. INVITES Eumetsat to confirm within six months its commitment to provide at no cost to the Agency the operational meteorological instruments, the associated communications package and the related ground segment for processing, disseminating and archiving the data. The Agency will then take responsibility for integrating the instruments and communication package onto the Polar Platform.

6. INVITES interested Member States to expedite finalisation of the corresponding Declaration and Implementing Rules and take all other steps needed for the POEM-1 programme to start as early as possible so as to ensure coninuity with the POEM-1 Preparatory Programme.

couverture à l'échelle du globe. Ce programme sera exécuté en deux phases conformément à l'Annexe III de la Convention.

2. NOTE que cette première mission aura les principaux objectifs suivants:

(a) assurer la continuité des observations commencées avec les satellites ERS, y compris celles qui découlent de l'emploi de radars;
(b) accroître l'éventail des paramètres observés pour répondre à la nécessité d'améliorer notre connaissance des facteurs qui conditionnent l'environnement;
(c) fournir une occasion de vol de démonstration à l'ensemble de charges utiles de services météorologiques sur orbite polaire fourni par Eumetsat.

et NOTE également que ces objectifs seront atteints par la mise au point:

(d) d'un ensemble d'instruments choisis dans le cadre du programme préparatoire POEM-1 en cours pour satisfaire en synergie les besoins d'observation de la Terre et de son atmosphère à partir de l'espace, de manière à répondre aux interrogations portant notamment sur le réchauffement de la planète, les modifications du climat, les services météorologiques, la diminution de la couche d'ozone et la surveillance des océans et des glaces;
(e) d'un secteur sol comprenant un centre de gestion de planification des missions, un centre de contrôle des opérations et un système de réception, d'archivage, de catalogage et d'accès des utilisateurs prenant également en compte le modèle de l'infrastructure au sol actuelle de l'ESA utilisée entre autres pour ERS-1.

3. CONVIENT que la première phase durera jusqu'à fin 1992. La décision de passer à la phase 2 sera prise à la lumière du rapport préparé par le Directeur général conformément aux dispositions du Chapitre IV de la Résolution sur le Plan spatial européen à long terme 1992–2005 et les programmes adoptée le 20 novembre 1991. Ce rapport contiendra la proposition du Directeur général sur la décision finale pour une plate-forme compte tenu des aspects de coopération internationale et des moyens d'atteindre les objectifs de la mission en conciliant au mieux les impératifs de coût et d'efficacité.

4. NOTE que le coût du programme POEM-1, y compris l'exploitation et le secteur sol qui lui est associé, est estimé à 929 MUC (aux conditions économiques de 1990) dans l'hypothèse où l'on inclut dans la charge utile un instrument SAR/AMI. Toutefois, s'il s'avère techniquement réalisable, à la lumière d'études conduites dans le cadre du programme préparatoire POEM-1, d'inclure un SAR de technologie avancée dans la charge utile de POEM-1 tout en préservant le calendrier de la mission, le Directeur général présentera une proposition technique et financière relative à une démarche en ce sens;

PREND NOTE des niveaux de participation prévus énoncés dans l'Annexe de la présente Résolution.

5. INVITE Eumetsat à confirmer dans les six mois son engagement à fournir à titre gratuit à l'Agence les instruments météorologiques opérationnels, l'ensemble de télécommunications associé et le secteur sol correspondant qui servira à traiter, diffuser et archiver les données. L'Agence se chargera alors d'intégrer les instruments et l'ensemble de télécommunications sur la plate-forme polaire.

6. INVITE les Etats membres intéressés à hâter la mise au point définitive de la Déclaration et du Règlement d'exécution correspondants et à prendre toutes autres mesures nécessaires pour que le programme POEM-1 puisse démarrer dès que possible afin d'assurer la continuité avec le programme préparatoire POEM-1.

CHAPTER IV
Preparatory Programme for Follow-on Polar-Orbiting Earth Observation Missions

1. INVITES the Director General to prepare a programme proposal for a preparatory programme for the development of the necessary technologies in order to provide for flight continuity beyond POEM-1, and to present it in due time to Member States for their consideration before the end of 1992.

2. NOTES in particular that this Preparatory Programme for the follow-on Polar-Orbiting Earth-Observation Missions is planned to include:
   (a) studies to define the mission objectives and implementation alternatives;
   (b) technological investigations and critical hardware developments to support the candidate instruments, including future advanced imaging radar options, such as ASAR (if not flown on POEM-1), a multi-frequency SAR, and others;
   (c) assessment of the options for the flight of Announcement of Opportunity Instruments including Earth- and space-science instruments;
   (d) procurement of long-lead items for the follow-on missions.

3. NOTES that this programme is also planned to include, in co-operation with Eumetsat, studies to determine the optimum long-term solution for the flight of operational meteorological instruments in polar orbit. These should explore the potential for synergy between such operational instruments and instrumentation required for long-term climate monitoring.

ANNEX

The Delegations declare their intention to participate in the POEM-1 programme and to subscribe to the corresponding programme Declaration as follows:

Scale of contributions of the POEM-1 Programme

Participating State	Scale (%)
Austria	1
Belgium	2.72
Denmark	1
France	0—20
Germany	22
Italy	16
Netherlands	2—3
Norway	1—1.5
Spain	0—12
Sweden	up to 6
Switzerland	4
United Kingdom	up to 25
Finland	0—1.6
Canada	2.6

Indicative schedule of payment appropriations (in millions of Accounting Units)

1990 E.C.	92	93	94	95	96	97	98	99	00	01	02	03	Total
POEM-1	40	72	115	121	121	112	100	73	47	47	46	35	929

CHAPITRE IV
Programme préparatoire relatif aux missions ultérieures d'observation de la Terre sur orbite polaire

1. INVITE le Directeur général à préparer une proposition relative à un programme préparatoire ayant pour objet le développement des technologies nécessaires pour assurer la continuité des vols au-delà de POEM-1, et à la présenter en temps opportun aux Etats membres pour qu'ils l'examinent avant la fin de 1992.

2. NOTE en particulier que ce programme préparatoire relatif aux missions ultérieures d'observation de la Terre sur orbite polaire doit comprendre:

   (a) des études pour définir les objectifs des missions et des solutions de rechange pour leur exécution;
   (b) des recherches technologiques et la mise au point de matériels critiques en soutien des instruments candidats, y compris de futures options fondées sur un radar imageur de technologie avancée du type ASAR (à moins qu'il ne soit embarqué sur POEM-1), un SAR multifréquences et d'autres instruments;
   (c) l'évaluation des options relatives à l'emport d'instruments devant faire l'objet d'avis d'offre de participation, y compris dans le domaine des sciences de la Terre et des sciences spatiales;
   (d) l'approvisionnement d'éléments à long délai de livraison pour les missions ultérieures.

3. NOTE que ce programme doit également comprendre l'exécution, en coopération avec Eumetsat, d'études visant à définir la solution optimale à long terme pour l'emport d'instruments météorologiques opérationnels sur orbite polaire. Ces études devront évaluer les possibilités de synergie entre lesdits instruments opérationnels et l'instrumentation nécessaire à la surveillance du climat à long terme.

ANNEXE

Les délégations déclarent qu'elles ont l'intention de participer au programme POEM-1 et de souscrire la Déclaration de programme correspondante selon le barème suivant:

Barème de contribution au programme POEM-1

Etats participants	Contribution (%)
Allemagne	22
Autriche	1
Belgique	2,72
Danemark	1
Espagne	0–12
France	0–20
Italie	16
Norvège	1–1,5
Pays-Bas	2–3
Royaume-Uni	jusqu'à 25
Suède	jusqu'à 6
Suisse	4
Finlande	0–1,6
Canada	2,6

Echéancier indicatif des crédits de paiement (en millions d'unités de compte)

C.E. 1990	92	93	94	95	96	97	98	99	00	01	02	03	Total
POEM-1	40	72	115	121	121	112	100	73	47	47	46	35	929

Press Conference in Munich

Conférence de presse

Press Release

Council at Ministerial Level

Munich, 18, 19 and 20 November 1991

The Council of the European Space Agency, meeting at Ministerial Level in Munich on 18, 19 and 20 November 1991, under the Chairmanship of Mr C. Aranzadi, Minister of Industry, Commerce and Tourism, of Spain, considered the proposals put forward by the ESA Director General for the implementation of the Long-Term Space Plan following up the Ministerial Meeting in The Hague in November 1987.

The Ministers, representing the thirteen Member States of the Agency, Finland and Canada – the Commission of the European Communities, Eutelsat and Eumetsat having been granted observer status – took into account the rapidly changing political scene and the particular economic conditions prevailing in much of Europe when considering the way ahead for the European Space Agency's Programmes.

The Council adopted two Resolutions: Resolution No. 1 on the European Long-Term Space Plan 1992–2005, and Resolution No. 2 on the Earth-Observation Programme.

Resolution 1
In Resolution No. 1, the Ministers unanimously reaffirmed the objectives stated at the Meeting in The Hague, which represented a comprehensive undertaking touching upon all fields of space activity pursued by the Agency.

The Ministers also accepted the European Long-Term Space Plan 1992–2005 as a strategic framework for ESA's activities and programmes, and invited the Director General to submit in due course programme proposals for approval by the Member States, in order to achieve the objectives set out in the Long-Term Space Plan and to adhere to the development timetables.

The Ministers reaffirmed the need to intensify international cooperation, in the first instance in Europe, with a view to achieving fully the objectives of the European Long-Term Space Plan with the best possible relationship between the cost and effectiveness requirements, while optimising the use of European space resources available within the Agency and the Member States.

The Ministers agreed to continue work in 1992 under the Hermes, Columbus and Data-Relay System (DRS) development programmes within the framework of the proposals for these programmes, and in accordance with the respective contribution percentages already agreed by the Participating States.

The Ministers also agreed that, in addition to recognising the need to widen and strengthen cooperation with States that have already developed advanced space technologies, there should be synergy between the Agency and the European Communities and other European organisations.

The Ministers also called upon the Agency to ensure the closest possible adherence to the geographical-distribution policy, achieving a return coefficient as near as possible to the ideal value of unity for all countries.

Resolution 2
In Resolution No. 2, the Ministers approved the execution of the first Polar-Orbiting Earth-observation Mission (POEM-1) in two phases within the framework of the Agency, using the Columbus Polar Platform as a technical basis and exploiting the Data-Relay System (DRS) in order to acquire global data coverage. In so doing, the Ministers recognised the successful results from ERS-1, and the approval of the ERS-2 Programme, and noted the major contributions such missions make to the understanding of the global environment, and the significant European contribution to the International Space Year (ISY).

The Ministers were particularly happy to ensure that the excellent results already achieved in the science and applications programmes should be continued in a vital and far-reaching set of Programmes that would give a positive framework for ESA into the 21st Century.

Communiqué de Presse

Réunion du Conseil au niveau ministériel

Munich 18, 19 et 20 novembre 1991

Le Conseil de l'Agence spatiale européenne, siégeant au niveau ministériel à Munich les 18, 19 et 20 novembre 1991 sous la présidence de M. C. Aranzadi, Ministre de l'Industrie, du Commerce et du Tourisme d'Espagne, a examiné les propositions présentées par le Directeur général pour la mise en oeuvre du Plan spatial à long terme issu de la Conférence ministérielle de La Haye de novembre 1987.

Les Ministres, qui représentaient les treize Etats membres de l'Agence, la Finlande et le Canada – la Commission des Communautés européennes, Eutelsat et Eumetsat ayant obtenu le statut d'observateur – considérant l'évolution rapide du contexte politique et la situation économique particulière d'une grande partie de l'Europe, ont examiné la voie à suivre pour les programmes de l'Agence spatiale européenne.

Le Conseil a adopté deux Résolutions: la Résolution no. 1 sur le Plan spatial européen à long terme 1992–2005 et la Résolution no. 2 sur le Programme d'observation de la Terre.

Résolution 1
Dans la Résolution no. 1, les Ministres ont réaffirmé à l'unanimité les objectifs énoncés lors de la réunion de La Haye qui traçaient le cadre d'une action englobant tous les domaines des activités spatiales de l'Agence.

Les Ministres ont également entériné le Plan spatial européen à long terme 1992–2005 comme cadre stratégique des activités et programmes spatiaux de l'Agence et ont invité le Directeur général à soumettre en temps opportun à l'approbation des Etats membres des propositions de programmes conçus pour atteindre les objectifs fixés dans le Plan spatial à long terme tout en respectant les calendriers de développement.

Les Ministres ont réaffirmé la nécessité d'intensifier la coopération internationale, au premier chef en Europe, en vue de réaliser pleinement les objectifs du Plan spatial européen à long terme avec le meilleur rapport possible entre les impératifs de coût et d'efficacité, tout en optimisant l'utilisation des ressources spatiales européennes disponibles au sein de l'Agence et des Etats membres.

Les Ministres ont marqué leur accord sur la poursuite en 1992 des travaux se rapportant aux programmes de développement Hermès, Columbus et DRS dans le cadre des propositions relatives à ces programmes et selon les pourcentages de contributions respectifs dont les Etats participants sont déjà convenus.

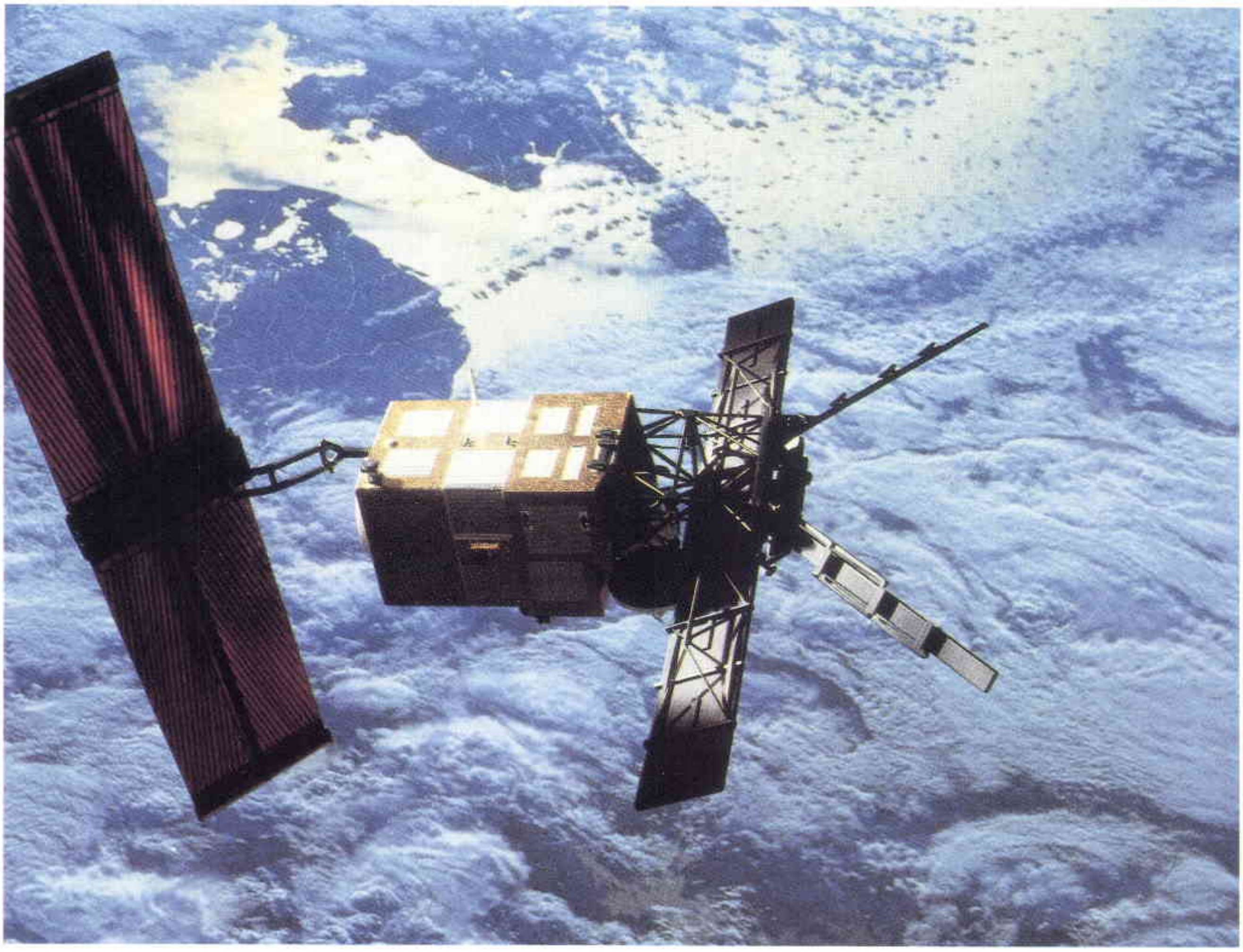
Les Ministres, reconnaissant la nécessité d'élargir et de renforcer la coopération avec les Etats ayant déjà développé des technologies spatiales avancées, sont également convenus de la nécessité d'une synergie entre l'Agence d'une part et les Communautés européennes et les autres organisations européennes d'autre part.

Les Ministres ont également invité l'Agence à veiller à ce que la politique de répartition géographique soit respectée de façon aussi rigoureuse que possible, en faisant bénéficier tous les pays d'un coefficient de retour aussi proche que possible de la valeur idéale égale à l'unité.

Résolution 2
Dans la Résolution no. 2, les Ministres ont approuvé l'exécution en deux phases de la première mission d'observation de la Terre sur orbite polaire (POEM-1) dans le cadre de l'Agence, en utilisant la plate-forme polaire Columbus comme base technique et en faisant appel au système de relais de données (DRS) afin d'obtenir une couverture à l'échelle du globe. Ce faisant, les Ministres se sont félicités des bons résultats d'ERS-1 et de l'approbation du programme ERS-2 et ont noté que ces missions apporteront une contribution majeure à la compréhension de l'environnement du globe et représenteront une importante contribution de l'Europe à l'Année internationale de l'espace.

Les Ministres se sont déclarés particulièrement satisfaits de ce que les excellents résultats déjà obtenus dans le cadre des programmes scientifiques et d'application puissent aussi trouver leur prolongement dans un ensemble de programmes d'importance vitale et de grande portée propre à fournir à l'Agence un cadre constructif pour son entrée dans le troisième millénaire.

Mission for the Blue Planet.



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A Close Encounter of the Second Kind — The Giotto Extended Mission (GEM)

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Having survived its first encounter, with Comet Halley, in March 1986, the Giotto spacecraft was redirected in July 1990 onto a course that will take it to a rendezvous with an older and less active target, Comet Grigg-Skjellerup, on 10 July 1992, just twelve days before that comet passes its perihelion.

The first encounter

On 2 July 1985, an Ariane-1 lifted off from ESA's launch site in Kourou, French Guiana, carrying the 960 kg Giotto spacecraft into geostationary transfer orbit. Giotto's unique mission was to make a close encounter with Comet Halley and, among other scientific goals, to take the first ever pictures of the comet's nucleus. The next day, the spacecraft's solid-propellant motor was fired, injecting Giotto into a heliocentric orbit on course to its rendezvous in deep space.

Eight months later, on the night of 13/14 March 1986 — dubbed the 'Night of the Comet' for its Eurovision coverage — Giotto made a successful encounter with Comet Halley; flying-by the nucleus at a relative speed of 68 km/s and passing within about 600 km of it (Fig. 1).

It was not expected that Giotto would survive the passage through the cometary dust surrounding Halley, which would impact the spacecraft with an explosive force fifty times that of a bullet. To reduce the danger until the time of closest encounter, the spacecraft (Fig. 2) was protected by a shield consisting of two sheets 23 cm apart. Dust particles impacting and vaporised in the first aluminium sheet would be absorbed by the second sheet made of Kevlar. This so-called 'bumper shield' worked extremely well, although Giotto was severely bombarded by dust particles.

Just 15 sec prior to reaching its predicted closest approach, Giotto suffered an attitude disturbance of the order of 1° due to the impinging dust particles, as well as damage to both the spacecraft itself and many of the experiments. The disturbance in orientation caused the spacecraft's telemetry signal to be depointed from the Earth, and the Parkes and DSN ground stations lost proper contact, although a weak fluctuating signal from Giotto was still detectable. For about 32 min the signal was intermittent, by which time the onboard nutation dampers had re-stabilised the spacecraft and the signal received back on the ground became normal again. The spacecraft still appeared to be functioning quite well and four of the experiments were still working normally and continuing to provide scientific data.

Although, according to the original plan, the mission should have terminated 15 min after closest approach, it was immediately decided to continue payload operation until

Figure 1. Giotto's images of Comet Halley revealed a 16 km long potato-shaped nucleus, hilly, cratered and covered with a layer of black dust. They confirm the 'dirty snowball' theory of cometologist Prof. Fred Whipple.

Beneath the outer layer is a mixture of dust and ice, 80% of which is water ice. Fine jets of dust and gas spew from a few active regions of the nucleus. These geysers appear bright because the dust particles reflect sunlight.

Experts believe the craters pitting the nucleus' surface are not due to impacts like those on the Moon, but result from irregular activity on the nucleus, only about 20% of which is active

the early morning of 14 March, and to add an additional science pass during the night of 14/15 March to get as clear a picture as possible of the status of the payload complement (Fig. 3).

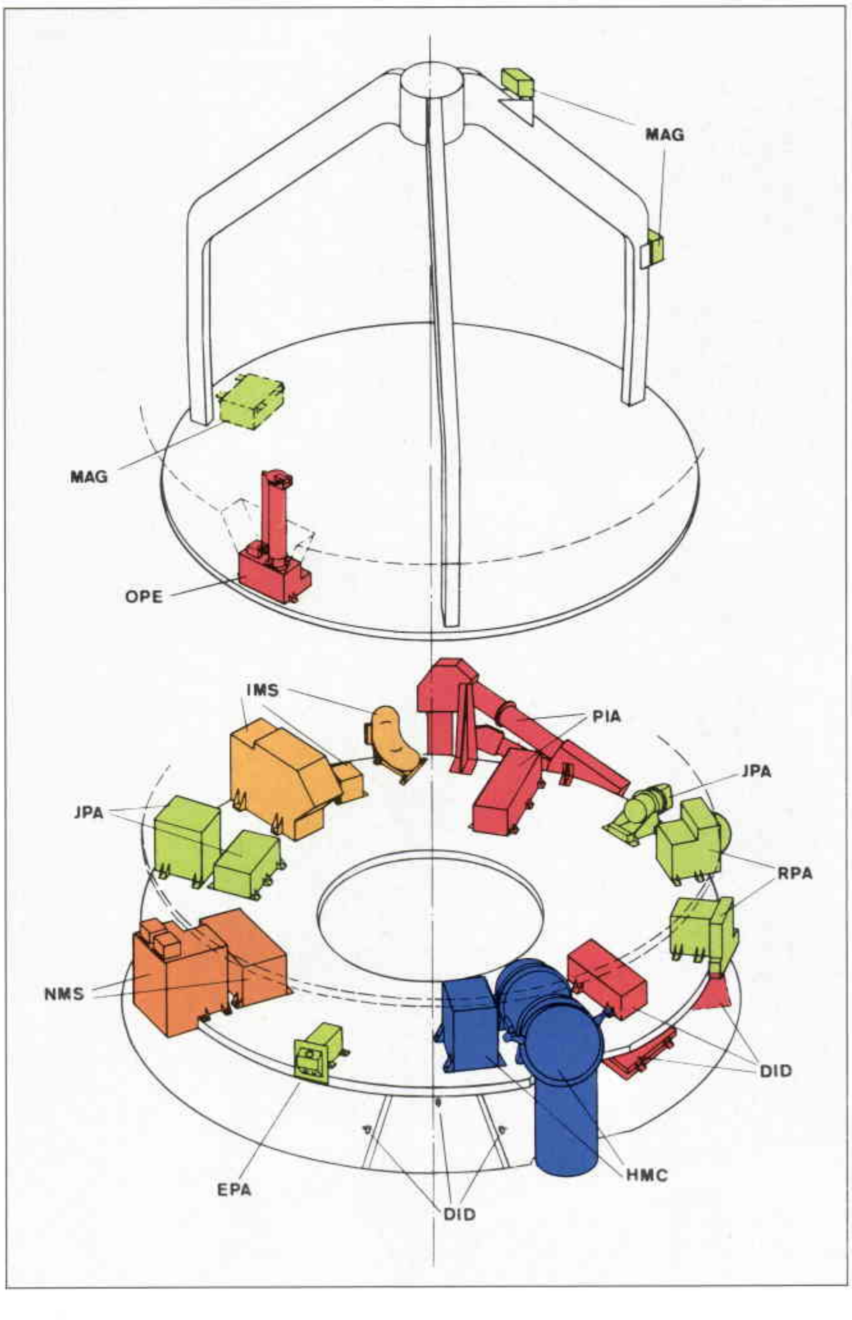
It was found that the Magnetometer (MAG), the Optical Probe Experiment (OPE), the Energetic Particles Analyser (EPA) and the Particulate Impact Analyser (PIA) were working normally; the Johnstone Plasma Analyser (JPA) and the Dust-Impact Detector System had lost some of their measuring capabilities, but could still provide more than 60% of their original science. The Ion Mass Spectrometer (IMS) had lost one measurement channel — HERS, the High Energy Range Spectrometer, optimised for measurements in the outer coma — but the High-Intensity Spectrometer (HIS) optimised for measurements in the inner coma had survived the encounter. The Rème Plasma Analyser (RPA) seemed to be severely damaged; only its Electron Electrostatic Analyser (EESA) could still provide some

Figure 2. The Giotto spacecraft

scientific data, sufficient to determine electron spatial density.

The big unknown remained the Halley Multicolour Camera (HMC). It seemed that the Camera's outer baffle had been lost during the encounter and that the unit was no longer correctly balanced. A certain degradation of its mirror had to be assumed due to the sandblasting effect of the impacting dust. The Camera's rotation range also appeared to be limited to about 148° after the encounter due to a blockage of some kind. However, despite the fact that no object could be imaged, there was no conclusive evidence at that time that the HMC may not be operational, despite some of the limitations due to the damage incurred. The CCDs and the electronics worked nominally and all mechanisms necessary for restricted, but successful, operation performed close to nominally.

Figure 3. Locations of the ten hardware experiments aboard the Giotto spacecraft (experiment codes are listed in Table 1)



With these preliminary findings, the science operations of the Giotto mission were terminated on 15 March 1986.

The first hibernation

After the switching-off of the experiments, operations with the spacecraft continued with the monitoring of its housekeeping data, attitude determinations and daily manoeuvres to maintain the telemetry link. Having used only 10% of its original 68 kg of hydrazine fuel during its journey to Halley, it was possible to perform a series of large orbit manoeuvres such that Giotto would pass close to the Earth five years after launch, to the day, on 2 July 1990. These manoeuvres were conducted between 19 and 21 March 1986.

In planning the hibernation phase, the spacecraft's performance during and after the encounter was examined and a configuration was established in which it could survive for an extended period without ground intervention. The spacecraft attitude for this so-called 'hibernation configuration' was selected such that:

(i) there would be sufficient power from the solar array to power the spacecraft at all times, and
(ii) the onboard thermal environment would be acceptable at both perihelion and aphelion.

The hibernation configuration was essentially one of minimum power consumption, with onboard autonomy enabled for the detection of unit failure only. No autonomous manoeuvres were planned, which implied that the revival from hibernation would have to be initiated by ground commands at the chosen time.

Entry into hibernation was completed on 2 April 1986, when the manoeuvre needed to take the spacecraft into its hibernation attitude, with attendant loss of coverage via the High-Gain Antenna (HGA), was conducted. The remaining configuration activities — the switching off of the star mappers, the rotation of the HGA, and the switching off of the transmitter — were effected by onboard time-tagged commands.

A new mission?

At the time of Giotto's entering hibernation, a final decision regarding an eventual future mission had not been taken, as the policy and funding requirements had still to be explored in the light of the status of the spacecraft subsystems and the payload. Also, a new target would have to be decided upon if spacecraft and payload were found to be still capable of undertaking a scientifically valuable mission. Already in January 1986, two months before the Comet Halley encounter, a preliminary study on a follow-up mission had identified Comet Grigg-Skjellerup as a potential new target.

In 1987, studies were conducted at ESA's European Space Operations Centre (ESOC) in Darmstadt (D) to examine all of the factors influencing implementation of a mission to encounter Comet Grigg-Skjellerup, including:
- damage sustained during the Halley encounter
- possible degradation as a result of up to six years of hibernation in space
- power and thermal status for a new encounter in July 1992
- ground-station support for each phase of the new mission.

A full Mission Implementation Plan was established, identifying and costing all the activities necessary for such a mission.

At a meeting in Paris on 20/22 June 1988, ESA's Director of Scientific Programmes placed a formal proposal before the Science Programme Committee (SPC) to reactivate Giotto and to conduct a detailed checkout of both the spacecraft and its payload, to determine their exact status after the Halley encounter and the subsequent hibernation phase. The SPC approved this undertaking, which would allow the decision on any future mission to be based on the known operational status of Giotto and its payload, subject to the availability of the necessary funds.

The reactivation

The reactivation strategy had to take into account the fact that the spacecraft's High-Gain Antenna would not be pointing towards Earth and contact could therefore only be made with Giotto via its tiny Low-Gain Antenna. This required extremely powerful ground-station transmitters for commanding, and very large antenna dishes for signal reception. Only NASA's Deep-Space Network (DSN) possessed such equipment at that time, and it kindly agreed to make its system available for the task.

The ultimate goal in the reactivation process was to put the spacecraft into an attitude where the HGA would be Earth-pointing. This involved a complex series of 'blind' manoeuvres from an indeterminate starting attitude, and had to take into account a wide range of possible onboard failures and other detrimental factors.

After all the necessary preparatory activities had been completed, the reactivation operations started on schedule on 19 February 1990. At 12.45 h, the command sequences to reconfigure the onboard systems from the powered-down hibernation mode to an active mode were initiated from ESOC via data links to the real-time command computers at NASA/JPL in Pasadena, and from there to the Deep-Space Network (DSN). The DSN tracking station near Madrid was used for all tracking, telemetry and command operations.

The initial sequence of about 150 telecommands took about 2 h to complete, the round trip light time being 11 min 25 s at that time. At 14.55 h the command sequence to switch on the S-band downlink was transmitted from ESOC via Madrid, and at 15.06 h a signal was received at Madrid from Giotto via the spacecraft's Low-Gain Antenna. This signal, detected by the 70 m DSN antenna, had a strength of only −166 dBm, and was a carrier with no telemetry modulation. At this time, Giotto was still 102 000 000 km from Earth.

Because, as expected, the signal strength was below the telemetry threshold, operations were conducted for the first few days using only radio-frequency sensing and Doppler measurements. These first days of operations were nevertheless highly successful and confirmed that the orbit predictions and the pointing data provided to JPL by ESOC were remarkably accurate. In addition, the spacecraft's power supply, decoders and one receiver and transmitter pair were functioning. Doppler measurements revealed that Giotto was spinning at 15.3 rpm, which was consistent with pre-hibernation determinations.

Between 20 and 24 February 1990, a series of highly complex manoeuvres were conducted to point Giotto's High-Gain Antenna towards the Earth so that telemetry data could be acquired. The reactivation planning defined a logical set of manoeuvres which assumed a most probable starting attitude.

By 21 February, it was evident from Doppler data that the planned manoeuvres were not being executed onboard and spacecraft reconfigurations were conducted on 22 and 23 February to re-select operational units

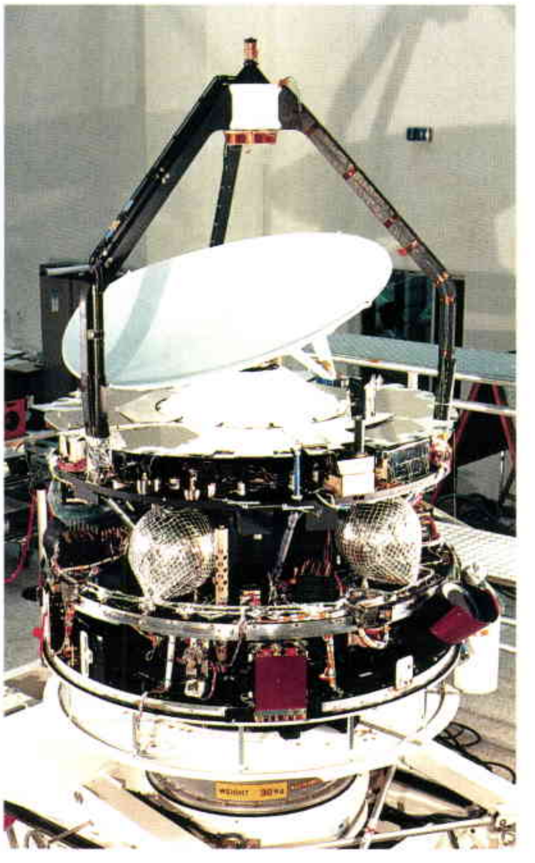


Figure 4. Giotto's High-Gain Antenna (HGA)

and to activate the High-Gain Antenna despin mechanism. Finally, by 23 February, Doppler data showed that the HGA was despun and that the Earth-pointing manoeuvres were now taking place.

On 24 February, a series of manoeuvres were carried out to improve the spacecraft's Earth-pointing attitude, and later that day a strong telemetry signal was received at the DSN station in Madrid. This signal ceased abruptly about an hour later, indicating a possible onboard failure. From the telemetry data received during this period, it was clear that although temperatures were high, spacecraft status was as expected. An attitude determination was performed using star-mapper data.

Late in the afternoon of 25 February, after a complete spacecraft reconfiguration, comprehensive telemetry data was received for the first time. It was concluded from this that one of the telemetry modulators had failed, but that the primary unit was operational.

The reactivation of Giotto was declared successful at this point, approximately 150 h after the start of the operations.

Spacecraft status

From the spacecraft telemetry data received and analysed, it was evident that Giotto had survived the Halley encounter and the four years of hibernation extremely well. Further onboard units were checked and found to be operational; the X-band system was successfully tested in low- and high-data-rate modes and both travelling-wave-tube amplifiers were found to be working satisfactorily.

Although the star mapper's baffle had apparently been perforated during the Halley encounter, data received by this unit when shadowed from the Sun by the spacecraft body could be used to determine spacecraft attitude reference data.

Failures were detected in:

- the second Central Terminal Unit (CTU-2) demodulator, which prevents reception of telemetry data via this unit, although commanding is still possible. CTU-1 is fully functional;
- one or more units in the second Service Converter – Attitude and Orbit Control Electronics – Power Distribution Electronics chain, preventing the High-Gain Antenna from being despun and pointed towards Earth.

These failures, however, do not prevent normal operation of the spacecraft, although the original redundancy in these areas has been lost.

Giotto's solar array has also survived the encounter and subsequent hibernation phase with no detectable ill-effects.

Radiation/micrometeorite damage and random-failure/ageing effects have been insignificant, and negligible array degradation is expected during the remainder of the mission.

The battery situation is rather different. Being of the silver-cadmium type, they have a life expectancy of between two and three years only, with approximately 1000 charge/discharge cycles to a depth of approximately 80%. Although Giotto's batteries have undergone only a few charge/discharge cycles, they have been in the spacecraft for more than 6 years. In addition, their temperature at the time of reactivation was about 40°C. The overall conclusion is that they will not be usable for the next encounter.

The thermal situation

Soon after the Halley encounter, it was apparent that the temperatures of spacecraft, subsystems and payload were markedly increased as a result of the damage that had been incurred. Some temperatures had increased by 10–20°C. That the damage to the spacecraft's thermal surfaces was substantial was confirmed soon after reactivation in February 1990, when detailed thermistor readings became available. These showed that the experiment temperatures ranged between 50 and 58°C, whereas the allowed upper nonoperational limit was 50°C and the allowed upper operational limit was 40°C.

The thermal situation was aggravated by the fact that then, about two weeks after reactivation, Giotto was passing through perihelion at a distance of about 0.8 AU from the Sun. Thereafter temperatures started to decrease. By 26 April they had decreased to the point where checkout of the payload could start without damaging the units being operated.

From the thermal results obtained, some further conclusions could be drawn regarding the damage incurred by the spacecraft during the Halley encounter:
- the baffle of the Halley Multicolour Camera (HMC) has been removed
- the main cone inner and outer blankets, and the launch adaptor, have been damaged
- the Nozzle Closure Mechanism (NMC) shells, the inner bumper shield, and the thermal blankets have been damaged.

The combined effect of this damage is to produce a warmer spacecraft than the configuration pre-Halley, and the changed thermal coefficients preclude an exact thermal prediction for the new encounter with Comet Grigg-Skjellerup.

Payload checkout

The payload checkout was designed to assess the health and performance capabilities of the individual instruments after the hibernation period, to compare them with their status after the Halley encounter, and especially to conduct a thorough test on the Camera.

Payload checkout was started on 26 April 1990, with nearly all Experiment Teams having travelled to ESOC with their Experiment Ground-Support Equipment (EGSE) to receive real-time telemetry from their instruments onboard Giotto.

In general, one can conclude with a high degree of confidence that the hibernation period has not caused any further degradation in instrument performances and that a viable payload remains to support another cometary encounter. Unfortunately, however, the HMC is no longer operational. It was checked out very thoroughly during a number of passes to determine its exact status in all operational modes, using the original HMC EGSE and the flight spare of the camera to simulate the very complex test sequences in real time on the ground.

Despite the fact that nearly all HMC mechanisms (rotation, filter wheels), the mass memory and the detectors (Reticon, CCD) have survived the encounter with Halley and the hibernation with little degradation, it was not possible to acquire an image of the Earth, Jupiter or a bright star, all of which had been selected as targets. An attempt to scan the whole sky in steps showed that the Camera's optical path is totally obscured.

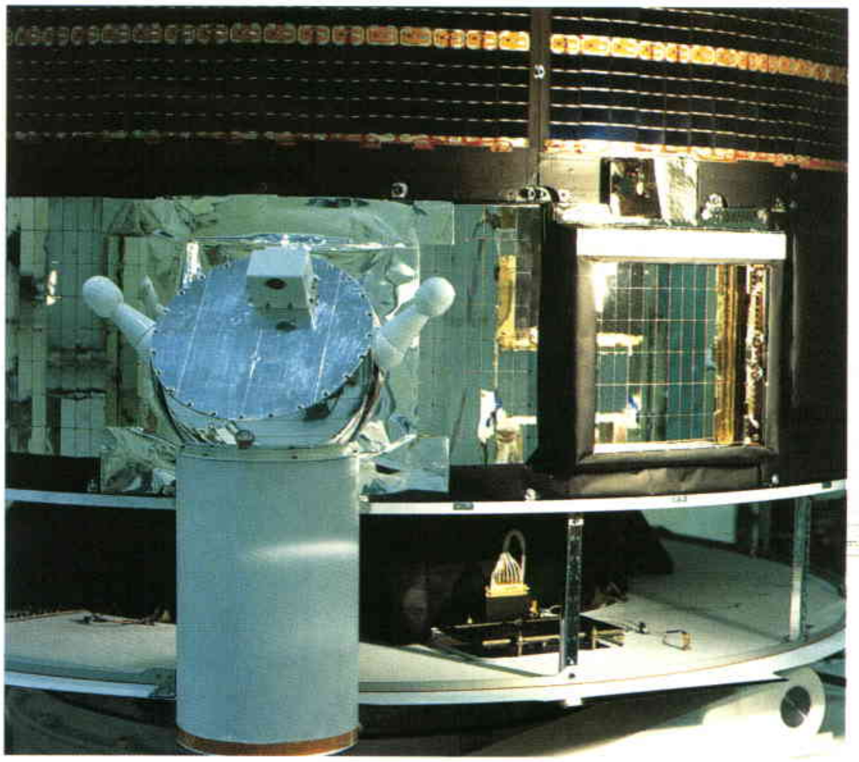


Figure 5. The Halley Multicolour Camera (HMC)

The most likely explanation is that the Camera's aperture is blocked, probably by a piece of the outer straylight baffle, which was destroyed during the Halley flyby. This conclusion is confirmed by the fact that there is no detectable shadowing of the solar array during HMC rotation, which would be reflected in the solar array's power output. The imbalance in the HMC was also clearly detected during spacecraft rotation (an indication of a change in the Camera's mass properties).

Table 1, based on the results of the checkout campaign, shows which experiments will be able to contribute to a new cometary mission. Scientific investigations that can be

conducted with this reduced payload include:
- characterisation of the changing features of the solar-wind flow and observation of cometary pick-up ions and anomalous acceleration
- determination of electron densities
- observation of upstream waves, and determination of the locations of the various boundaries (bow shock, ionopause, cometopause, etc.)
- observation of the magnetic pile-up region and cavity
- determination of dust spatial density and size distribution, and the optical properties of the dust grains
- discrete gaseous emissions
- combined dust and gas densities.

Table 1 — Payload status for the Giotto Extended Mission (GEM)

Experiment	Damage Assessment
Operational	
Energetic Particles Analyser (EPA)	No damage
Optical Probe Experiment (OPE)	No damage
Magnetometer (MAG)	No damage
Dust-Impact Detection System (DID)	MSM: No damage
	CIS: Slightly degraded
	IPM: ???
Johnstone Plasma Analyser (JPA)	JPA-IIS: No damage
	JPA-FIS: Damaged
Rème Plasma Analyser (RPA)	RPA-EESA: Reduced performance (electron density)
	RPA-PICCA: Damaged
Giotto Radio Science	NA
Operational but degraded performance (unfavourable encounter geometry and speed at Grigg-Skjellerup)	
Dust Mass Spectrometer (PIA)	No damage
Ion Mass Spectrometer (IMS)	HIS: No damage
	HERS: Damaged
Non-operational	
Halley Multicolour Camera (HMC)	Aperture blocked
	Outer baffle lost
	Mirror degraded
Neutral Mass Spectrometer (NMS)	CCDs of both detectors damaged

The Earth swing-by
On 2 July 1990, another 'first' in the life of Giotto was logged when the spacecraft passed within 22 731 km of Earth. This first-ever controlled Earth swing-by of an interplanetary space probe used the planet's gravitational force to give Giotto an energy boost that put it on a new trajectory towards an encounter with Comet Grigg-Skjellerup on 10 July 1992 (Fig. 6). Giotto is therefore the first operating spacecraft to have come from deep space to encounter the Earth in a high-inclination hyperbolic orbit.

Two instruments were operated in memory mode during the Earth fly-by, the Magnetometer (MAG) and the Energetic Particles Analyser (EPA), both providing excellent scientific data and demonstrating that they are fully operational. The magnetic-field measurements performed with MAG have provided a 'snapshot' of the Earth's magnetosphere with clearly identified inbound and outbound bow-shock and magnetopause crossings. These data are complemented by the simultaneous EPA measurements, adding still further to the overall scientific success of the Giotto mission.

The second hibernation
On 7 July 1990, a large attitude-precession manoeuvre was performed to rotate the spacecraft's spin-axis through 110° (the orbital effect of this manoeuvre had been taken into account in optimising the targetting for the Earth swing-by). It had been possible to choose a final attitude that once more allowed communications via the HGA and simultaneously satisfied all the attitude constraints for the next hibernation period and the second reactivation, planned for May 1992.

The subsequent determination of Giotto's orbit verified the precision of the Earth swing-by trajectory. A radial-pulsed manoeuvre made on 16 July was the final refinement needed to set the spacecraft on a collision course with Comet Grigg-Skjellerup.

On 23 July, after a further week of tracking, the spacecraft was configured for its second hibernation, the HGA despin mechanism was turned off, and the last telecommand sent switched off the on-board transmitter.

The GEM Payload Review Group
To obtain an unbiased and objective assessment of the status of the payload and the scientific potential of a mission extension to encounter Comet Grigg-Skjellerup, ESA's Science Programme Committee nominated a Payload Review Group, consisting of: Prof. D. Southwood, Chairman of the ESA Space Science Advisory Committee; Prof. Ph. Masson, Chairman of the Agency's Solar System Working Group; and two of the Giotto Principal Investigators, Prof. H. Balsiger and Dr. D. Krankowsky.

Meeting on 29 May 1990 at ESOC, the Group heard reports from the Giotto Project Manager and Project Scientist on the results of the spacecraft and payload checkout activities, respectively. It concluded that, despite the loss of the HMC's imaging capability, there was a strong scientific case for proceeding with the Giotto Extended Mission, and that major scientific results could be expected in at least three separate areas:

- The dust distribution can be derived for a comet whose dust characteristics are very different from those recorded by the same instrument at Comet Halley. Taken with a simultaneous ground-based observation programme, these results should yield significant new information on the gas-to-dust ratio in a less active cometary environment.
- The dust measurement can also provide important input for future European and international space programmes. Both the CRAF and Rosetta missions need engineering models of the cometary dust environment, which the Giotto Extended Mission should help to provide.
- The complement of magnetic-field and charged-particle instruments still operating can make a major contribution to cometary plasma science and to the study of solar-wind/comet interactions. The contrast with the results from Halley will be great because Grigg-Skjellerup is a less active comet. The working instrumentation carried by the GEM spacecraft is much superior to that carried by NASA's International Cometary Explorer during its encounter with Comet Giacobini-Zinner, in particular by permitting the direct detection of so-called 'pickup ions'.

The Payload Review Group therefore recommended that the Science Programme Committee approve the Giotto Extended Mission as a very cost-effective means of enhancing the ESA Space Science Programme.

The Review Group strongly supported the Agency's view that the prime scientific objective should be comparative studies based on the results achieved at Comet Halley, in order to compare an active comet with a fairly inactive one.

Organising/funding the new mission
Back in May 1989, the Space Science Advisory Committee recommended that the ESA Executive should explore the possibility of undertaking the Giotto Extended Mission as an Optional Programme, in order to alleviate an additional financial burden on the Agency's already strained scientific budget. After the successful reactivation and checkout, and the positive endorsement by the Payload Review Group, work was started on preparing the necessary Programme Proposal.

A first meeting of potential participants took place on 18 September 1990 in Paris, where all aspects of the future mission were discussed. Eight Member States were represented at this meeting, which decided that the GEM resolutions should be endorsed by the SPC before being transmitted to Council for voting. At its November 1990 meeting, the SPC recommended that the Council adopt the Enabling Resolution for GEM at its meeting in March 1991.

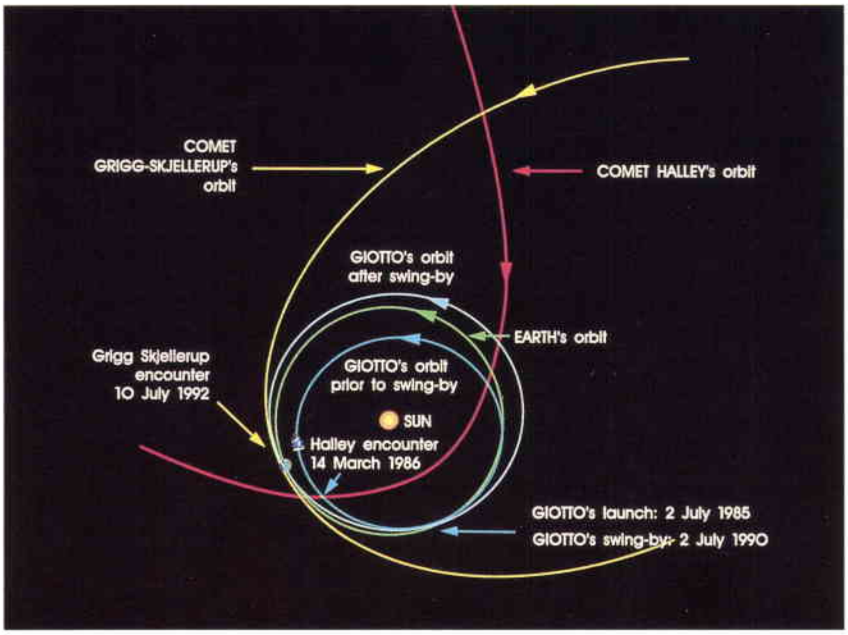


Figure 6. Orbit geometries and key dates for Giotto's encounter with Comet Grigg-Skjellerup

In the meantime, a detailed review of ESA's scientific budget had started in order to find ways to improve the financial situation. In the light of these activities, the SPC agreed at its meeting on 26/27 February 1991 to a proposal from the Executive to defer any further decision on GEM until its next meeting on 12/13 June 1991, by which time the special measures under review by the Council would have been approved and their impact assessed.

In the light of the Council's decision at its December 1990 meeting to continue the annual 5% increase in the Scientific Programme's budget until 1994 and to create savings through changes in both management procedures and the internal recharging policy, and given the strong interest shown by the scientific community in the extended mission, the Executive proposed, and the SPC agreed at its meeting on 12/13 June 1991, that GEM should be included in the Agency's mandatory programme.

The choice of Comet Grigg-Skjellerup

There were about five potential target comets within the Giotto Extended Mission's reach: Grigg-Skjellerup, Hartley-2, Du Toit-Hartley, Tuttle-Giacobini-Kresak, and Honda-Mrkos-Pajdusakowa. Taking into account all the factors to be considered in mission planning, Grigg-Skjellerup (Fig.7) was identified as the preferred target because:

- it is scientifically interesting
- has a well-known orbit
- has a good observation history, and
- can be reached by Giotto within two years of the Earth swing-by.

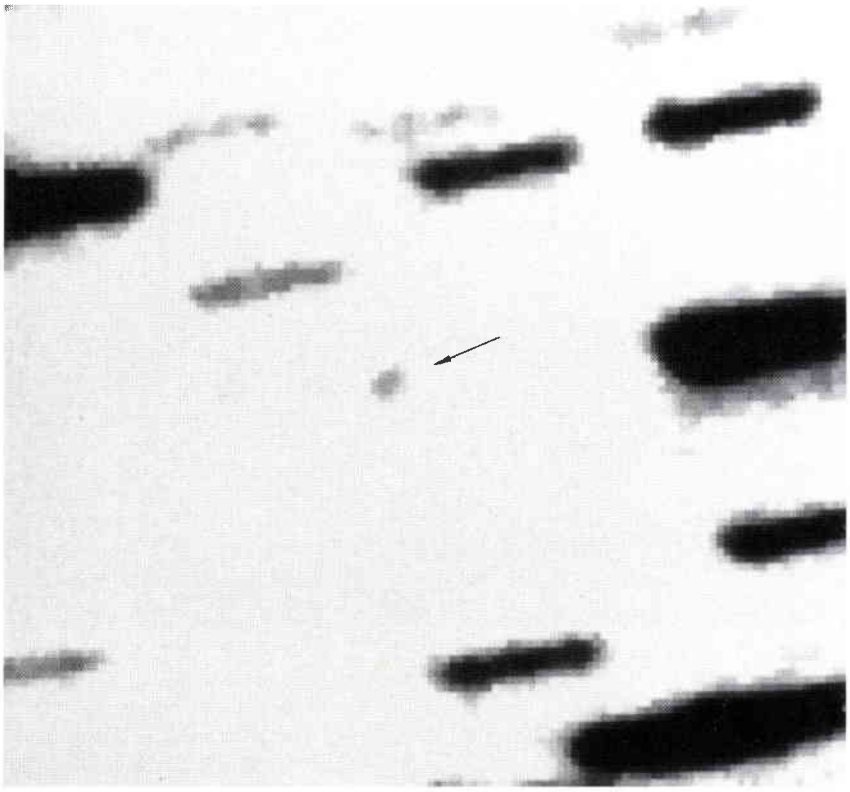


Figure 7. Comet Grigg-Skjellerup (arrowed) imaged with the 3.5 m telescope of the Max-Planck Institute for Astronomy (Heidelberg) at Calar Alto in Southern Spain

Grigg-Skjellerup's orbit has an aphelion distance of 4.94 AU and belongs to the Jupiter family of comets. The perihelion distance of 0.99 AU makes this comet extremely attractive for an encounter on 10 July 1992, just 12 days before it passes its perihelion.

The comet has an orbital period of 5.09 yr and is an old comet in the evolutionary sense, i.e. it is relatively inactive, which will provide an interesting contrast to Halley, which is relatively fresh and active.

The nucleus of Comet Grigg-Skjellerup seems to be much smaller than that of Comet Halley. Based on both ground-based optical and radar observations, an upper limit of about 2 km for its radius seems realistic.

Table 2 compares the key parameters for the Grigg-Skjellerup fly-by with those for the previous Halley scenario.

Table 2 — Key parameters for the Grigg-Skjellerup fly-by (Halley fly-by data included for comparison)

	Grigg-Skjellerup	Halley
Encounter date	10 July 1992	14 March 1986
Relative fly-by velocity	13.99 km s^{-1}	68.37 km s^{-1}
Fly-by distance	0 – 2000 km:	596 km
Heliocentric distance	1.01 AU	0.90 AU
Geocentric distance	1.43 AU	0.96 AU
Distance above/below ecliptic	0.10 AU below	0.02 AU below
Phase angle	79.30°	107.05°
Angle between spin axis and relative velocity vector	70° (at 89.6° SAA*)	0° (at 107.2° SAA)

* SAA = Solar-Aspect Angle

The second reactivation and encounter

Contact will be re-established with Giotto in May 1992. The second series of reactivation operations are likely to be even more complicated than the first because of the much greater geocentric distance, leading to a five-fold reduction in signal strength. The spacecraft will then be navigated to encounter the comet on 10 July 1992 and pass within 1000 km of its nucleus, in an orbit 14.4 million kilometres below (south of) the ecliptic, when the heliocentric distance will be 1.01 AU and the geocentric distance 1.43 AU. Closest approach will occur at 15:25 UT ±10 min.

Acknowledgement

Contributions from D.E.B. Wilkins, H. Nye and T.A. Morley of ESOC have been used in the preparation of this article. Their inputs are gratefully acknowledged.

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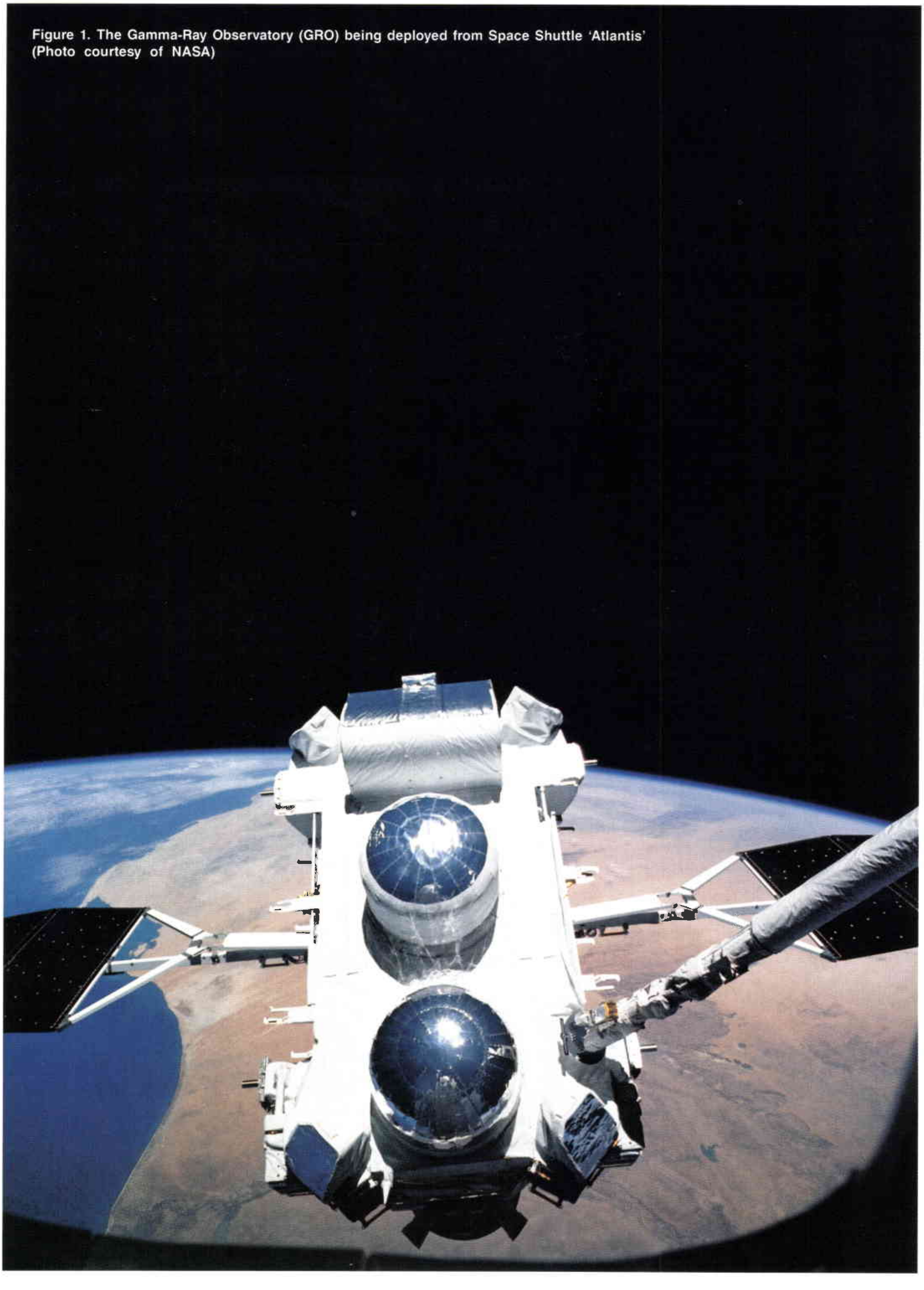

Figure 1. The Gamma-Ray Observatory (GRO) being deployed from Space Shuttle 'Atlantis' (Photo courtesy of NASA)

First Results from GRO-COMPTEL

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On 5 April 1991, the Space Shuttle 'Atlantis' launched the Gamma-Ray Observatory (GRO), the heaviest scientific satellite to date (Fig. 1), into a circular Earth orbit with an altitude of 450 km and an inclination of 280°. The Compton Imaging Telescope (COMPTEL) that constitutes a key part of the GRO payload is the product of a collaborative European effort in which ESA Space Science Department is a partner.

Introduction

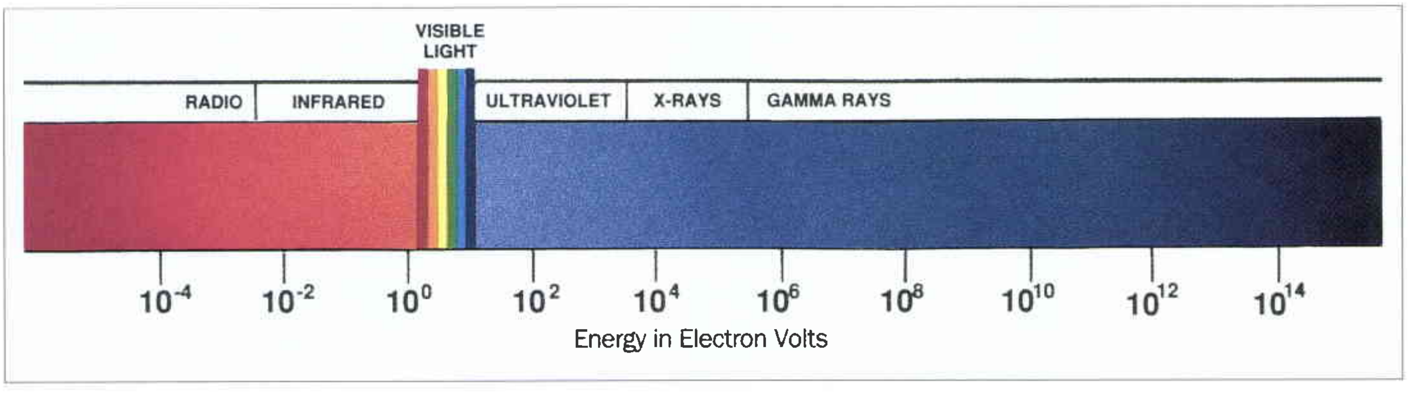
A gamma ray is a photon, or packet of light, whose energy is usually measured in units of MeV (millions of electron volts), i.e. anything above one million times that of a light photon which may be detected by the human eye (Fig. 2). Gamma rays are produced in, and are thus indicators of, the highest energetic processes that take place in the Universe. They are very rare, making up only about one part in a million of the high-energy cosmic radiation. When one adds to this the difficulty of detection, one can appreciate why gamma-ray astronomy is still in its formative years.

Gamma rays travel essentially unhindered through space from their point of origin to their point of detection. Paradoxically, they are easily absorbed by the upper layers of the Earth's atmosphere, making it necessary to mount detectors on stratospheric balloons and satellites to see beyond the atmospheric veil.

Although the ubiquitous gamma rays have been sought for several decades as tracers of sites where cosmic rays are generated, it was not until the mid-1960s that the first positive signals were detected. In 1969, a detector onboard the OSO-3 satellite measured an increase in radiation from the direction of the Galactic Centre. This was soon confirmed by several balloon instruments, and in 1971 the first point source of gamma radiation was detected, namely the Crab Pulsar.

ESA and European scientists have always played a important role in the pursuit of celestial gamma rays. In 1972, ESRO's TD-1A carried two small gamma-ray telescopes, and in 1975 ESA launched Cos-B (Fig. 3), which became the first telescope to completely map the galactic plane at gamma-ray energies (Fig. 4). Around twenty galactic 'point sources' of emission were discovered, but their exact nature is still far from understood. A distant quasar, 3C273, was detected and detailed studies were carried out on the only two identified objects: the Crab and Vela Pulsars. These pulsars were monitored regularly throughout the 6.8 year mission and evidence of time-variability was detected, providing more input with which to attack the problem of the production processes surrounding the rapidly spinning neutron star.

Figure 2. The electromagnetic spectrum as delineated by the astrophysicist



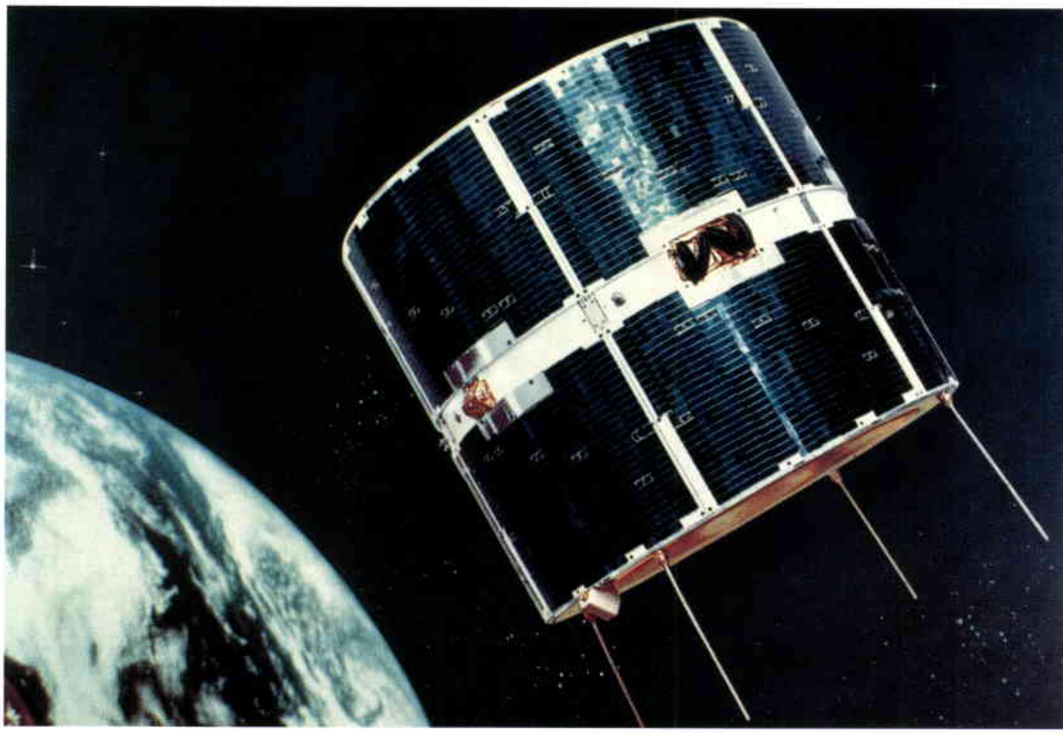


Figure 3. ESA's Cos-B satellite, launched in 1975

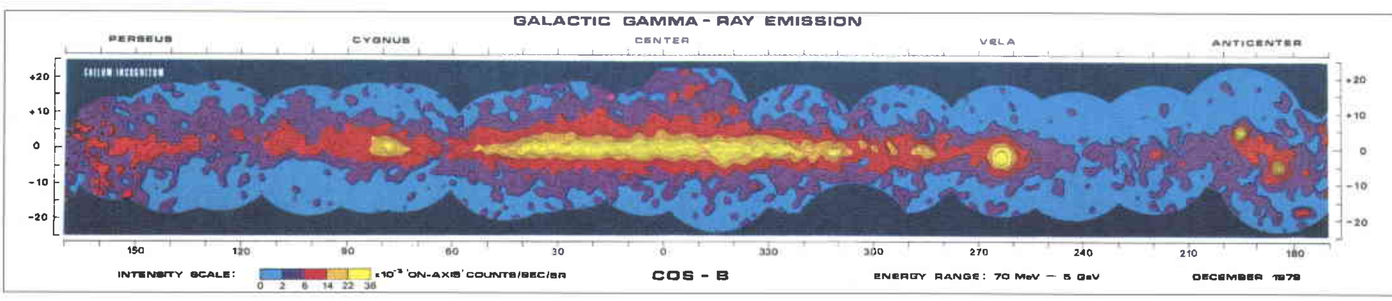


Figure 4. The Cos-B gamma-ray map of the Galaxy

One of the legacies from the Cos-B mission is the lingering question concerning the nature of the bright emission some 20° away from the Crab in the constellation Gemini. 'Geminga', as it has become known, is the brightest object in the gamma-ray sky at the higher Cos-B energies. It is situated in a low-galactic-background region and is therefore well located, but we still have no clues as to the nature of this powerful emitter, especially as a definite counterpart has not been proven at other wavelengths, nor has time-variability been detected.

The excellent results from the Cos-B and earlier missions reinforced the conviction that the next gamma-ray mission required a quantum leap in sensitivity, which would only be possible by employing a very large spacecraft carrying very large experiments. Only the US Space Shuttle had the ability to launch such a large observatory and in 1978 NASA sought proposals for the 'Gamma-Ray Observatory'. ESA's Space Science Department was represented on several proposals and is a member of the team which successfully proposed the Compton Imaging Telescope.

The COMPTEL Scientific Collaboration

Principal Investigator

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Co-Principal Investigators

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B. Swanenburg, Laboratory for Space Research, Leiden, The Netherlands

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The Gamma-Ray Observatory

With a weight of around 16 tons and dimensions of 7.7 m by 5.0 m by 4.6 m, GRO is the heaviest scientific satellite launched to date. It carries four experiments or telescopes covering a wide spectrum of energies and objectives:

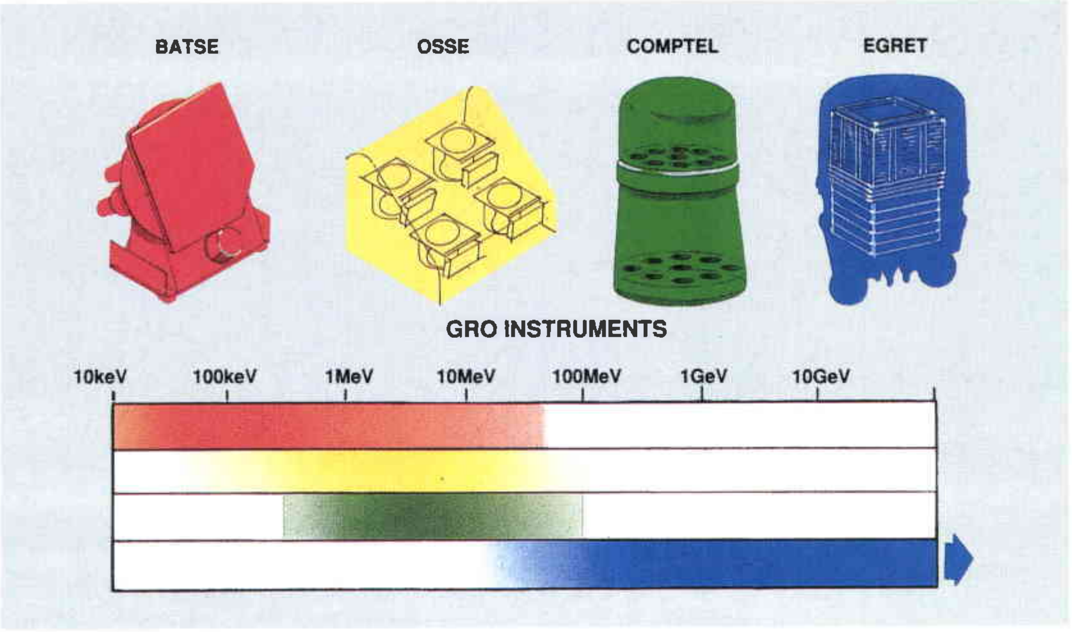

Figure 5. The wide range of gamma-ray energies covered by the GRO instruments

EGRET	Energetic Gamma-Ray Telescope	30 MeV to 30 GeV
COMPTEL	Compton Imaging Telescope	1 MeV to 30 MeV
OSSE	Oriented Scintillation Spectrometer Expt.	100 keV to 10 MeV
BATSE	Burst and Transient Source Experiment	20 keV to 1 MeV

EGRET is intended to extend the path-finding work of NASA's SAS-2 and ESA's Cos-B in a similar energy range, while OSSE is looking at the hard X-ray range above that of Exosat and similar X-ray telescopes. The main aim of BATSE is to study the gamma-ray bursts that flash almost daily across the sky, but whose origin has not yet been determined. The three other telescopes will provide complementary information for the burst investigations.

COMPTEL

COMPTEL is unique in that it has no satellite-borne precursor. It occupies the middle position in terms of both physical location and energy coverage on the GRO spacecraft and it surveys the gamma-ray sky in the energy range from 1 to 30 MeV. Its measurements effectively bridge the gap in existing observations between the hard X-ray and high-energy gamma-ray bands. It combines a wide field-of-view (about 1 sterad) with 1° angular resolution. Its imaging properties make it an ideal instrument for the first comprehensive survey of the sky at MeV-energies.

COMPTEL is designed to study:

- discrete galactic gamma-ray sources
- extragalactic sources: active galaxies, quasars and galactic clusters
- galactic diffuse emission: both line and continuum emissions
- spectra and spectral evolution of cosmic gamma-ray bursts
- solar-flare gamma rays and neutrons.

COMPTEL's energy range is one of the most difficult ones in which to work because background radiations in spacecraft structures, the atmosphere and the instrument itself 'muddy the waters' just at the wavelengths that are being investigated. Novel techniques had therefore to be developed to reduce the background noise to a tolerable level. This was achieved by demanding a complex event signature before accepting an event: this signature cannot be easily mimicked by the background and COMPTEL's strength lies in its ability to reject background events very effectively.

As shown in Figure 6, COMPTEL consists of two detector arrays. Gamma rays are detected by two successive interactions: an incident gamma ray is first Compton-scattered in the upper detector, and then totally absorbed in the lower. The locations of the interactions and energy losses in both detectors are measured. The accuracy in the measurement of these parameters determines the overall energy and angular resolution of the telescope. Event data obtained by COMPTEL can be used to reconstruct sky images over a wide field-of-view with a resolution of about 1 deg (slightly better than Cos-B in its higher energy band).

The two detectors are 1.5 m apart and this gap is traversed by a gamma-ray in 5 ns: this particle is distinguished from a reverse-moving gamma ray (or background event) by onboard electronics and time-of-flight measurements. Each detector is entirely surrounded by a thin anticoincidence shield of plastic scintillator, which detects and discriminates against charged cosmic-ray particles. On the sides of the telescope structure, between both detectors, are two small radioactive plastic-scintillator devices used for in-flight calibration of the instrument. All told, the scintillation detection assemblies make use of 254 delicate photo-multiplier tubes, a record number for a single instrument flown in space.

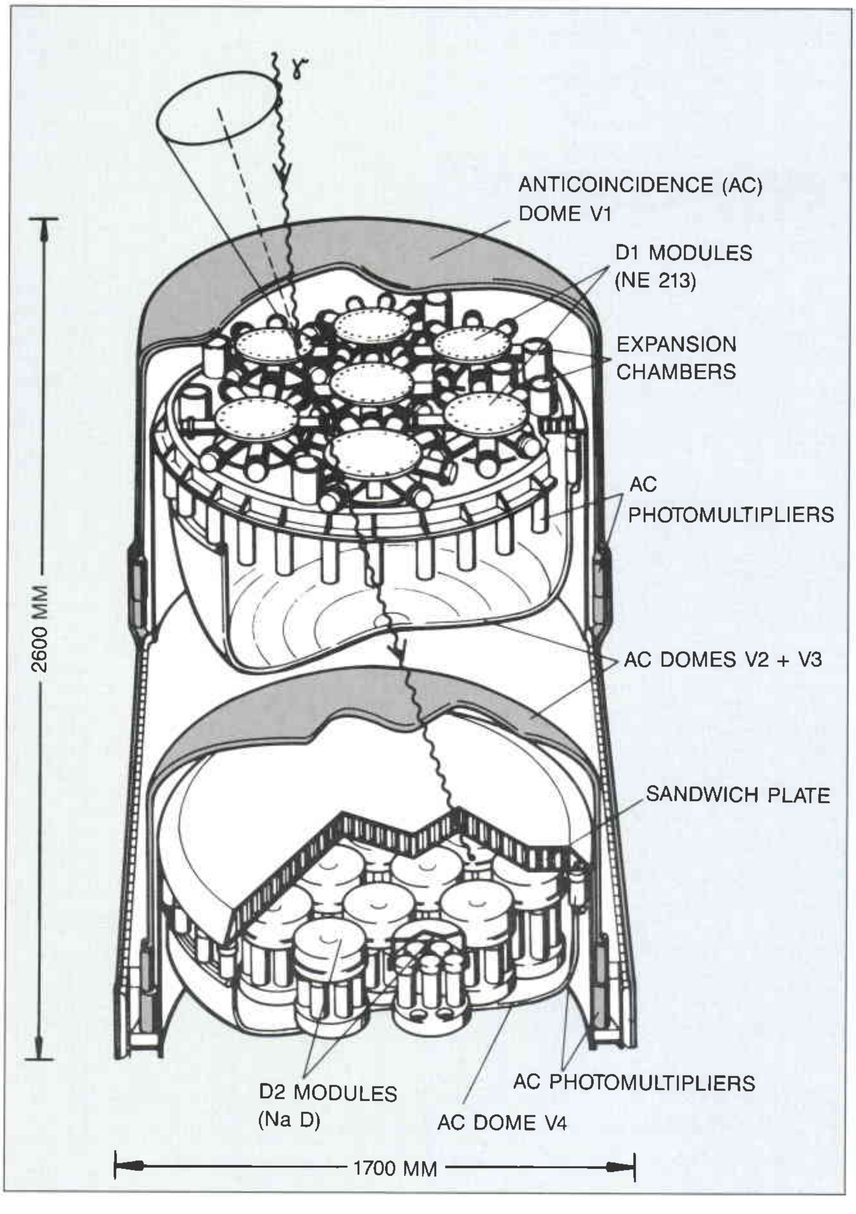

Figure 6. Schematic of COMPTEL, showing how a gamma ray Compton-scatters in the telescope, the scatter angle being determined from the energy deposits in the detectors

The specific contribution of ESA's Space Science Department to the COMPTEL hardware consists of the onboard Calibration Units, the Digital Electronics Assembly (providing the spacecraft telemetry interfaces and instrument command and control), and Instrument Ground-Support Equipment used to control and monitor COMPTEL throughout integration testing as well as in orbit.

The quantities measured for each selected gamma-ray event are:
- The energy of the recoil electron of the Compton-scattered gamma ray in the upper detector (D1).
- The location of the interaction in D1.
- The shape of the scintillation pulse in D1, to distinguish between gamma rays and neutrons.
- The energy deposit in the lower detector (D2).
- The location of the interaction in D2.
- The time-of-flight of the scattered gamma ray from D1 to D2.
- The absolute time of the event.

COMPTEL's main features

Instrument Properties

• Total surface area	8620 cm^2
• Effective sensitive area	20–50 cm^2
• Energy range	0.8–30 MeV
• Energy resolution	5–8% (Full Width Half Maximum)
• Angular resolution	1.7–4.4° (FWHM)
• Geometric factor	5–30 cm^2 sterad
• Field-of-view	~1 sterad
• Source position determination	5–30 arcmin

Instrument Specifications

• Weight	1460 kg
• Dimensions	2.61 m×1.76 m diameter
• Power	206 W
• Telemetry rate	6125 bit/s (equivalent time-average)
• Timing accuracy	1/8 ms with respect to UTC

Figure 7 shows the integrated COMPTEL system being loaded first into the naked GRO structure. In terms of complexity, the COMPTEL instrument can be likened to that of a complete satellite; no meagre task to be taken on by the four scientific groups.

The mission design life of GRO is 27 months, although the spacecraft consumables could support a lifetime of up to 8 years. The low altitude of the spacecraft, combined with its large cross-sectional area, causes significant atmospheric drag. GRO descends slowly to around 350 km, and then its orbit is raised by about 100 km. The first such orbit adjustment will not be necessary until at least the beginning of 1993.

Very little astronomy has been carried out in the COMPTEL energy range and the sensitivities designed for in 1978 when the instrument was first proposed remain valid today.

Ground and in-orbit operations

The observation strategy calls for conducting the first complete survey of the sky at MeV-energies during the first 15 months of the mission. This will be achieved by a series of 33 individual pointings, each lasting about 14 days. Once the sky survey is complete, selected celestial objects and regions of the sky will be studied in greater detail. Extensions of the mission beyond the baseline duration of two years will provide the opportunity for deeper study of sources of gamma-ray emission, including their possible long-term temporal variability.

The spacecraft is operated by the Flight Operations Team (FOT) at Goddard Space Flight Center (GSFC), with each institute involved in the project responsible for command and control of its own instrument via Instrument Ground-Support Equipment (IGSE) located at the various scientific sites. The COMPTEL IGSE is located at the University of New Hampshire (USA) and forms part of a private wide-area network based upon the X.25 protocol. Commands are built and submitted to the FOT from the IGSE and eight or so real-time data passes are received and scrutinised each day at the University. Three hours of quick-look data are transmitted daily which, with additional sets provided on request, provide the first scientific insight into the observation data. This is especially relevant for the response to solar flares and gamma bursts. The full telemetry stream from an observation is shipped routinely by tape to MPI Garching, in Germany, with just one week's delay. After initial processing, the reduced, calibrated data-sets are mailed electronically to the other three collaboration sites for detailed analysis.

The raw data consist of individual 'event messages' containing approximately twenty parameters which characterise a selected event once the telescope is triggered by an incident gamma photon. To process and analyse the large amount of data received from COMPTEL, the Collaboration has developed a customised and modular data-analysis package, called 'COMPASS' (i.e. COMPTEL Processing and Analysis Software System), which uses the ORACLE database-management system for configuration control and to monitor user access. Each of the four collaborating institutes is responsible for the development and maintenance of particular software subsystems which make up the COMPASS package. COMPASS is designed to run at all four institutes with approximately equal capabilities for data processing and scientific analysis, though particular processing tasks have been assigned within the Collaboration to specific sites.

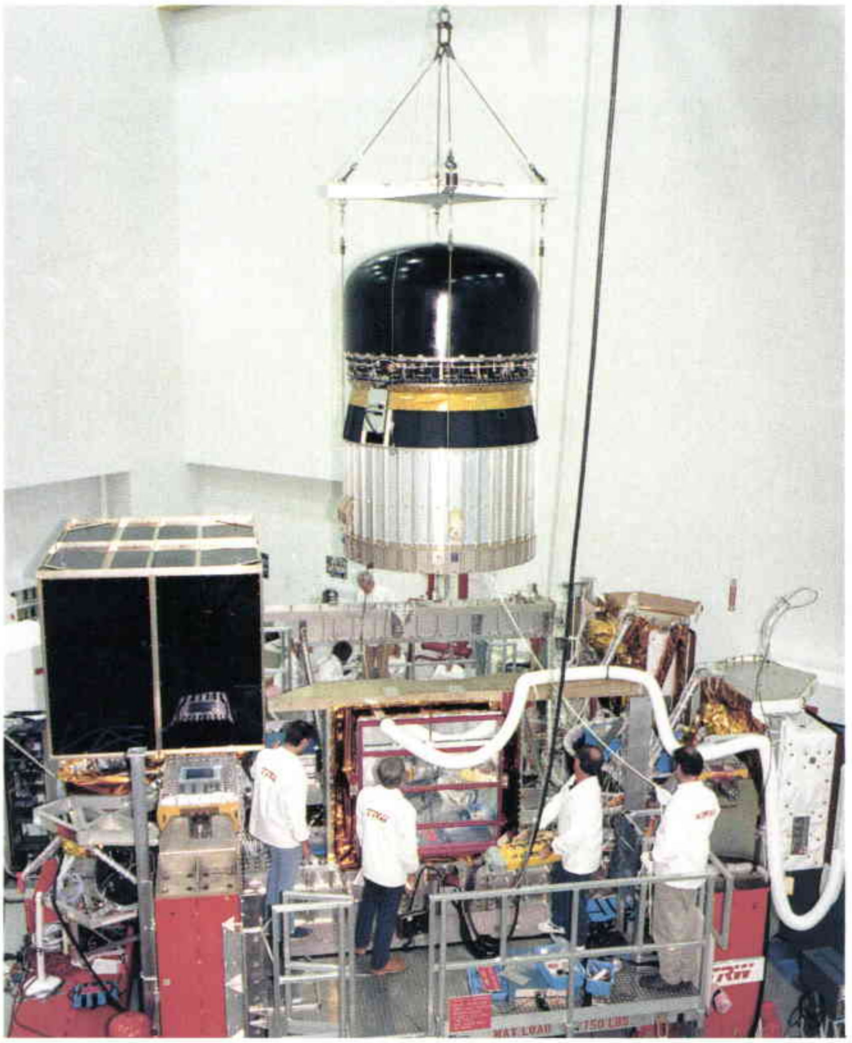

Figure 7. COMPTEL being integrated into GRO (Photo courtesy of NASA)

Routine scientific analysis of processed COMPTEL data begins with the production of images of the sky over the field of view of the instrument for a given observation period. A number of deconvolution algorithms can be employed within the COMPASS environment to produce images of the sky; these are based primarily on maximum-entropy, maximum-likelihood and cross-correlation techniques, and the parameters of an identified source are determined. These state-of-the-art techniques can reveal both localised and extended sources (e.g. molecular clouds or the galactic plane). Successful application of these methods has been a significant triumph for the COMPTEL data-reduction team. If pulsars or other sources with expected temporal signatures lie within the field of view of the instrument, a search for modulated emission can be performed. Similarly, the analysis of burst events, and of gamma rays and neutrons of solar origin, is carried out via specialised tasks within COMPASS.

Figure 8. The Crab Nebula which contains the gamma-ray pulsar PSR 0532.

The activation of the spacecraft was completed on schedule by mid-April, within nine days of launch, and the instrument checkout and activation was performed in just ten further days. The aim of the subsequent instrument tuning phase was to set the thresholds and onboard data selection to fit the event rates comfortably within the available telemetry. Since all subsystems exhibited nominal behaviour and the rates were observed to be moderate, tuning was relatively simple.

Several factors affect the telescope trigger rates: particle-induced background, which is inversely proportional to geomagnetic latitude; Earth aspect angle; and time since passage from the South Atlantic Anomaly (the spacecraft encounters the SAA up to eight times per day for periods of up to 25 minutes; during these passages, the high voltages of the telescope detectors are switched off). By setting conservative thresholds on the detector pulse heights and time-of-flight windows, the sky-viewing event rate can be reduced to about 25% of the available bandwidth, thereby allowing a margin for events which may come in a burst.

The first two weeks of operations were used as a verification phase for all of the instruments. Five different pointings were selected in order to establish the background and the instrument performance with different inclinations to the orbit. The first three pointings put the Crab Nebula at different positions in the field of view, while the fourth pointing viewed a low-emissivity region of the Galaxy, and the last pointing viewed the Vela Pulsar, which was nearly perpendicular to the orbital plane.

First results

Validation data yielded a clean image of the Crab Nebula and a striking light curve from the Crab Pulsar using the Radio Ephemeris produced by both the Jodrell Bank (UK) and Greenbank (USA) radio telescopes. Although not the first light curve to be produced in this energy range, the statistical precision is unprecedented. It is well known that the X-ray light curve of the Crab differs from the high-energy (Cos-B) gamma-ray light curve. To make the puzzle yet more intriguing, in Figure 9 it can be seen that the COMPTEL light curve is again different and, it seems, varies on a time scale of weeks. Detailed statistical testing of this variability is in progress.

The high-energy 'Geminga' source is not obvious in the first COMPTEL maps, which means its spectrum is falling rapidly at lower energies as if it were a pure high-energy gamma-ray source. Any upper limit to the low-energy gamma-ray emission of this and other Cos-B sources will help to constrain the source models.

A most pleasant surprise of the validation period was the observation of a gamma burst from the Auriga direction within the field of view of COMPTEL on 3 May (Fig. 10). Within the burst duration of approximately 10 s, the telescope event rate was swamped by burst events. This background-free sample of events has yielded the first-ever image of a gamma burst from within a single telescope.

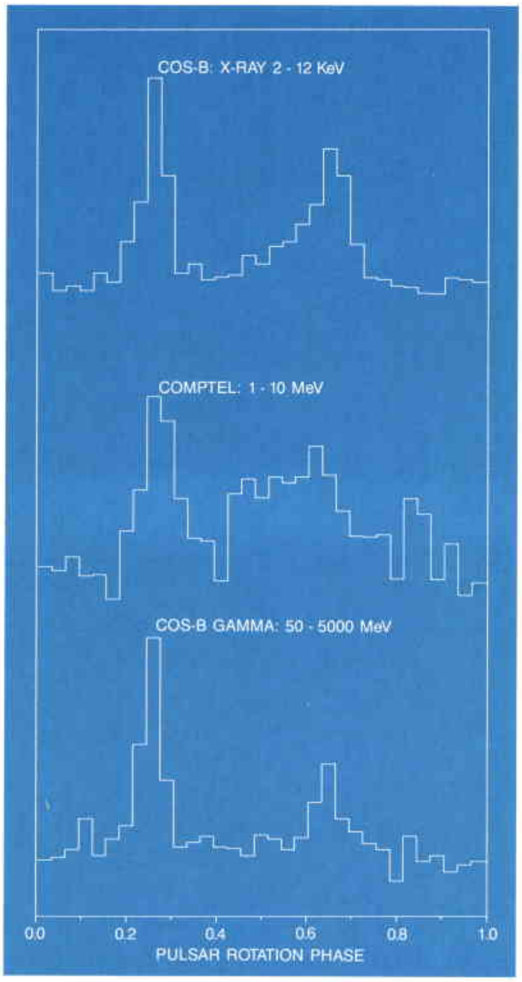

Figure 9. The Cos-B X-ray and high-energy gamma-ray light curves compared with that measured by COMPTEL for the Crab Pulsar

Several methods were used to image the data, all of which give a consistent position within the present knowledge of the detector response. Furthermore, the same burst was detected by ESA's Ulysses mission and, by a process of 'triangulation', a 'ring of origin' was drawn using the arrival time of the burst at the two widely separated spacecraft. The ring cuts the image drawn by COMPTEL, demonstrating that COMPTEL's imaging techniques are working reliably and that such intersections can reduce the search regions for counterparts by an order of magnitude or more. This is important in increasing the chances of detecting a possible counterpart of any gamma-ray burst.

At the start of the observation of the Cygnus region, a second gamma-ray burst was detected by COMPTEL on 1 June.

This Cygnus observation was urgently interrupted on the ninth day when the Sun was declared a 'target of opportunity'. The highly active Sun was giving predictors for a large solar flare and so it was agreed to reorientate GRO towards it on 8 June. The reward was that two huge solar flares were observed on 9 and 11 June. During the impulsive phase of the flares, the rates were so high that COMPTEL experienced near 100% dead time. As the rates faded away, the enduring gamma rays were seen to be imaged from the Sun, which clearly demonstrated both the robustness of the COMPTEL design and the reliability of the imaging techniques.

The gamma rays from the 11 June burst show the Sun to have moved in right ascension by the correct amount in the two-day interval. Furthermore, COMPTEL was set into a neutron-sensitive mode during the entire Sun-pointing period and preliminary data analysis indicates that the telescope has detected solar neutrons produced during the flare. These neutrons arrive for up to 45 min after the impulsive part of the flare at a speed dependent upon their energy, giving a clue to the energies of the protons magnetically confined in the flare regions.

Gamma-ray astronomy has certainly entered a new era with the launch of GRO. For example, the recent EGRET discovery of a gamma-ray quasar 3C279 makes this the most powerful gamma-ray emitter known in the Universe! Not only are the different instruments providing copious data for the Principal Investigator groups, but the anticipated length of the mission will yield sufficient data to allow members of the wider scientific community to take part in the

Figure 10. Preliminary image of the 3 May gamma burst (accuracy of around 1 deg)

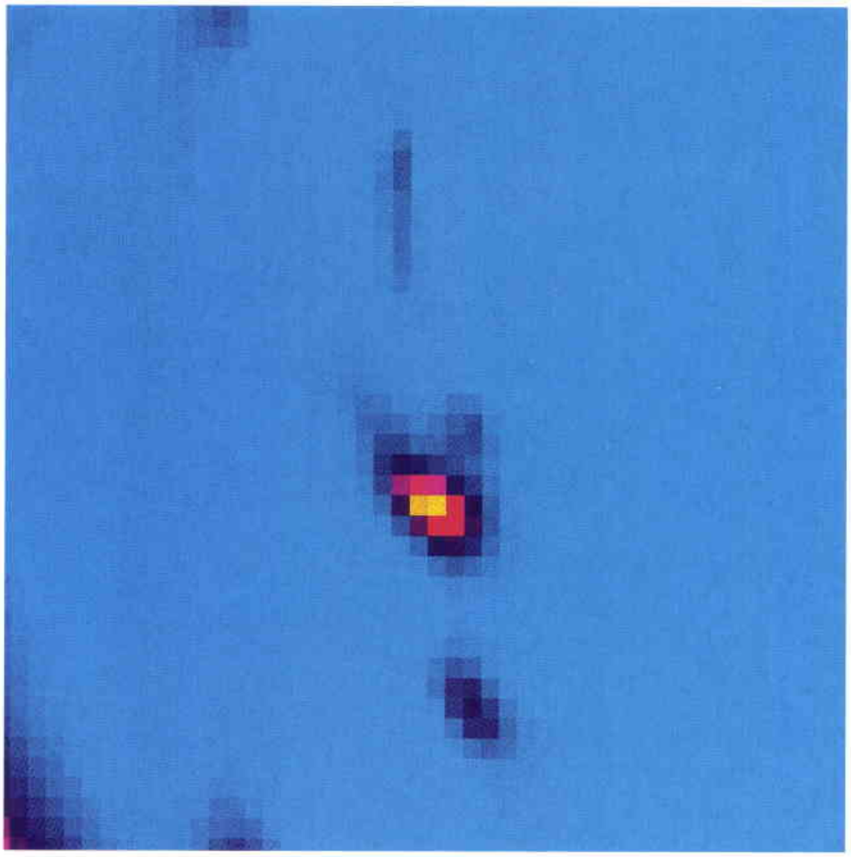

Figure 11. Two superimposed gamma-ray images of solar flares that occurred two days apart

venture too. On completion of the sky survey, Guest Observers will be able to propose their own observations for up to 30% of the time. The fraction of observation time open to guests will steadily increase, while access to archival data will be made available through the existing NASA infrastructure (NSSDC).

Although the community's appetite for data will certainly be sated to a great extent by GRO, it is inevitable that, as in the case of Cos-B, the rich results and discoveries will raise new questions. It is therefore most appropriate that a follow-on mission to GRO is already under study jointly by NASA and ESA. The so-called 'Integral' mission would provide improved spectroscopy and imaging in the COMPTEL energy range. Such ventures clearly demonstrate the importance of maintaining the momentum of the scientific research and stress the importance of looking deeper and deeper into the high-energy astrophysics processes taking place in the Universe.

Acknowledgements
The authors have benefitted from excellent support from ESA Space Science Department technical staff and we are grateful to colleagues throughout ESTEC who have worked with us to provide quality instruments which are proving to work so well in orbit. In addition, we would like to acknowledge the close and fruitful relationship with SIRA Limited during manufacture of the Digital Electronics Assembly for COMPTEL.

The Olympus Mission Recovery — 'Mission Impossible?'

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The events of 29 May 1991 that led to the loss of stability of the Olympus experimental communications satellite and its consequent drift from station have been examined in great detail by the Olympus Enquiry Board and its findings will be published shortly. This article concentrates on the endeavours of the Olympus Mission Recovery Team charged by ESA's Director General, on 3 June, with the task of recovering the mission using all possible means.

The scale of the challenge

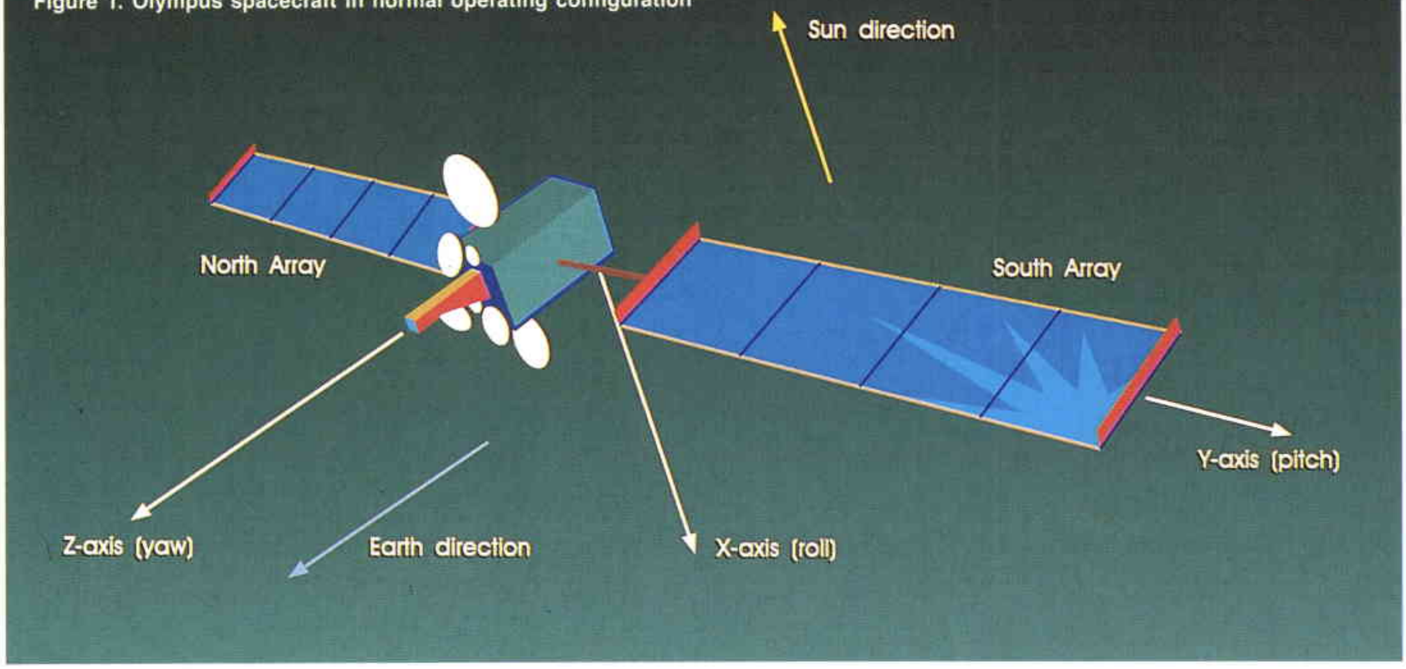
In the early hours of 29 May 1991, the Olympus spacecraft (Fig. 1) switched itself into a safety mode called the 'Emergency Sun-Acquisition Mode'. This mode can be entered due to any number of onboard anomalies and is a design safety feature on most three-axis-stabilised spacecraft. During the return to the normal mode of control on this occasion, however, the Olympus Control Centre at Fucino in Italy encountered problems and the spacecraft began to tumble, eventually rolling about one of its axes (Fig. 2).

Olympus' power-supply system could not maintain battery charging in this mode, nor could it provide sufficient power to maintain heaters for thermal control, because the solar arrays were aligned away from the Sun. As a result, the temperature of the spacecraft eventually plunged to between −50 and −60°C and the onboard fuel, oxidiser and batteries froze.

In addition, thruster firings caused by autonomous system operations at the time of the anomaly had forced Olympus out of geostationary orbit and it was drifting eastwards at 5 deg per day, thereby moving out of range of the Fucino tracking station.

Some months previously, on 28 January, the south solar array on Olympus had developed a fault which resulted in the subsequent loss of 50% of available power. In addition, the lack of reliability of the two infrared earth sensors, together with an apparent loss of signal from a radio-frequency

Figure 1. Olympus spacecraft in normal operating configuration



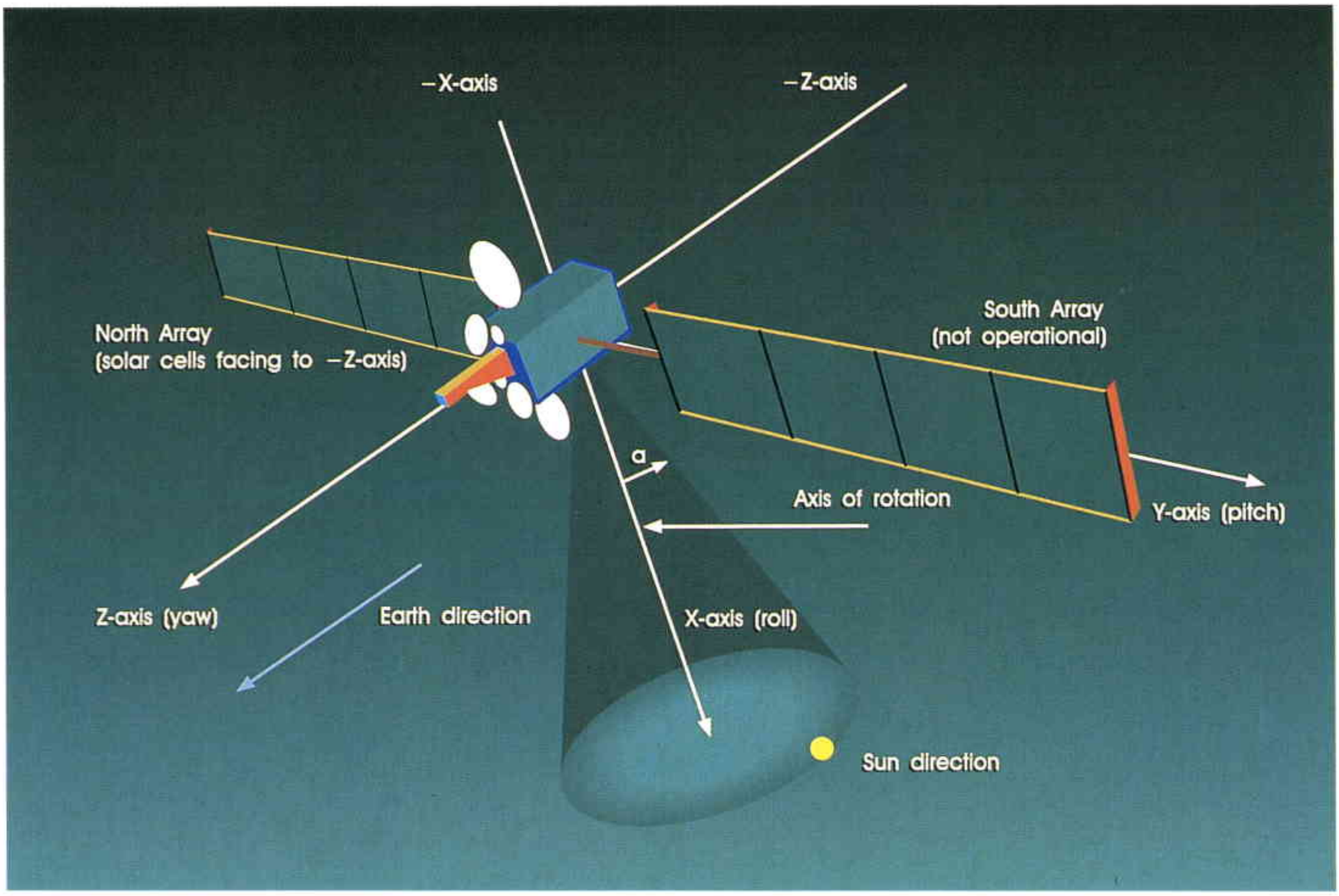


Figure 2. Olympus spacecraft attitude after 29 May 1991

sensor (RFS-A), had necessitated using the backup unit (RFS-B). In the period between 28 January and 29 May, an intensive procedural updating had been in effect at British Aerospace (Stevenage, UK), at ESTEC and at Fucino, to cope with these spacecraft anomalies and to reduce service outage time. The use of an incompletely validated procedure during the return to 'normal mode' on 29 May resulted in the loss of stabilisation.

The status of Olympus on the morning of 29 May was as follows:

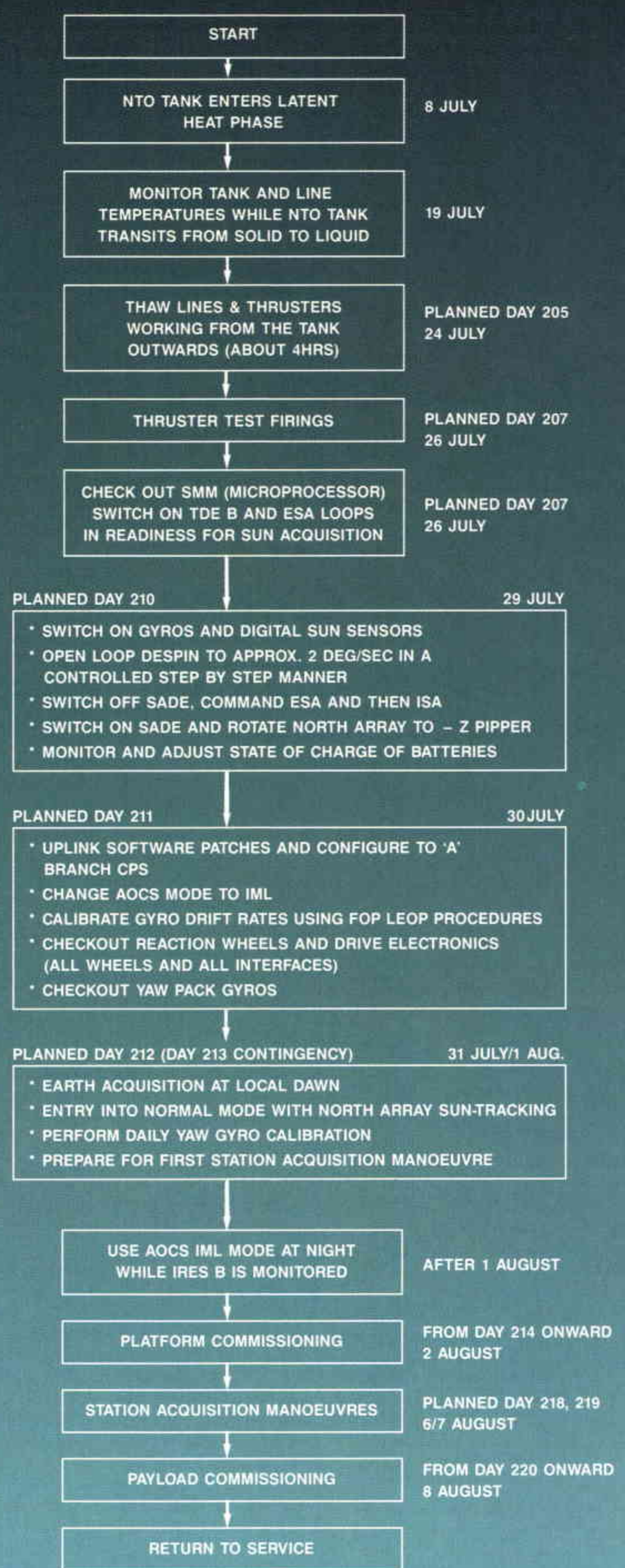
- The spacecraft was cooling.
- Its batteries were completely discharged.
- It was spinning about its X-axis, with its spin-axis (inertially fixed) pointing at the Sun.
- The spin period was 89 s per revolution (equivalent to 4 deg/s).
- The main bus voltage was oscillating with spin rate between 0 and 25 V.
- There was no telecommand access, except possibly via the spacecraft's Direct Distribution Unit.
- There was no telemetry data except for Central Distribution Unit internal words.
- Many commands had been sent since the loss of telemetry, especially to the telecommand, tracking and control (TTC) remote units and heaters, but the status was uncertain in those areas.

An assessment made one week later indicated the following possible damage and degradation due to the anomaly:

- Possible damage to items containing liquids, such as:
  - The nickel-hydrogen battery: probably recoverable, but capacity and charge efficiency reduced until reconditioned, and possible overheating when potassium-hydroxide catalyst redissolved at −33°C.
  - The nickel-cadmium battery: possible physical damage due to freezing, and possible risk of damage by hydrogen generation if charged at high current when too cold.
  - The Combined Propulsion System (MMH and NTO): possible damage during thawing of internal elements, and possible catastrophic damage to pipework and valves if thawing liquid had no space into which to expand.

- Electronic systems: probably not damaged, though one or two units could have failed, but this could be accommodated within normal redundancy.

Figure 3. Olympus outline recovery plan



The Agency's response

The Olympus Mission Recovery Team, established on 3 June 1991 by ESA's Director General, Mr J-M. Luton, was given the task of attempting recovery of the mission by using all available means. The Team was drawn from ESA and British Aerospace (BAe) specialists, headed by an ESA Chief of Operations at ESOC. BAe, the company that had led the industrial consortium that developed Olympus, provided engineering advice and planning expertise to the ESA Team.

The Olympus Mission Recovery Team, consisting of more than 50 engineers from a variety of disciplines, was already hard at work from early June, planning and executing a very complex recovery plan of operations (Fig. 3). Additional tracking stations were brought up for support (with the cooperation of NASA and CNES), and the ESOC Operations Control Centre's (OCC) command, control and communications facilities were expanded to assume misson control from the Olympus Control Centre at Fucino. The modifications to the ESOC Control Centre, the tracking network and the communications systems took place as the Mission Recovery Plan was prepared.

The basic recovery plan, established during early June and up-dated frequently thereafter, set out to do the following:

- Obtain readable telemetry data when solar-array illumination was more favourable, and continually monitor spacecraft status.
- Reduce power demand by turning off propulsion-system line and thruster heaters.
- Prevent thruster firings by disabling thruster electronics.
- Further reduce power demand to less than 200 W, leaving on only essential units and tank and battery heaters.
- Recharge the nickel-hydrogen battery when battery temperature exceeded −25°C, and when solar power was available.
- Enable battery-discharge regulators and switch on the battery-management system.
- Recharge the nickel-cadmium battery when battery temperature exceeded −10°C, and when solar power was available.
- Optimise the solar array's position periodically to maximise power.
- Warm the spacecraft gently using its heaters, ensuring that daily tank temperature rise did not exceed 5°C.

- Thaw the fuel and oxidiser tanks.
- Thaw all lines.
- Thaw roll, pitch and yaw thrusters and perform test firings.
- Reduce the spacecraft spin rate from 4 deg/s to 2 deg/s.
- Acquire the Sun and command the Attitude and Orbit Control System (AOCS) into emergency Sun-acquisition mode to stop the spin, and proceed to a stable Sun-pointing attitude.
- Acquire the Earth with Infra-Red Earth Sensors (IRES) and return the AOCS to its normal mode of operation.

By 31 July, all of the above key tasks had been carried out according to plan, the last four events taking place between 26 and 31 July. Several thousand telecommands were transmitted from ESOC via the tracking stations at Perth in Australia, Goldstone in California, Kourou in French Guiana, and Villafranca in Spain in order to complete these activities.

The Mission Recovery Team had therefore successfully conducted a series of operations never previously accomplished (to ESA's knowledge) with a crippled spacecraft. On 30 May, there had been no useable telemetry from Olympus, no telecommand capability, only marginal fluctuating power, on-board systems were freezing, and the spacecraft was drifting quickly away from station. By 1 August, the Olympus spacecraft platform was fully operational and fully under control. The operations described were conducted over a period of 64 days as Olympus drifted eastwards over the Pacific and Atlantic Oceans.

The planning of this series of complex operations, based on engineering analyses performed by BAe, required engineers to work long hours under extreme pressure. Detailed operations procedures had to be prepared and complex sequences of telecommands loaded into the ESOC computers. In many cases the validation of the procedures required simulation before actual operations could be conducted, and the essential nature of the Olympus spacecraft simulator was very evident.

The Olympus Recovery Team's next task was to stop the spacecraft drifting, re-position it at its operational station at 19°W longitude, and begin station-keeping. This sequence of manoeuvres began on 2 August with an eastward burn of 8 min and 6 s, producing a ΔV of 7 m/s and reducing the drift rate from 5 to 2.9 deg per day.

On 6 August, an inclination correction manoeuvre was performed using the north thrusters to bring the orbit inclination within station-keeping dead bands. This manoeuvre lasted 11.55 min and produced a velocity increment (ΔV) of 15 m/s.

On 9 August, a further east burn was performed, reducing the drift rate to 0.9 deg per day, and on 13 August the final station-acquisition thrust positioned Olympus at 19°W longitude, where the station-keeping cycle began with a west burn that same day.

Olympus is maintained at 19°W in a 'box' which extends $\pm 0.1°$ in both the east/west and north/south directions. This precise station-keeping is necessary both to ensure the correct communications coverage and to avoid getting too close to three other communications satellites operating nearby.

The payload commissioning began on 14 August and lasted for 20 days, during which time all elements of the communications payload were extensively tested. Test data have shown that the performance of all payload elements is within specification and very close to that measured before the events of 29 May.

Conclusion

The efforts of the Olympus Mission Recovery Team have rescued a satellite worth more than 650 MAU ($800 000 000) from almost certain disaster. This collaboration between ESA and BAe has demonstrated that Europe has the technical and operational expertise to perform complex and extremely critical operations using facilities and resources that had not been designed for this specific task.

The staff of three ESA Directorates (ESOC, ESTEC and Telecommunications) worked closely with the spacecraft manufacturer, BAe, in planning and executing the operations. International cooperation with both NASA and CNES provided additional tracking-station coverage from Goldstone and Kourou which, together with the facilities at Perth, Villafranca and Fucino, permitted almost continuous coverage of the Olympus spacecraft during its journey around the Earth.

Vulcain engine testing on the PF50 test stand in Vernon, France (SEP). (Courtesy of SEP)

Ariane's Vulcain Engine — 1991 A Vintage Year

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Ariane-5, which will be the next member of the already highly successful Ariane launch-vehicle family (Fig. 1), is being developed as an ESA Programme, with programme management delegated to Centre National d'Etudes Spatiales (CNES, the French National Space Agency). The main propulsion for the new launcher will be provided by two solid-rocket boosters (P230's) and one single cryogenic stage (H155). The Vulcain engine will provide most of the energy needed to place the vehicle's payloads into orbit.

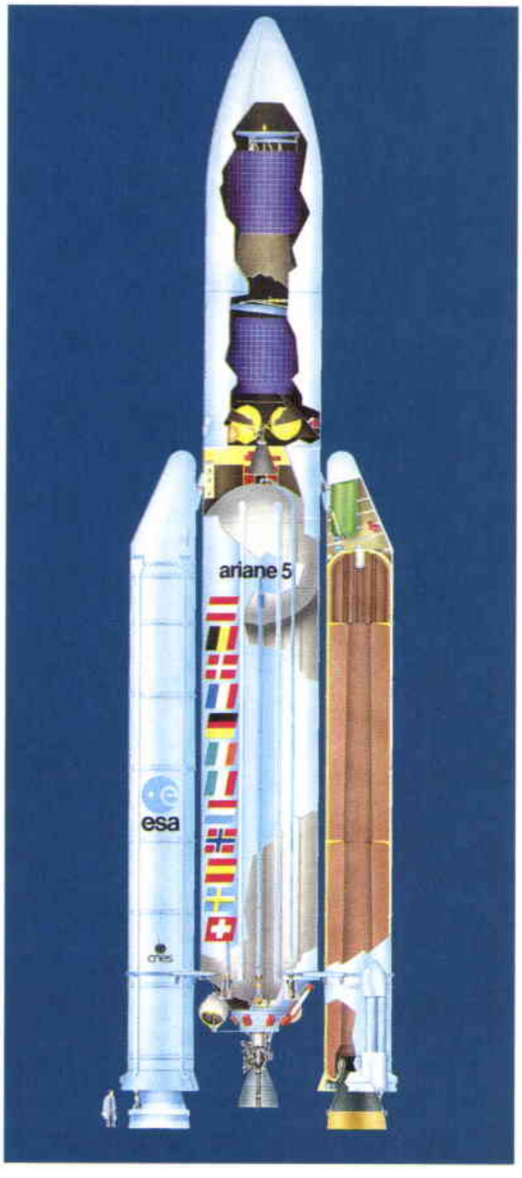


Figure 1. The Ariane-5 launcher

Introduction

The Vulcain programme started with a preliminary phase in 1985. The go-ahead for the main industrial development programme was given, with the endorsement of the Ariane-5 Programme, at the ESA Council Meeting at Ministerial Level held in The Hague (NL) in November 1987.

The Vulcain engine (Fig. 2) is being developed by Société Européenne de Propulsion (SEP) in Vernon (F), with the support of more than 30 industrial firms throughout Europe, including MBB and DLR in Germany, FIAT AVIO and MICROTECNICA in Italy, VOLVO in Sweden, FNM in Belgium, SPE in The Netherlands, AVICA in the United Kingdom, DEVTEC in Ireland, and FAGOR in Spain.

Engine development is on schedule and that schedule has not been changed since the beginning of the programme. The key milestones are as follows:
- Start-up in 1985
- First component tests in 1987
- First subsystem tests in 1988
- First engine tests in 1990
- First-stage tests in 1993
- First flight in 1995.

The challenge of Vulcain

The challenge of the Vulcain programme is to develop a new high-performance rocket engine by using the high-energy combination of liquid hydrogen and liquid oxygen. The performance specifications, it should be emphasised, are high, but not the highest possible. Rather, they are consistent with the vehicle's needs for optimum cost and minimum risk.

High reliability is required as a direct consequence of the intense competition for future space transportation and the high cost of payloads. Safety is necessary not only for man-rating for the launch of Europe's

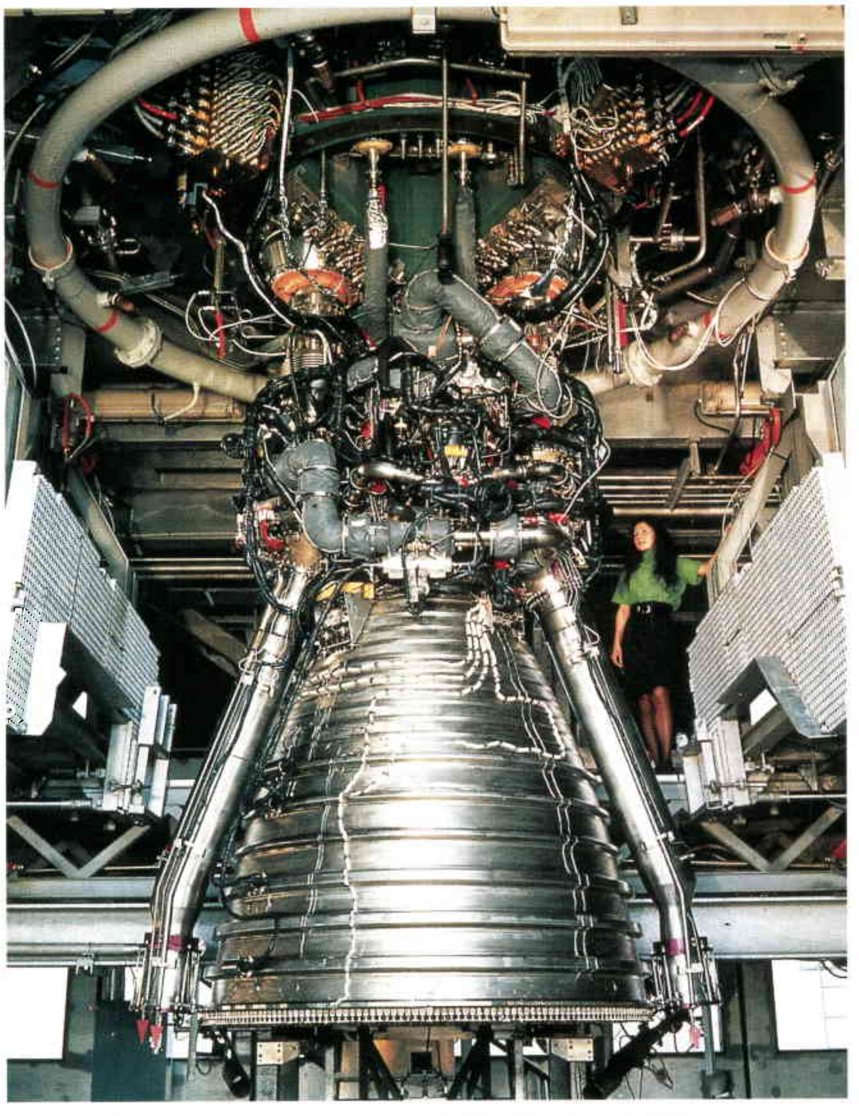


Figure 2. The Vulcain engine on the test facility (Courtesy of SEP)

Hermes spaceplane, but also for minimising development risks. In addition, the design-to-cost objective is a new and real challenge being addressed by all of the contractors involved in the programme.

The main technical choice made at the outset was that of a gas-generator-cycle engine with two turbopumps and turbines fed in parallel, with pressure in the thrust chamber limited to 100 bar.

These choices, which could be seen as conservative, still require a large technological step forward with respect to previous European engines, such as the Viking or HM7: pressure increased by a factor of three, power by a factor of five, and a major increase in size.

With these choices, it has also been possible to produce an engine with relatively modular subsystems, which are both interchangeable and more easily developed by various companies distributed throughout Europe. Great emphasis has been put on easy repair, simple inspection and pre-flight checkout procedures, and adequate sensors for 'green light' lift-off authorisation.

As far as possible, well-known technical features already proven on HM7 have been used to minimise development risk, for example: gas generator cycle, separate turbine exhausts and coaxial injection. When necessary, however, new technologies have

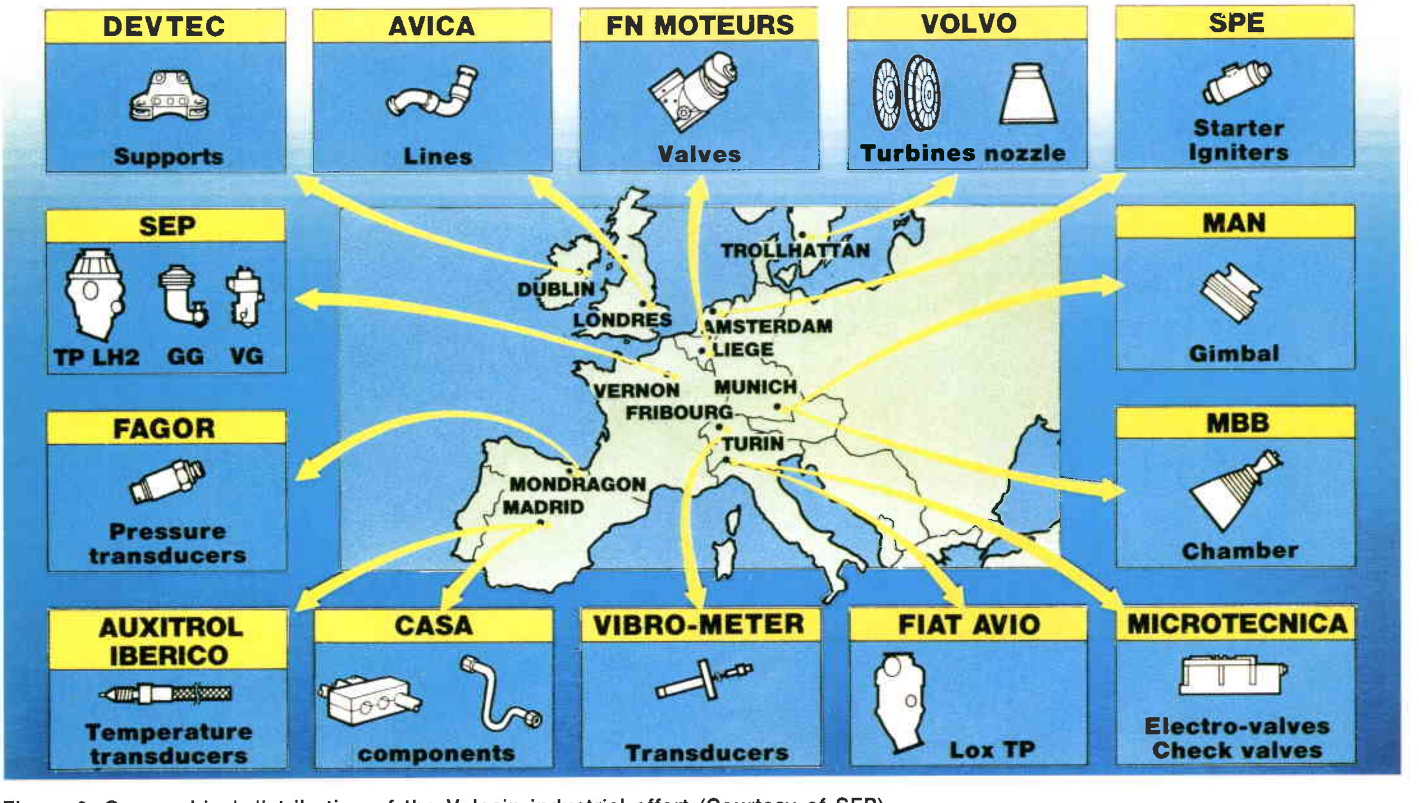


Figure 3. Geographical distribution of the Vulcain industrial effort (Courtesy of SEP)

also been applied, such as a new copper alloy for the thrust chamber, automatic welding for the nozzle tubes, high-strength materials for the turbopumps, dynamic axial balancing piston, high-power supersonic turbines, etc.

The geographical distribution of the industrial effort throughout the ESA Member States on the Vulcain programme is summarised in Figure 3.

Primary engine characteristics

The Vulcain engine itself has been described in detail in ESA Bulletins Nos. 44 (November 1985) and 61 (February 1990) and, as its overall design has not changed in the meantime, just a short summary will be given here. This article will concentrate instead on the development effort that has taken place in the meantime and the many milestones that have been successfully achieved.

The Vulcain engine design requirements are:

Vacuum thrust	1070 ± 50 kN
Mixture ratio	5.1 ± 0.2
Vacuum specific impulse	≥ 430 s
Propellant suction pressure	
Oxygen	≥ 1.5 bar
Hydrogen	≥ 0.4 bar

The main features of the engine are:

- Liquid-oxygen and liquid-hydrogen ($LOX-LH_2$) propellants with two turbopumps.
- Single $LOX-LH_2$ gas generator.
- Two separate turbines driven in parallel.
- Single thrust chamber with classical geometry, coaxial injection and regenerative cooling.
- Dump-cooled nozzle.
- Pyrotechnic starter and igniters.
- Pneumatic (helium) command system.

Vulcain is a gas-generator-cycle engine (Fig. 4), the thrust chamber being fed by separate turbopumps with turbines in parallel and separate gas exhausts. The gas generator and combustion chamber are ignited at low pressure by pyrotechnic igniters, and the turbopumps are started by a solid-propellant cartridge.

The two gas-generator injection valves and the mixture-ratio two-position hot-gas valve are calibrated during engine tests using hydraulic actuators and ground computers. In flight, the pneumatic valves open to one of two limits preset by mechanical stops in order to achieve the correct thrust and mixture ratio.

Figure 4. Vulcain engine flow diagram (Courtesy of SEP)

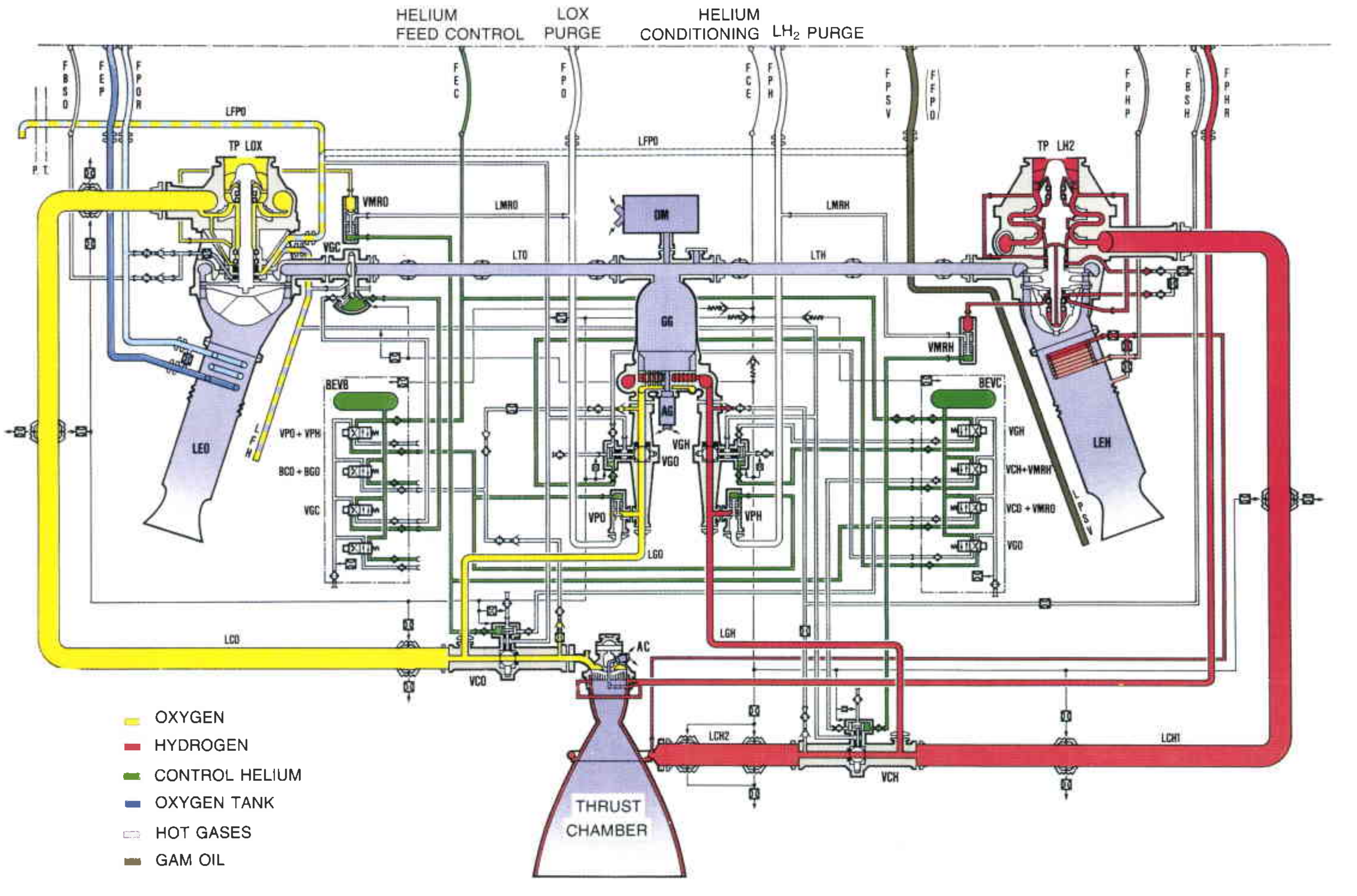
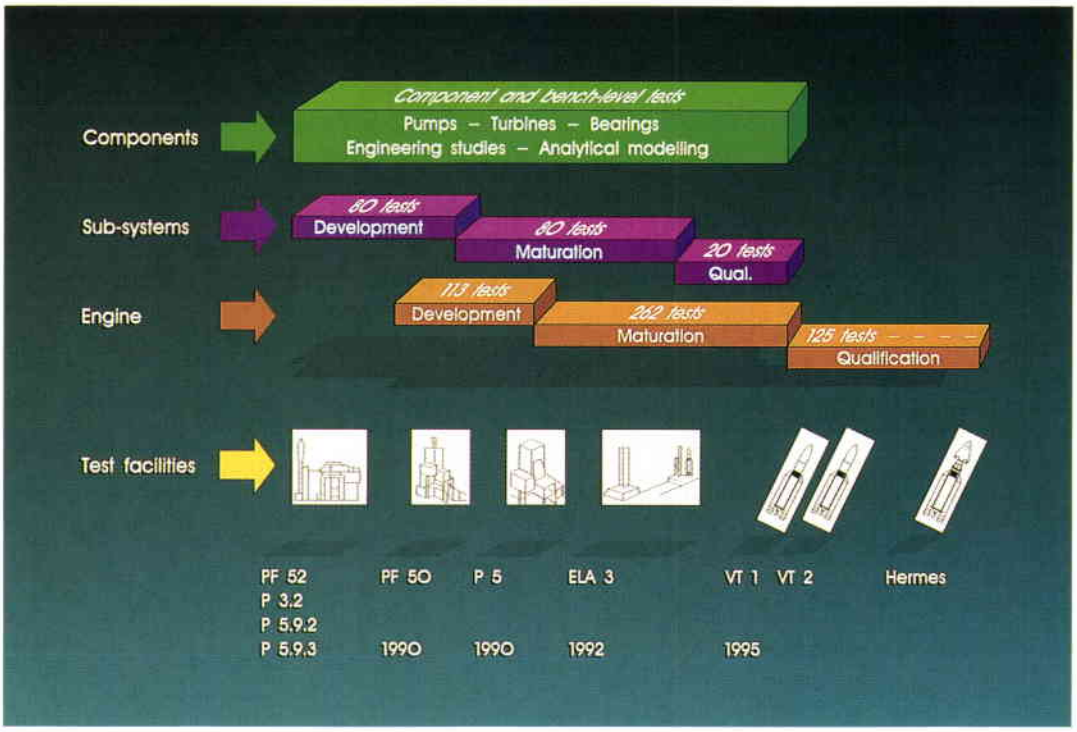


Figure 5. The Vulcain engine development programme



Development logic

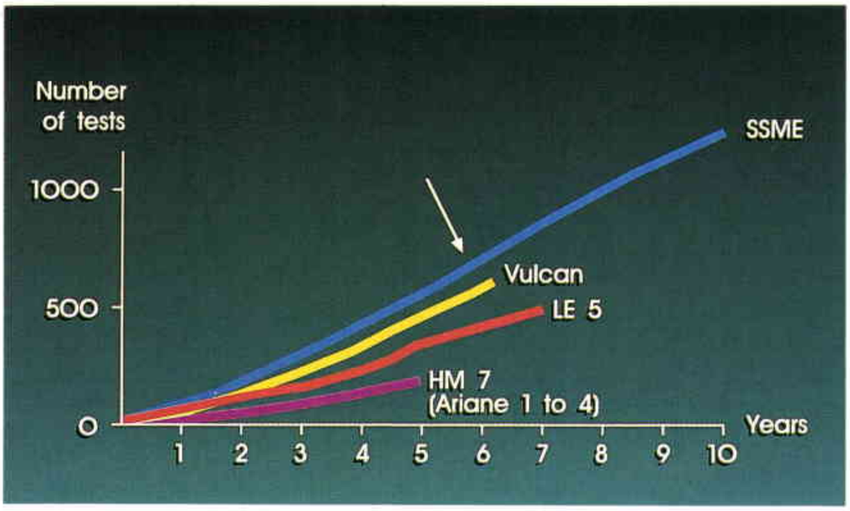
The development logic is based on three levels of testing – component, subsystem and engine – and three major engine configurations – prototype, maturation and demonstration. The overall organisation of the development programme is shown in Figure 5.

For each subsystem (turbopump, gas generator and thrust chamber), special tests are planned at specific test facilities (PF52 in Vernon, France, for the turbopumps; P5.9 in Ottobrunn, Germany, for the gas generator and the oxygen turbopump; and P3.2 in Lampoldshausen, also in Germany, for the thrust chamber).

The 600 s flight duration will be demonstrated in engine testing (with extension to 900 s for performance margin demonstration). Five hundred engine tests and 90 000 s of operation are planned before the completion of engine development to demonstrate a high level of reliability and safety.

Figure 6 compares the numbers of tests for different cryogenic engines (SSME=Space Shuttle Main Engine, LE 5=H1 second-stage cryogenic engine).

Figure 6. The cryogenic engine development programme



Thrust chamber status

The thrust chamber (Fig. 7) is the assembly of an injector composed of a 516 LOX/LH_2 coaxial-element injection system with a central igniter tube, an LH_2 regeneratively cooled combustion chamber with an inner liner made from copper alloy and an outer electro-deposited nickel shell, a dump-cooled tubular nozzle extension, and a ball-type gimbal bearing.

The technical characteristics of the chamber are:

Mass	620 kg
Pressure	100 bar
Mixture ratio	5.9
Flow rate	240 kg/s
Specific impulse (vacuum)	439 s

On 15 December 1988, the first hot test (excluding nozzle extension and gimbal) at low power took place on the P3.2 test facility in Lampoldshausen. On 23 February 1989, the full power level was demonstrated. In the following tests the run duration was extended up to the test facility maximum of 18 s, including the start-up and shut-down transients.

The basic results of these tests were as follows:

- Proper functioning and integrity of the thrust chamber was demonstrated up to full power.
- No combustion instability was apparent under either transient or steady-state conditions.
- There was good agreement between test and design data regarding thrust-chamber pressure drop and coolant temperature rise.

In the test campaign of May 1989, the nozzle extension was attached and tested, and during the second test a buckling of the nozzle occurred. The analysis by MBB (D) and VOLVO (S) of this incident showed that the nozzle needed to be reinforced. A second nozzle with this modification was tested successfully in November 1989 (Fig. 8). Further tests in 1990 and 1991 have demonstrated thrust-chamber performance for the entire operational envelope from 80 to 115 bar, and for mixture ratios of 4.9 to 8.5.

To date, eight thrust chambers and nozzles have been built by MBB and VOLVO and subjected to a total of 94 tests on the P3.2 facility, while 48 tests have been carried out on the engine as a whole.

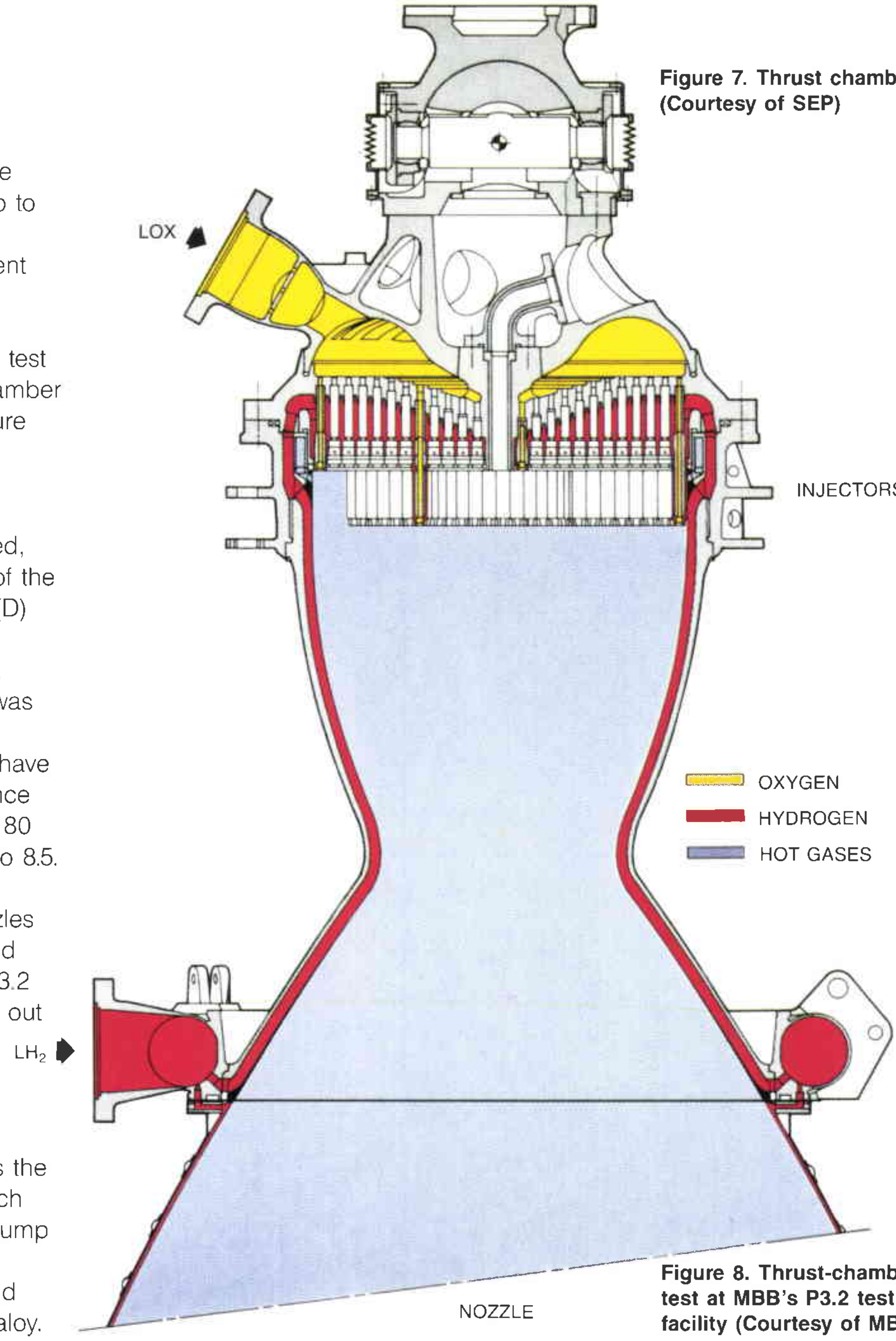


Figure 7. Thrust chamber (Courtesy of SEP)

Hydrogen turbopump status

The second subsystem to be tested was the liquid-hydrogen turbopump (Fig. 9), which is composed of a titanium three-stage pump (one axial inducer and two centrifugal impellers) in an Inconel 718 housing, and a two-stage supersonic turbine in Waspaloy.

The technical characteristics of the LH_2 turbopump are:

Mass	220 kg
Rotation speed	34 000 rpm
Turbine power	11 mW
Pump inlet pressure	3 bar
Pump outlet pressure	160 bar
Flow rate	40 kg/s

The subsystem-level tests began in May 1988 after delivery of the first turbopump to the PF52 test facility on 11 April. The first tests were devoted to examination of the turbopump's behaviour during chill-down with different inlet pressures and flow rates. Subsequent tests achieved a maximum speed of 32 400 rpm in liquid hydrogen with the turbine driven by gaseous hydrogen (16 tests in total and 50 s total duration).

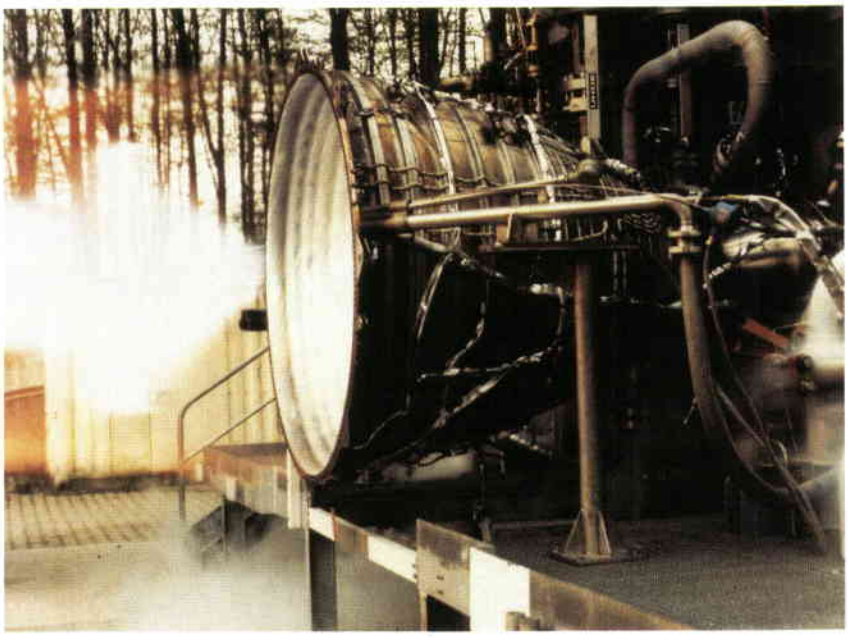


Figure 8. Thrust-chamber test at MBB's P3.2 test facility (Courtesy of MBB)

Figure 9. Hydrogen turbopump (Courtesy of SEP)

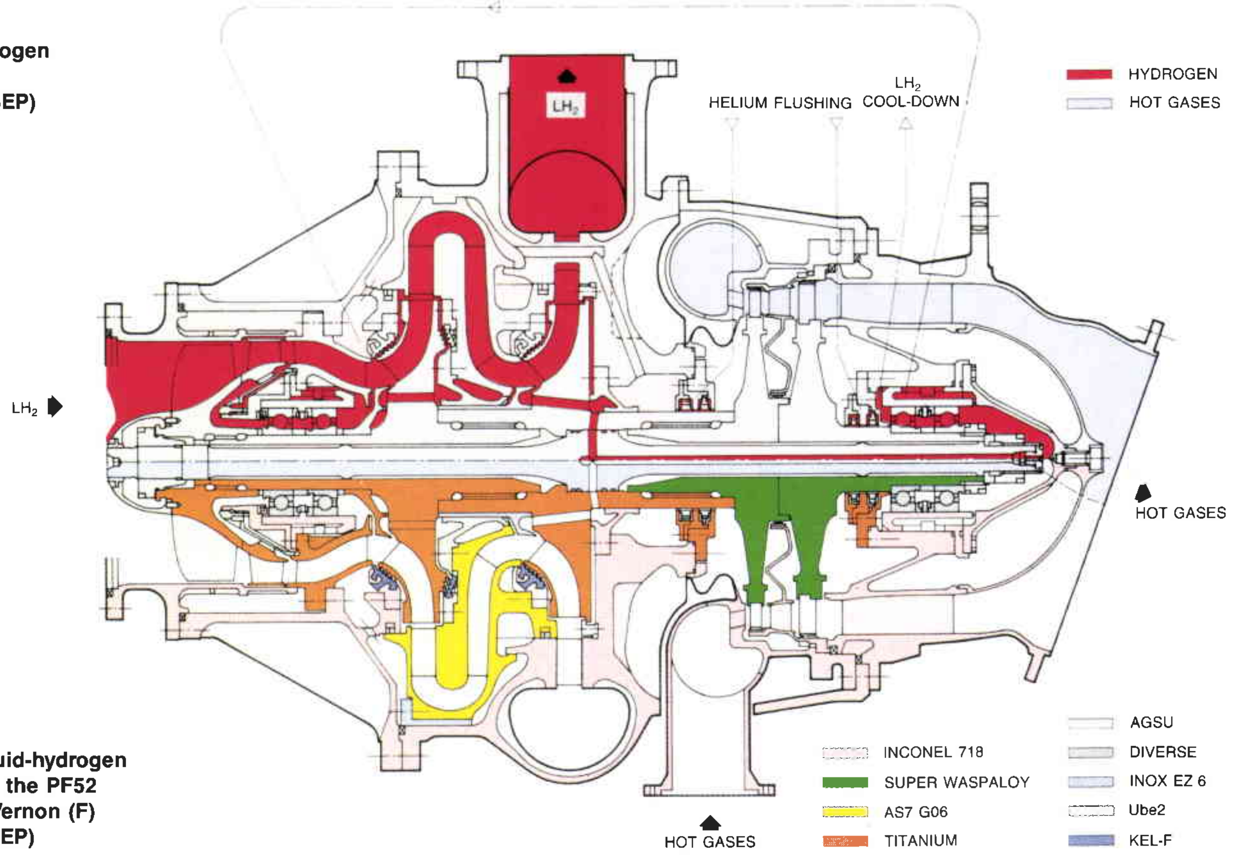
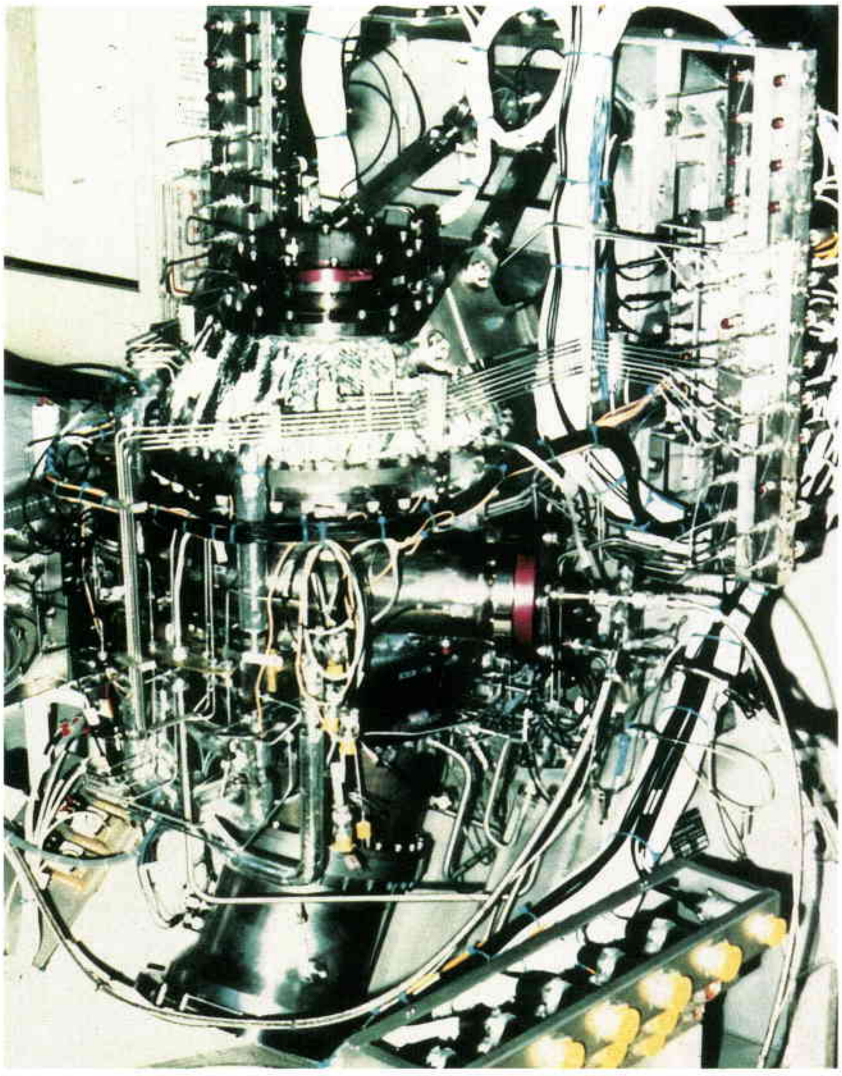


Figure 10. Liquid-hydrogen turbopump on the PF52 test stand in Vernon (F) (Courtesy of SEP)



The main results were:

- cavitation specification fulfilled
- hydraulic design frozen
- good general mechanical behaviour demonstrated (dynamic rotor, bearings, seals, axial balancing system).

Tests were also conducted with hot gases from a gas generator, on the PF52 test facility, which both confirmed the results obtained in cold tests and verified correct turbopump behaviour during transients and thermal shock (Fig. 10). Tests at the maximum power of 15 mW were carried out for periods of 90 s (maximum duration possible in the test facility).

To date, seven turbopumps have been built and tested at SEP (F) for a total of 56 tests at turbopump level, and 48 tests with the engine.

Oxygen turbopump status

The first liquid-oxygen turbopump was delivered to the P59.3 test facility on 10 May 1988. This pump (Fig. 11) is composed of a two-stage pump (one axial inducer and one centrifugal impeller) in an Inconel 718 housing, and a single-stage supersonic turbine in Waspaloy.

The technical characteristics of the oxygen

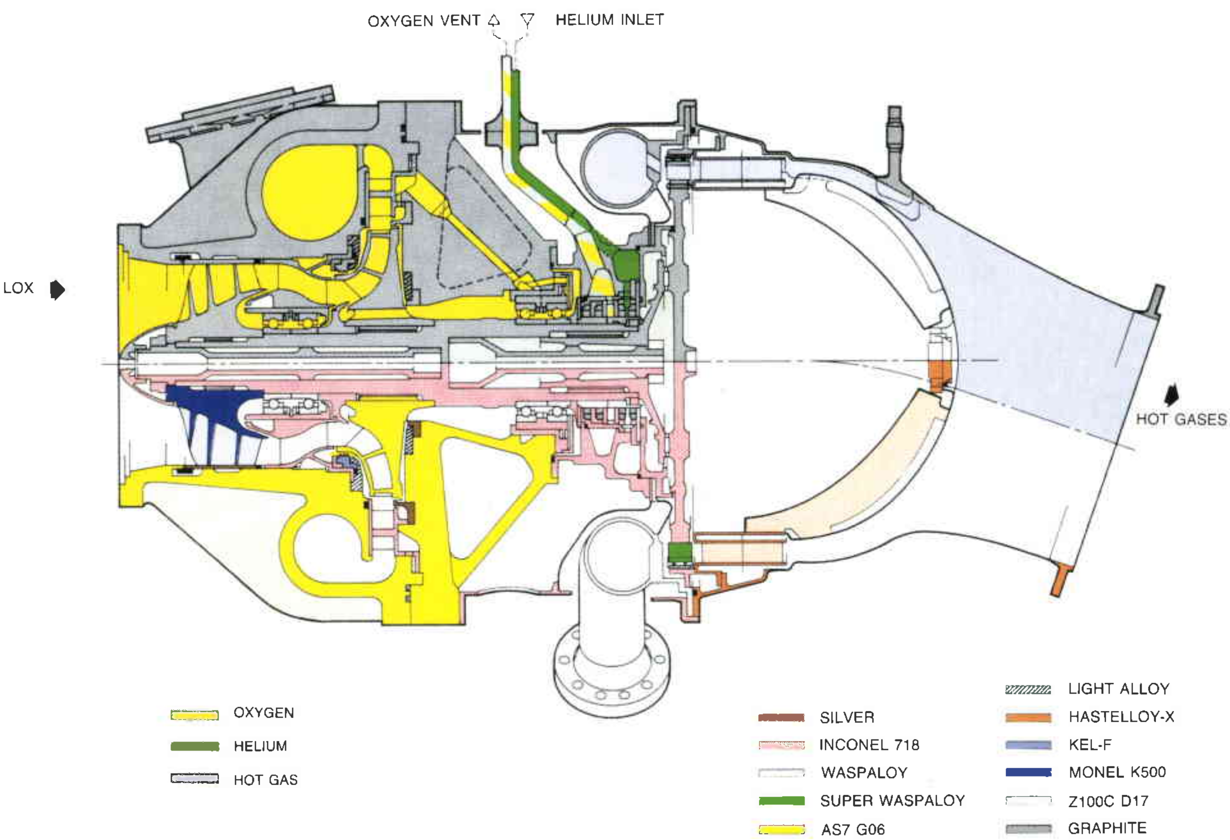


Figure 11. Oxygen turbopump (Courtesy of SEP)

turbopump are as follows:

Mass	130 kg
Rotation speed	13 000 rpm
Turbine power	3.2 mW
Pump inlet pressure	3 bar
Pump outlet pressure	130 bar
Flow rate	200 kg/s.

Component tests have been carried out for the pump (in water at ENEA/FIAT/CIEI, Turin, Italy), the turbine (in cold and hot air at VOLVO, in Trollhattan, Sweden), bearings and dynamic seals (in liquid oxygen at FIAT AVIO, Turin).

As for the LH_2 turbopump, the first tests were devoted to the examination of turbopump behaviour during chill-down, and then the pump was tested in liquid oxygen — the turbine initially being driven by gaseous hydrogen and later by hot gases from a gas generator.

Cavitation tests were carried out to verify cavitation specifications. As for the LH_2 turbopump, the results were:
- cavitation specification fulfilled
- hydraulic design frozen, and general mechanical behaviour satisfactory.

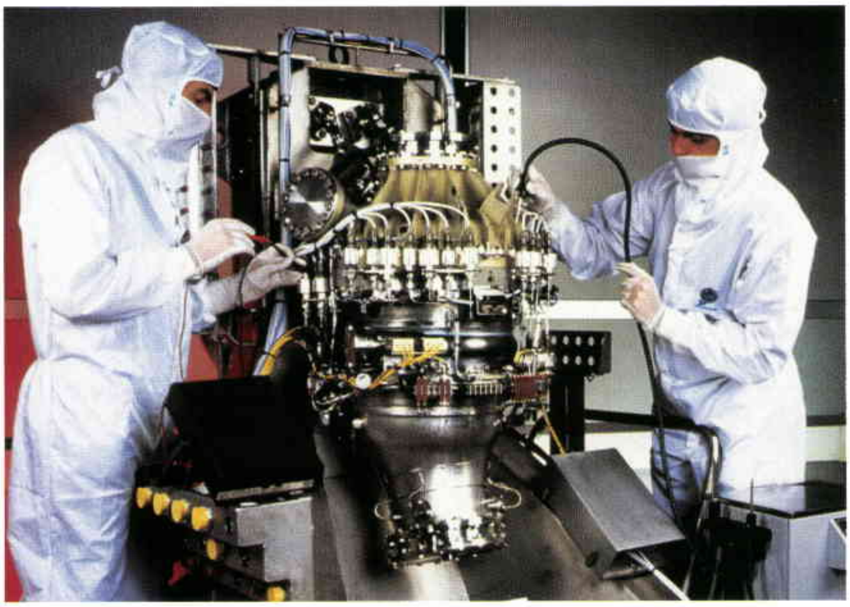
A weak point in the housing was discovered during testing, requiring modification of the hardware. This led to a delay in deliveries, with the result that few tests could be carried out in 1991.

So far, seven turbopumps have been built by FIAT AVIO and used for a total of 45 tests at turbopump level and 48 tests with the engine (Fig. 12).

Gas generator status

The gas generator (Fig. 13) head, made primarily of Inconel 718, has 60 LOX/LH_2 injection elements. The body, in Waspaloy, is a single-wall uncooled combustion chamber, with baffles and acoustic cavities to provide a

Figure 12. Final acceptance testing of the LOX turbopump before delivery (Courtesy of FIAT AVIO)



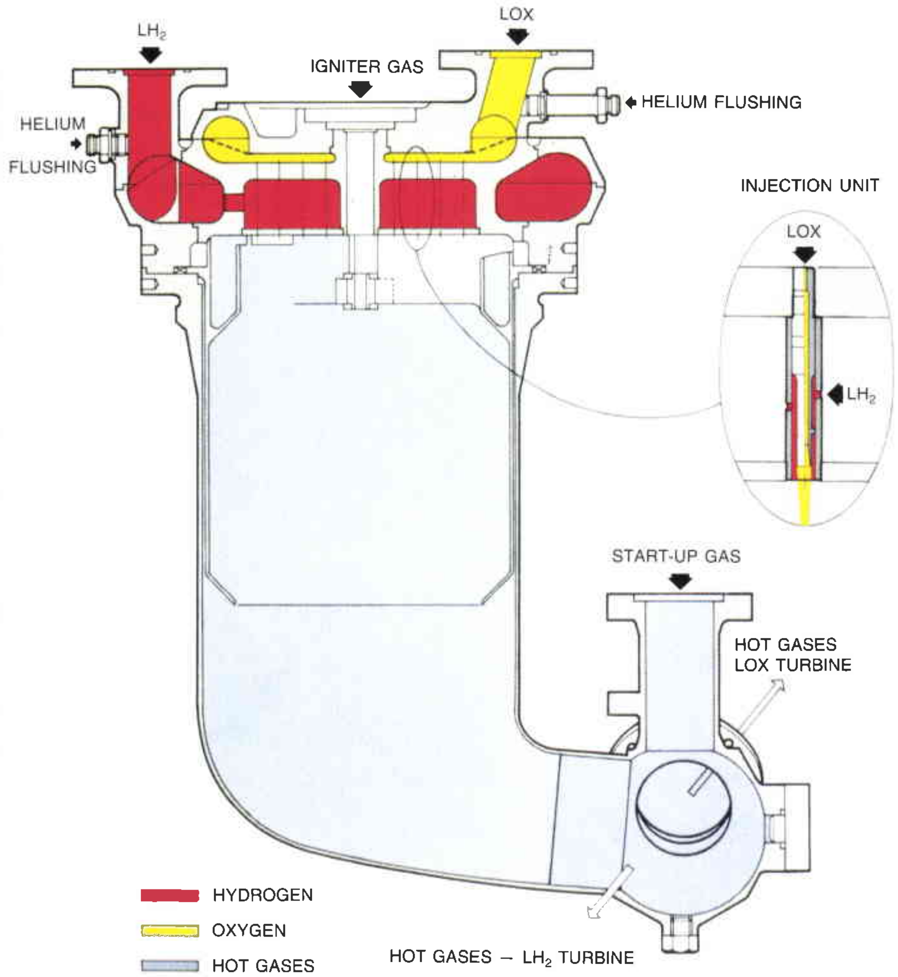


Figure 13. Gas generator (Courtesy of SEP)

Figure 14. Gas generator at the P59.3 test facility in Ottobrunn (Courtesy of MBB)

margin in relation to the onset of combustion instabilities.

The technical characteristics of the gas generator are:

Mass	40 kg
Pressure	80 bar
Mixture ratio	0.9
Flow rate	8 kg/s.

Hydraulic, thermal transient and combustion models are available, and flame-temperature models have been validated through mono-element firing tests at SEP (F). Hydraulic tests and impingement-pattern tests on the injector head conducted by ONERA (F) on mockups, and in water tests at SEP on actual hardware have provided a high degree of confidence prior to full-scale firing tests.

The first gas generator was assembled on the test facility on 25 February 1988 (Fig. 14), and 64 such gas-generator tests have been made on the P59.2 test stand with good results, demonstrating full compliance with specifications. Ninety-eight other tests have been conducted with turbopumps on stands P59.3 and PF52, and with engines on PF50 and P5.

The extreme operational domain has been explored with turbine inlet pressures between 55 and 133 bar and mixture ratios between 0.6 and 1.1 in order to demonstrate satisfactory operating margins. Subsequent disassembly of the first units has shown all components to be behaving satisfactorily.

By the end of August 1991, 11 gas generators had been built and subjected to a total of 146 tests.

Component status

The first set of components (pneumatic, solenoid and check valves) have been manufactured and tested by SEP, FNM (B) and MICROTECNICA (I). They are being used at test facilities and on engines with cryogenic fluids at real pressures and flow rates.

A 'Command System Mock-Up' was tested in Spain with all of these parts.

The first lines containing articulations have been manufactured by AVICA (UK), delivered to the test facilities (PF52 and P5.9), and built into the engines, where they have already been used with cryogenic fluids or hot gas at design pressures and flow rates.

The first sets of mechanical support items have been manufactured by DEVTEC–Aer Lingus (Ire) and delivered to SEP, to be used on the engine vibration mock-up, and the first engines.

The pyrotechnic devices made by SPE (NL) have been tested and used during the chamber, gas-generator, turbine and engine tests.

In addition, elementary components such as turbines, dynamic joints, ball-bearings, inducers, etc. have been under scrutiny since 1987 at special test facilities. More than a thousand such tests have been carried out.

Engine status

The first engine assembly, M1, was completed during early 1990. This engine was set up on the PF50 test facility in Vernon on 4 April — the very date planned three years previously!. At the same time, a vibration mock-up was submitted to high-level vibration testing to verify its mechanical behaviour, stiffness, and the engine's bending modes.

These were major achievements and tangible proof of both the efficient cooperation taking place between all of the partners in the programme, and the great motivation of the people involved in Vulcain development.

The first hot test with ignition of the chamber was carried out on 5 July, and after only 15 tests in 1990 the steady-state-condition and short-duration tests (10 s) had been achieved. These tests allowed the definition and verification of the start-up and shut-down sequences, as well as of the safety red lines and safety software used during tests.

In parallel, a second engine was set up on the second test stand (P5) at Lampoldshausen, and 11 tests were performed confirming proper engine behaviour. During this campaign, a 5 s test was conducted at a power level corresponding to a thrust of 1330 kN.

In January 1991, the third engine, M3, with a long nozzle, replaced M1 on PF50 to undergo a long-duration test campaign. This engine ran perfectly for seven months, and the following major milestones were achieved:

- first test at nominal power and of nominal duration (600 s) in June 1991
- first test of maximum duration (900 s) in July
- accumulated firing duration test of 2300 s at the end of August.

In addition, after refurbishment, the M1 engine underwent a 600 s firing test in July 1991.

Figure 15. Vulcain engine testing on the PF50 test stand at Vernon

Conclusion

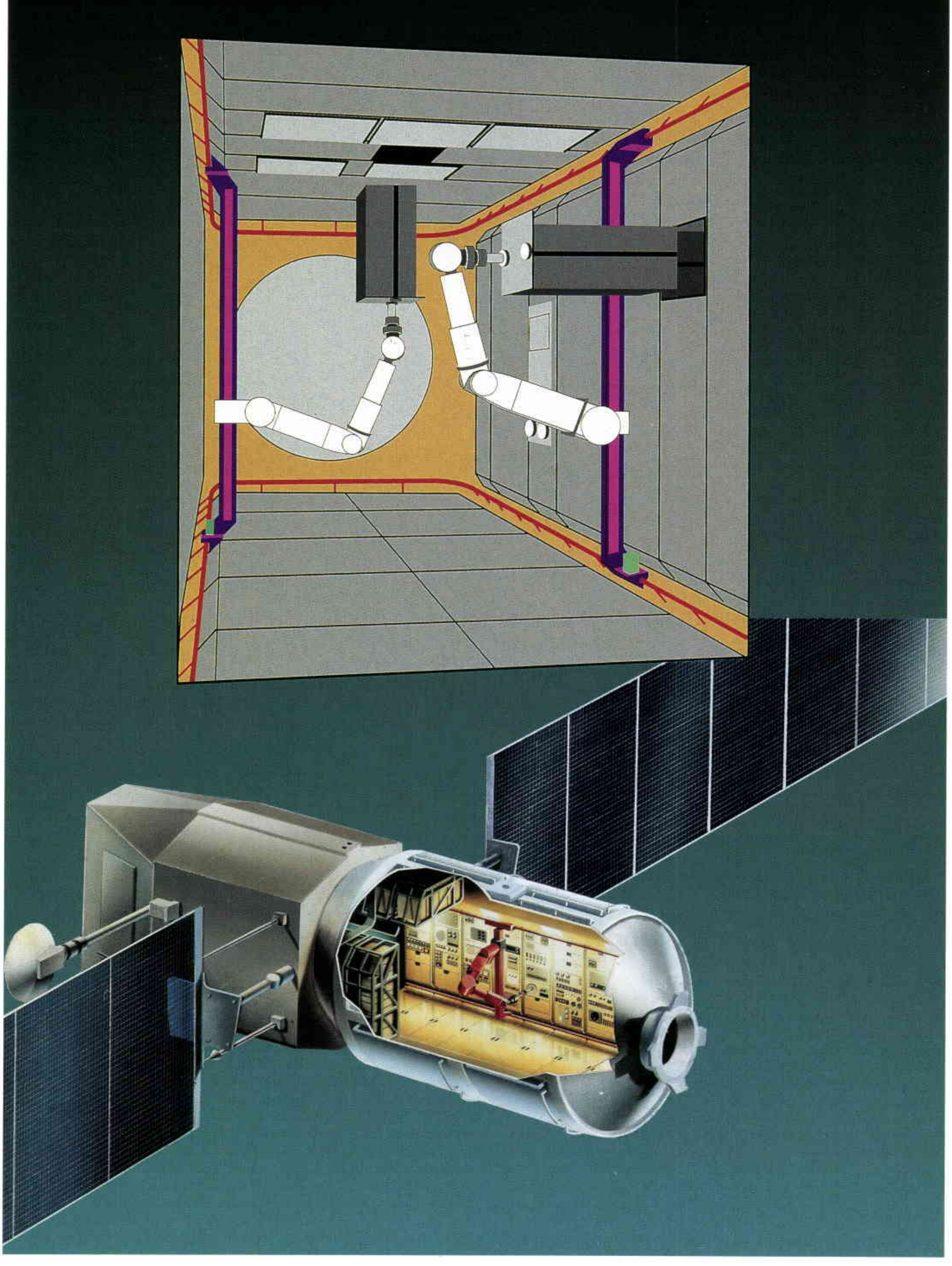
Seven years after the commencement of the Vulcain programme, test results, now at subsystem and engine level, are confirming the validity of the technical choices made during the conception phase. At the end of August 1991, a very encouraging picture of Vulcain development exists:

- The first three engines have permitted the completion of 48 tests for a total duration of 3300 s, without excessive damage to any materials.
- The principal subsystems, thrust chamber, liquid-oxygen and liquid-hydrogen turbopumps, and gas generator have already demonstrated their ability to function within the overall qualification envelope.
- The industrial manufacturing and test installations have all been accepted and are fulfilling user expectations.

Most of the basic design choices have already been validated, but await final confirmation from additional long-duration testing of units at engine level. For this purpose, 500 engine tests and 90 000 s of operation are planned before engine development is deemed complete, in order to demonstrate high levels of both reliability and safety.

All of the achievements to date, supported by consistent analysis and component testing tools, have given us confidence for the subsequent phases of the Vulcain programme.

Figure 1. Two rail-based mobile robots performing sample transportation tasks and experiment manipulation



Automation and Robotics: A Flexible Technology for In-Orbit Payload Operations

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The Agency's Columbus Programme has made its entry into Automation and Robotics (A&R) technology by initiating development of the Columbus Automation and Robotics Testbed. This ground-based testbed is intended primarily as a tool for evaluating the benefits of A&R for the microgravity experimenter, and for familiarising potential users, payload engineers, and operators with A&R concepts and applications. It will be operational at ESTEC by mid-1992 and will be integrated with the Telescience and Crew-Workstation Testbeds to allow the realistic end-to-end simulation of spaceborne experiment scenarios.

Introduction
The Space Station era will introduce new ways of conducting payload operations. It will allow the user to choose between permanently manned or man-tended flight opportunities, either on board the Columbus Attached Laboratory docked to International Space Station 'Freedom', or on board the Columbus Free-Flying Laboratory. Compared to Spacelab, Columbus and the Space Station will provide users with an almost tenfold increase in capacity for accommodating experiments, continuous operations within an infrastructure that is permanently in orbit, and a higher level of basic resources.

The Columbus Free-Flying Laboratory is conceived as a man-tended platform, and the Attached Laboratory is also planned to be operated in man-tended mode in the early phases of its lifetime. These constraints imply the use of automation to operate both the payloads and the system during the unmanned periods. Even later on, with the permanent presence of the four-man crew aboard Space Station 'Freedom', it is assumed that they will have insufficient time to operate the hundreds of instruments on board, unless crew efficiency and productivity can be dramatically enhanced through the use of advanced technologies.

Among those advanced technologies, Automation & Robotics (A&R) can play an important role in complementing and enhancing human abilities and skills. It is therefore attractive to consider modes of operation in which the cognitive abilities of humans are used to their fullest whilst the well-defined routine operations are left to robots.

Automation of space operations
The automation of system and payload operations in space must be based on practical concepts, drawing lessons from existing terrestrial systems that have a proven validity. Automated systems used, for example, in manufacturing, underwater engineering, nuclear servicing or aviation, can serve as a valuable source of inspiration for the development of automated systems for use in space.

Knowledge and experience gained on Earth and from previous space programmes has already provided a good understanding of which operations are suited to automation and which are bound to rely on human intervention. In general, well-defined and repetitive tasks for which a clear execution procedure exists are good candidates for automation, such as nominal experiment servicing, logistic transport, inspection, and cleaning. On the other hand, even with today's state-of-the-art technology, the crew remains indispensable for carrying out ill-defined or unforeseen tasks that require a good deal of cognitive ability, such as scientific diagnosis, contingency actions, repairs and maintenance.

Hybrid automation concept

A certain task can be automated in several different ways, ranging from 'hard' to 'flexible' automation. With the former, the functions are implemented unchangeably in a dedicated mechanism or electronic circuit. With the latter, on the other hand, the functions are programmed in software and can therefore be modified easily and quickly. This makes flexible automation much more adaptable and universal (i.e. suited to cover a wider range of applications) than its hard counterpart. In addition, elements of each type of automation can be combined to produce a cost- or performance-optimal configuration, which is commonly referred to as 'hybrid automation'.

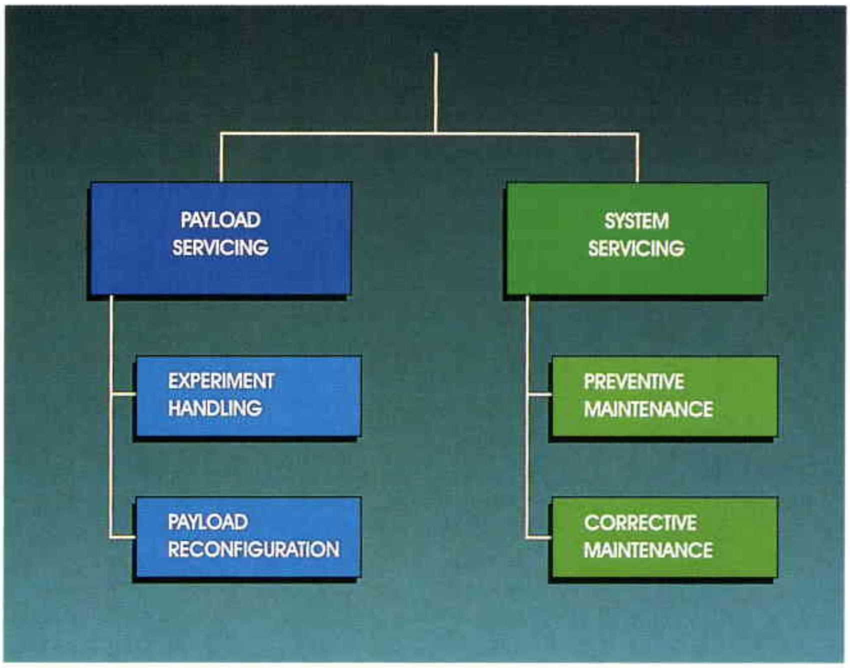


Figure 2. Overview of possible servicing tasks for a central robot

In any Columbus payload servicing scenario, two major considerations virtually dictate the choice of a hybrid automation concept. Firstly, particular experimental conditions, such as the need for a closed container to preserve atmospheric conditions or to prevent toxic spill, sometimes do not allow a general-purpose solution, necessitating the use of dedicated automation equipment. Secondly, an optimal Columbus utilisation concept does not allow the duplication of all functions in each payload facility, especially functions that are not intensively used and are common to several experiments. This functional commonality between various experiment subsystems (e.g. storage, coolers, freezers, incubators, centrifuges, video cameras, and transportation systems) has led to the concept of 'common facilities', with various functions carried out by multi-user subsystems that are available to several experiments.

An example of such a subsystem would be a mobile robotic system, installed in a central aisle, which takes care of the logistic transport of samples, cartridges, tools, cameras and other equipment between the various experiment facilities, storage and other common facilities (Fig. 1).

Automation and Robotics (A&R)

Robots are basically programmable motion machines, the usefulness of which depends heavily on the total automation structure in which they are implemented. In a modern A&R concept, automation is no longer associated with rigidness, pre-defined operations and lack of interaction. On the contrary, it brings flexible interactivity and powerful modes of operation, whilst still retaining all of the classical automation benefits such as increased reliability and repeatability, parametric optimisation, and cost reduction. The Columbus Programme, being an experimental environment, is hence an ideal environment in which to use A&R.

Although an A&R system could in principle be implemented either inside or outside an experiment rack, it is most effective when installed in the central aisle, as shown in Figure 1, from where it can provide much more that just payload servicing. Its versatility then allows it to accomplish several other meaningful tasks, such as payload reconfiguration, and system-preventative and corrective maintenance (Fig.2). Although the relevance of such a robotic system may be comparable for all four types of tasks, experiment servicing in particular is of direct interest to the end user and this role will therefore be focussed upon in this article.

Experimentation using A&R techniques

The availability of multi-user and common facilities, and especially a central robotic system, has a significant impact for the end user. Instead of having to build a completely autonomous facility, the experimenter can make use of systems already available on board. These 'systems' can then be linked together by the central robot to provide a complete experiment scenario. The benefits include:

- the ability to set up low-budget experiments
- a significant reduction in payload development time and cost
- higher reliability through the use of proven systems
- greater operational flexibility because of the A&R system's capabilities
- a reduction in space hardware logistic transport.

Interactive autonomy
Of particular relevance to users is the manner in which they can execute an experiment using a robotic system. The best known modes of operation are so-called 'tele-manipulation' and 'full autonomy', but other powerful working scenarios are also possible.

In a 'tele-manipulation mode', a skilled human operator directly generates servo-level inputs by means of a master arm or joystick. The robot (or rather, the manipulator), which is remote from the operator, slavishly follows these inputs. In general, a complex sensor and communication system is needed to give the operator good feedback. This mode is commonly used in underwater engineering and nuclear servicing, where one also has only a sketchy prior knowledge of the working environment. Its use for space applications, however, is less obvious because of the communications delays and the risk of human error. Its space uses will therefore primarily be in the areas of repair and maintenance, and contingency operations.

In an 'autonomous mode', the robot receives its commands from an application program running on a computer-based controller. This is a typical mode of operation for robots in the manufacturing industry and is certainly of relevance for space applications, particularly the nominal servicing of experiments.

However, the execution of a scientific experiment in orbit often requires that its Principal Investigator (PI) remains 'in the loop' to guide the course of the experiment depending on the intermediate results being achieved — this approach is often referred to as 'tele-science'. If, for instance, a particular experiment step does not show the expected result, the PI can repeat that step or can process more samples to get better statistical evidence. In this scenario, full autonomy is not relevant, but nor is tele-manipulation a realistic alternative either.

A so-called 'interactive autonomy' mode is the solution here, being based on an autonomous program in which decision points and continuation options are foreseen to allow the PI to branch, via simple tailored commands, to an alternative path for the further course of the experiment.

The interactive-autonomy mode preserves the benefits of reliability and optimal performance, while providing the PI with all the flexibility needed to interact with the experiment. The scientist's involvement is kept at a command level, so that the PI is not called upon to exhibit special senso-motoric skills (i.e. no training is needed) and just a keyboard or mouse can be used to issue the input commands (Fig. 3).

Basic A&R control concept for Columbus
The A&R control concept for Columbus is driven by the need for system integration: various components such as robots, mechanisms, and process and logic controllers must be coherently designed and combined into a powerful programmable control system. It must have a structure that clearly allocates functions in a hierarchical fashion and allows a distributed system implementation. This is of prime importance when striving simultaneously to shorten

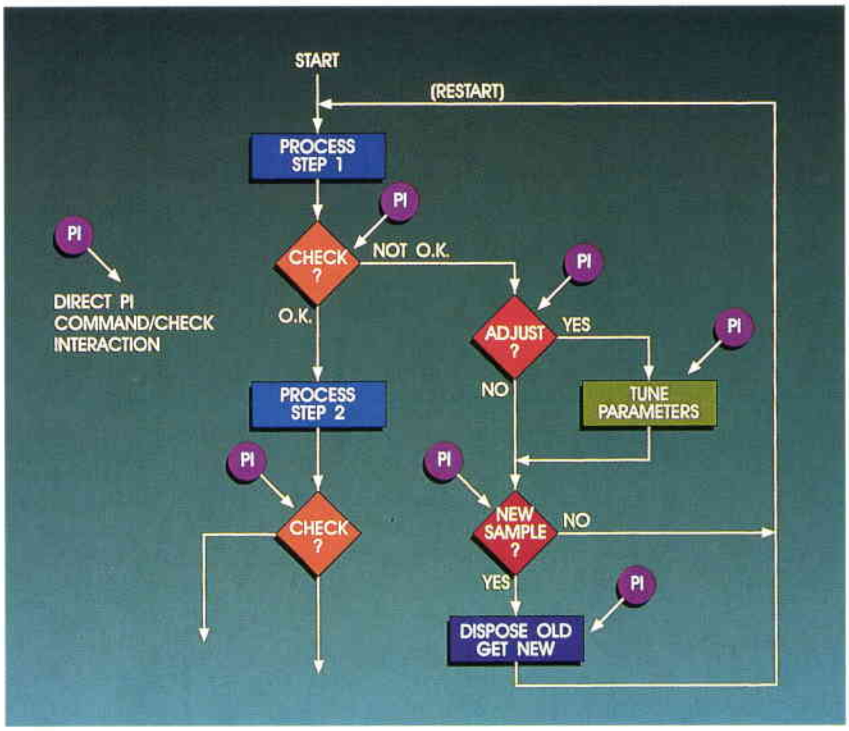


Figure 3. Example of a possible operational flow with Principal Investigator (PI) interactions

development time, simplify development management, improve module design and testability, enable easy reconfiguration and enhancement, and reduce sensitivity to possible changes in the Columbus element configuration.

Because of the prime importance of establishing a very sound control architecture for space A&R, major efforts have been expended within ESA's Technology Research Programme (TRP) to define a Control Development Methodology (CDM). This methodology makes extensive use of reference models (functional, application and operational models), which are a very efficient tool for achieving compatibility between system architectures and clear

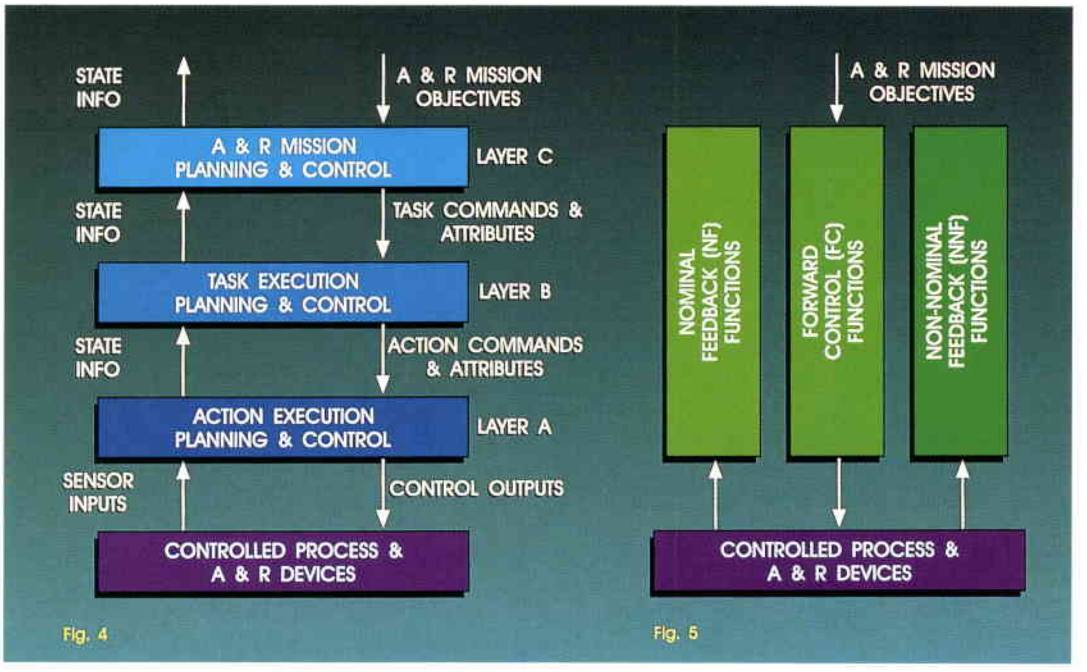


Figure 4. Vertical control structure

Figure 5. Horizontal control structure

interfaces between subsystems, and for enhancing understanding and communication within the development team.

The basic control architecture that has been developed has well-defined vertical *and* horizontal structures. The vertical structure (Fig. 4) is a three-layer hierarchical breakdown, reflecting the various steps to be performed during mission and operational analysis. The horizontal structure (Fig. 5) has three functional branches that result from generic control structures: forward control, nominal feedback, and non-nominal feedback. The combination of vertical and horizontal structure results in a matrix-type control architecture that interrelates all of the functions to be performed, within which the appropriate algorithms and logic have to be implemented that best suit a particular application (Fig. 6).

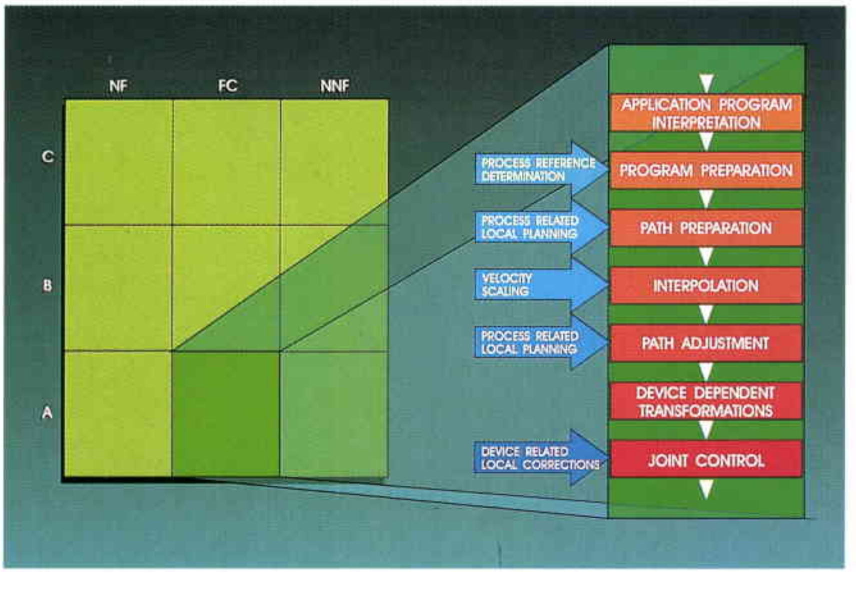


Figure 6. Example of control structure detail (FC-A)

In operating this system, there is an additional consideration in that some functions are performed in real-time during execution, or 'utilisation', while others are performed well in advance during the application program generation, or 'preparation' (Fig. 7). The functional split between these two sectors varies depending on the technology available and the actual space mission to be conducted. Since the 'preparation' is part of the ground-segment effort and because the work is done offline, efficiency can be greatly improved by shifting as many tasks as possible to this sector. This both reduces the volume and complexity of the onboard electronics needed and also minimises operational risk.

The Columbus Automation & Robotics Testbed (CAT)

The CAT is a ground-based testbed which will be put at the disposal of the Columbus experimenters, payload and system engineers and operations specialists, in order to:

- provide potential users with the opportunity to familiarise themselves with A&R and test payload breadboards
- assess and validate interface concepts between the Columbus system, payloads, A&R and other common facilities
- develop and validate A&R-specific operations procedures
- evaluate A&R capabilities and the growth potential for both Columbus modules.

In its initial phase, the CAT will serve more as a utilisation facility than a technology testbed. A 'rapid prototyping' philosophy has there-

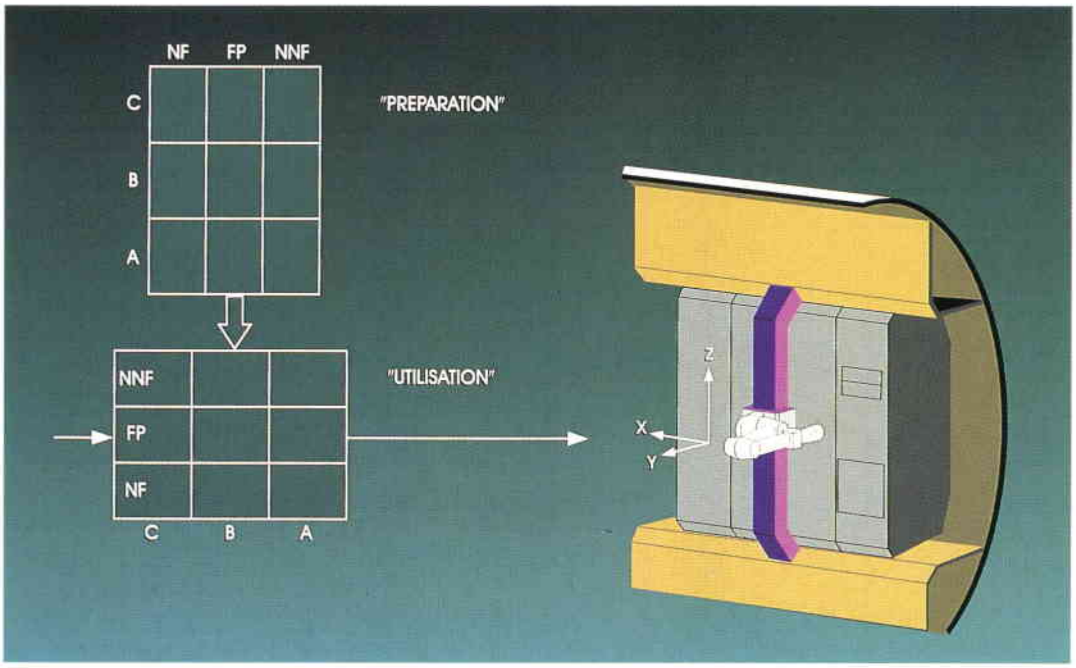


Figure 7. Overall A&R control architecture

fore been chosen for its development, whereby a full operational capability can be built up from commercial components to keep the cost, technology risk and development time as low as possible. Nevertheless, a realistic payload servicing scenario can be emulated by means of functionally representative A&R tools. The current set-up (Fig. 8) consists of the following components:

Space segment:

- Four breadboard/mock-up experiments (A, B, C, D) mounted on a selfstanding frame (E). The chosen experiments cover the most important microgravity disciplines – bioscience, materials science, and fluid science – and are representative of future Columbus payloads.
- One anthropomorphic robot arm (F) including an end-effector, mounted on a vertical mobile gantry (G). This versatile configuration with 6+2 degrees of freedom allows the emulation of any kinematic structure.
- One industrial work-cell controller (H), which represents the on-board part of both A&R and payload control. It allows the emulation of various concepts, ranging from centralised to distributed payload control.

Ground segment:

- One offline programming system (I), including simulation and graphic display. This constitutes a major part of the ground segment and is where the

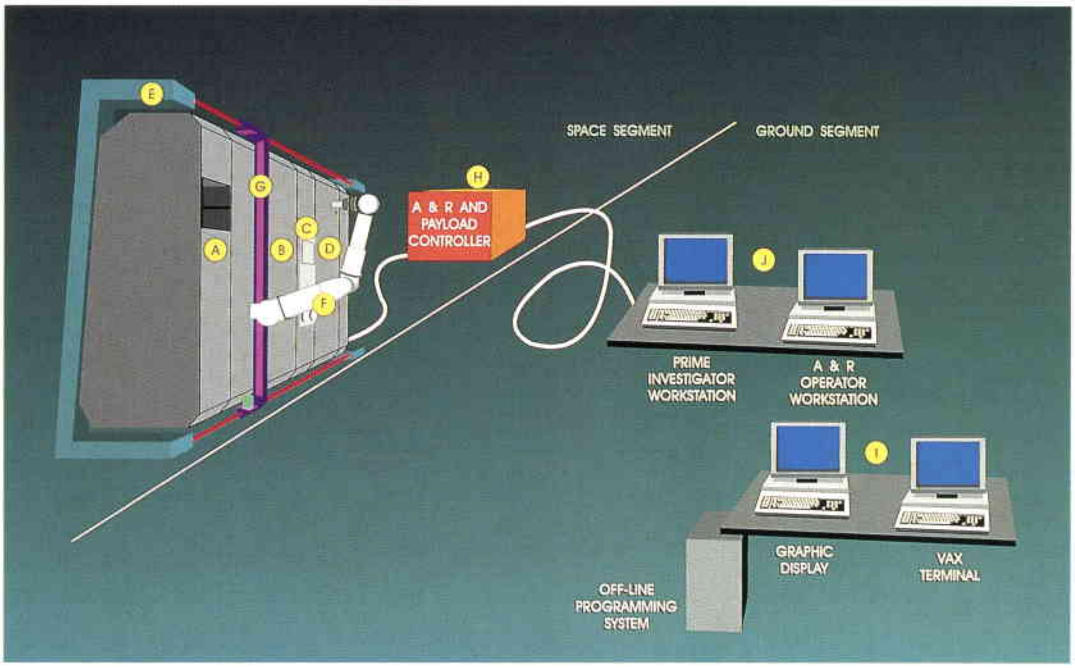


Figure 8. Overview of Columbus A&R Testbed set-up

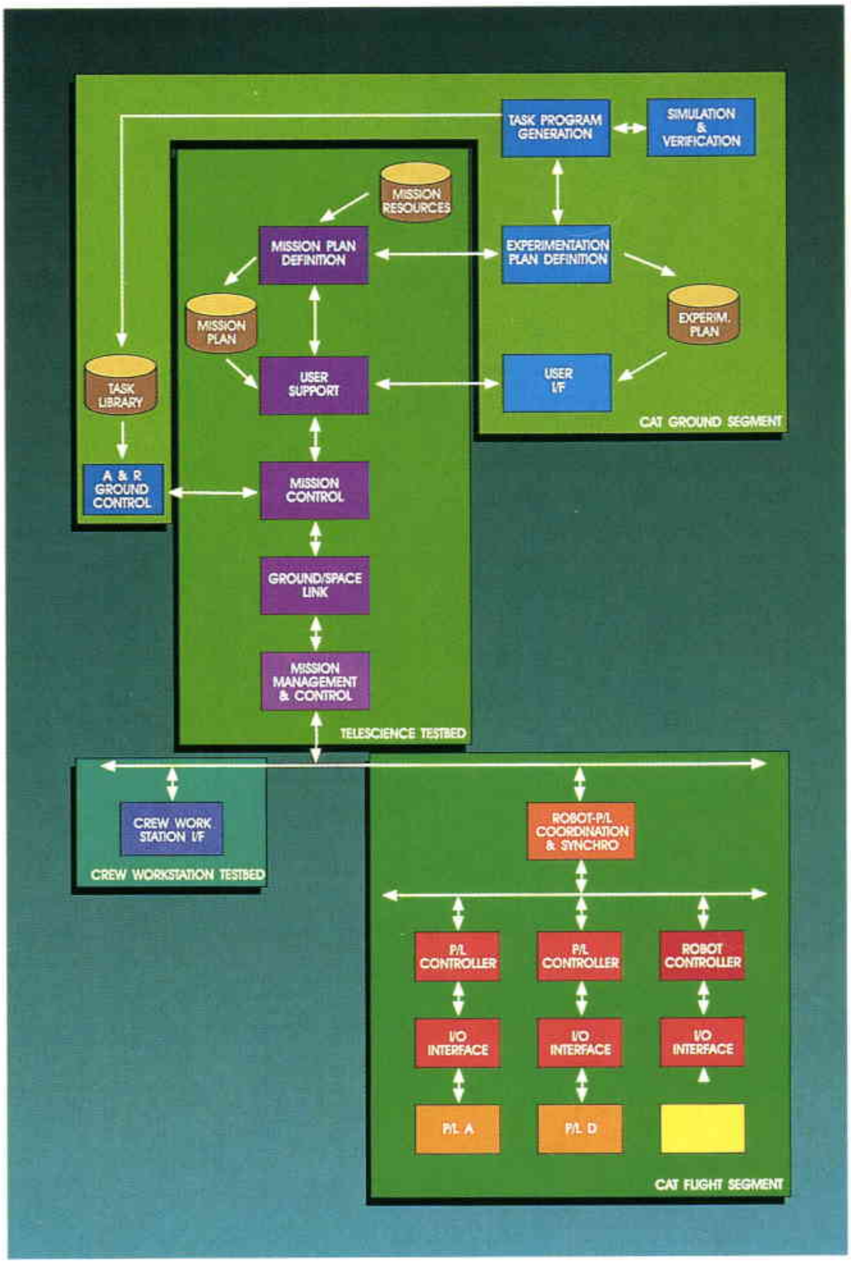


Figure 9. CAT functional architecture

application programs are developed, tested, debugged and optimised prior to execution.

- Two workstations (J) for the A&R operator (a specialist who supports the users) and the PI (the scientific end user).

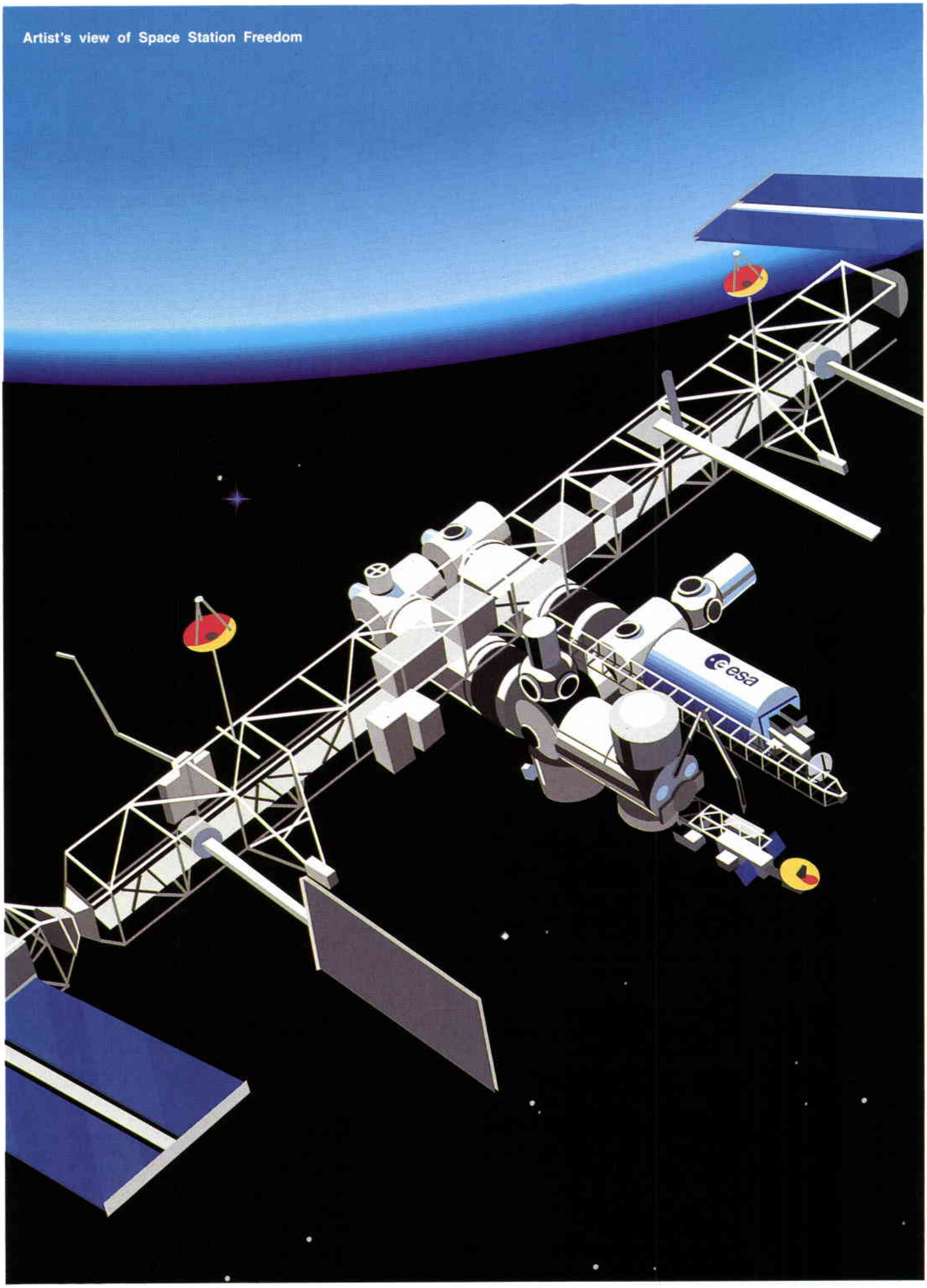
Because of the 'rapid prototyping' philosophy, a clear distinction has to be made between the functional structure of the testbed and the arrangement of hardware/software modules on which these functions are implemented (Fig. 9).

The CAT will be integrated with the Telescience Testbed (TTB), the Crew-Workstation Testbed (CWS) and later the Data Management System Testbed (DMS). This integration of the four testbeds will allow very realistic, end-to-end simulations of space experimentation scenarios.

The functions directly related to A&R are implemented in the CAT. The other functions needed to set up a complete operation scenario, such as the ground network, mission control, up/down link, data management system and crew interaction, are taken care of by the Telescience and Crew-Workstation Testbeds.

The CAT hardware and software are not representative for space, but they allow the implementation of the functional structure shown in Figure 9 with mainly off-the-shelf components, the main effort being focussed on interface development and integration.

The CAT will be fully operational at ESTEC by mid-1992. It will be gradually upgraded thereafter to further improve its fidelity and to integrate new experiments. Piece by piece, the 'rapid prototyping' philosophy will be abandoned and parts will be replaced by more space-relevant hardware and software, which is to be developed for use in a Columbus Utilisation scenario. CAT will thereby evolve into a true technology development testbed for the integration, testing and evaluation of designs, concepts, and components for our future European space-operations endeavours.



Artist's view of Space Station Freedom

Training for International Space Station 'Freedom' — A New Perspective

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The International Space Station 'Freedom' involves several unique challenges which must be addressed if an effective and affordable training programme is to be developed. Compared with past programmes, 'Freedom' will be much larger, will involve much longer stays in space for the crew, and will operate more like a ground-based laboratory than a space vehicle. Although they may initially seem insignificant, these three parameters will have a profound impact on both the structure and content of the Space Station training programme.

Introduction

The International Space Station 'Freedom' (SSF) Programme offers a unique opportunity to re-think and potentially restructure the type of training provided to flight crews. Unlike past programmes, the SSF will be much larger in size (relative to Spacelab and Skylab), will involve much longer mission duration for the crew (three to six months), and will operate more like a ground-based laboratory than a space vehicle. These three differences have important implications in terms of the most effective training approach for the flight crews.

For example, because a considerable period may have passed since the crew last trained on the ground for a particular space activity, the longer duration mission implies that:

(i) flight crews will require some type of training on-board to refresh their knowledge or skills prior to the execution of a particular task
(ii) ground-based training should focus more on techniques that promise the greatest retention, and
(iii) the programme should place less emphasis on ground-based training for tasks which is not retained as easily, since over time the investment may not be worth the effort.

Similarly, operating the Space Station more like a ground-based laboratory than a spacecraft implies a fundamental change in the knowledge and skills required by the crew. Hence the training programme that develops and maintains this knowledge and skill will have to be restructured or at least refocussed. Finally, the increased size of the SSF relative to previous space laboratories implies that more training (and therefore more training time) is required, at least from a payload perspective, since more experiments must be performed.

Crew training time – a critical resource

Few question that crew time on-board is an extremely valuable but very limited resource, largely because past missions (with the exception of Skylab) have lasted only one to two weeks. Yet, the crew's time on-board is not the only critical resource. Although it is not nearly as visible, the amount of time available for the crew to train on the ground (for on-board activities) is equally valuable and at least as limited.

As Figure 1 shows, of the two thousand or so work hours available in one year, a crew member will spend at least half in direct support of the mission, i.e. participating in the test and checkout of flight equipment and procedures, attending flight-technique/safety/readiness and similar reviews. Of the remaining thousand hours, the typical flight crew member will spend 600—650 h in formal training, i.e. either training on a simulator, on real flight hardware/software, or in a classroom. The remaining hours are spent travelling or on informal training, e.g. time the crew may use to review procedures in preparation for a formal training session.

On a yearly basis then, given the 600 or so hours available for formal training, it takes

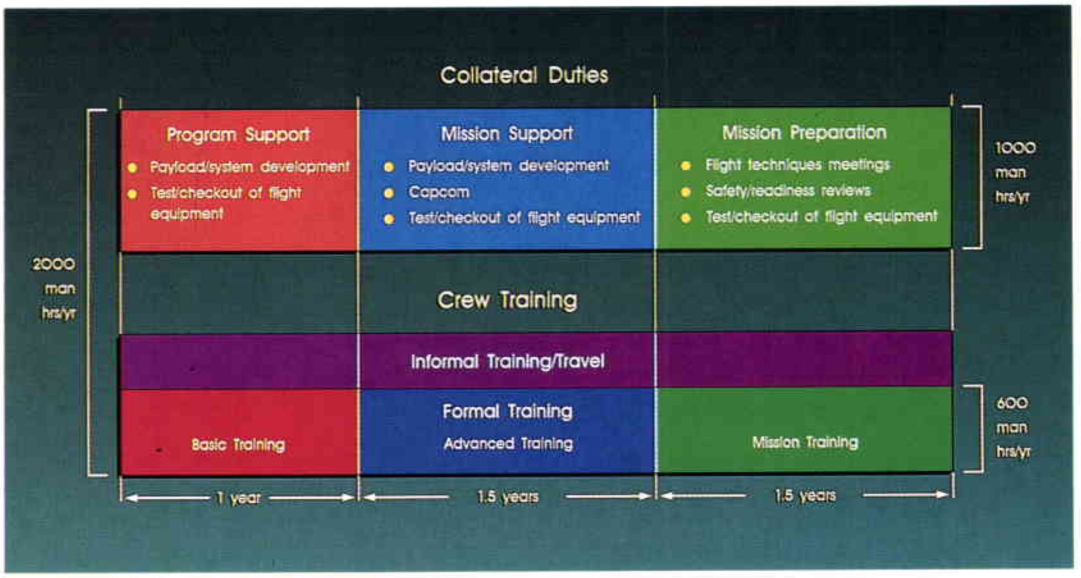


Figure 1. Typical breakdown of crew tasks/hours

approximately four years before a crew member is ready to fly. Of these four, at least one and a half are dedicated to training specifically for one mission. Two points then become clear:

(i) there are limits to the time for which the crew is available to train; in the aggregate, they spend approximately one third of their time in formal training; and

(ii) given these limits, it takes one to two years to train for a specific mission.

Ground-based training for the SSF era may also be more critical than for past Spacelab missions, in that one SSF laboratory module is roughly equivalent to two Spacelab modules, whether looked at from a facilities or a rack point of view. From the facilities viewpoint, the Spacelab-D1 mission contained six experiment facilities, whereas the Columbus Attached Laboratory will contain 12. In rack terms, the Attached Laboratory will contain the equivalent of 40 single racks of experiments/equipment, whereas Spacelab contained 20.

Since the current SSF configuration calls for three laboratory modules, the overall result is that the combined SSF research facilities will require nearly six times the training required for a Spacelab mission, if you assume that each crew member must be able to operate all experiments and that the scientific training for operations in one module is not transferable to other modules.

The bottom line then is that it could take the equivalent of nine years of training (6×1.5 years required for D1) to train for SSF payload operations, and this only for experiment operation! Training for systems operation and maintenance also needs to be taken into account.

This quick analysis indicates that it will not be possible to train the crew if the training approach for on-board SSF operations is identical to that for past Spacelab missions. Clearly, a new approach is required since the SSF programme could not support a nine-year training schedule, or even half of that. How then can one maximise the effectiveness of the crew training on the gound for the SSF training programme?

There is little doubt that SSF training will be be similar in many respects to Spacelab training; the question is more one of degree. The degree of similarity will depend largely on how much operations on-board the SSF will differ from past Spacelab missions, for in the end an effective training programme must develop the skills, knowledge and attitudes required to successfully conduct those operations.

Different operating mode for 'Freedom'

Perhaps the most fundamental difference between 'Freedom' and past space vehicles is that the SSF is intended to be a research facility that operates in space rather than a space vehicle which does scientific research. Although the distinction may seem subtle, it has profound implications for manned spaceflight operations (Fig. 2).

The working methods employed on space vehicles (and for experiments that have flown on them) have been determined in part by their close association with safety-, mission-, or time-critical operations of space-vehicle systems, operations which themselves have been directly inherited from aircraft operations. To avoid costly mistakes when conducting complex operations, procedures in the form of precise strictly-ordered steps are developed, trained for, and rigorously performed. Clearly, for safety-, mission- or time-critical operations, this approach will continue to be the safest and most effective, whether controlling a space vehicle or conducting a scientific experiment. However, for those experiments that fall outside this realm, a different mode of operation may be more advantageous.

For example, although most Earth-bound laboratory work also involves performing a series of steps, they usually serve only as a reference. The experimenter uses judgement/analysis in tailoring the experimental procedures to specific needs and responding to unexpected phenomena. To be unduly constrained in this respect could seriously hinder the experiment and potentially the progress of science. Factors that permit this on-the-spot optimisation include: the greater overall time available, and hence the slower pace possible in assessing the situation; the feedbacks available to the experimenter based on the nature of the observations and preliminary results; his basic understanding of his discipline, its inherent principles and theories; and finally, his understanding of the experiment in terms of its hypotheses, objectives, and the flexibility of controls built into it.

Another important distinction between past missions and the SSF lies in the flight durations of the vehicles (Mercury, Gemini, Apollo, Shuttle) and/or their manned payloads (Spacelab), which have been restricted to the order of days, or at most weeks. Manned experiments to be operated in this environment have therefore had long preparation times and very short operating times, in the interests of maximising scientific return. Analysis of the data gathered has usually been postponed until after the mission, and crews have rarely been afforded time to exercise their 'judgement' in response to unanticipated phenomena. On the other hand, laboratories on Earth, those that have already been flown in space (Skylab, Mir), and those planned for the future, usually operate for many months or, in some cases, many years. There is thus more available time in which to assess, analyse and respond in real time.

Another difference between space-vehicle and laboratory operations lies in predictability. In space vehicles, the optimum procedures can almost always be predicted ahead of time, even if they are a series of complex procedures that respond to a malfuction. However, because experiments by definition study phenomena that are not well understood, the optimal set of procedures often cannot be predicted until some initial results are obtained. In other words, the distinction between the two modes of working is that space-vehicle operations are 'procedures-oriented', while laboratory operations are 'discovery-oriented'. Too strict a procedural control on the experimental process can then greatly slow the progression of science.

Alternatives for reducing crew training time and increasing its effectiveness
Given these differences between operating a research facility in space and a spacecraft

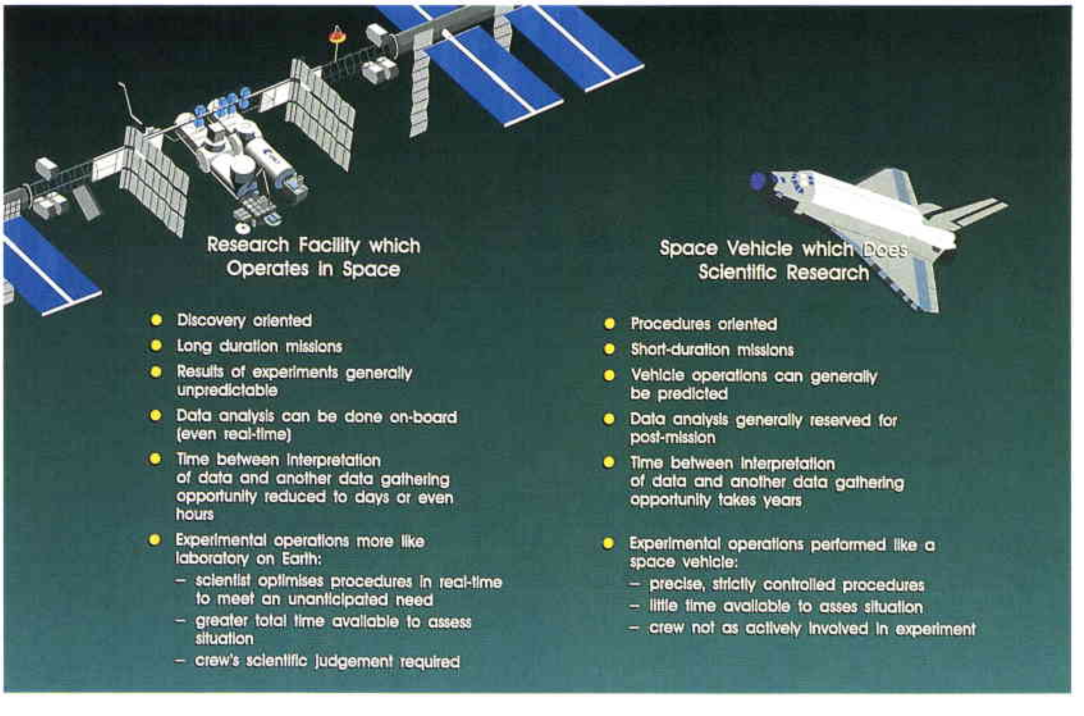


Figure 2. Operating modes for International Space Station 'Freedom' and the Space Shuttle

performing scientific research, how then can the Space Station training programme be restructured to provide the new skills, knowledge, and attitudes required and also potentially reduce today's inordinately long training times? Seven different options are examined below which can either be employed separately or in combination, ranging from placing more emphasis on experimental backgound and objectives, to employing more automated or tele-operated activities.

1. Move towards more scientific background/ objective training and less procedural training

In many respects the training that occurred for a Spacelab mission was very much like that for an Olympic event. Crews generally trained for about four years for one week of very intense activity. As a direct result of the limited time in space, the training was very much drill-oriented, as illustrated in Figure 3a.

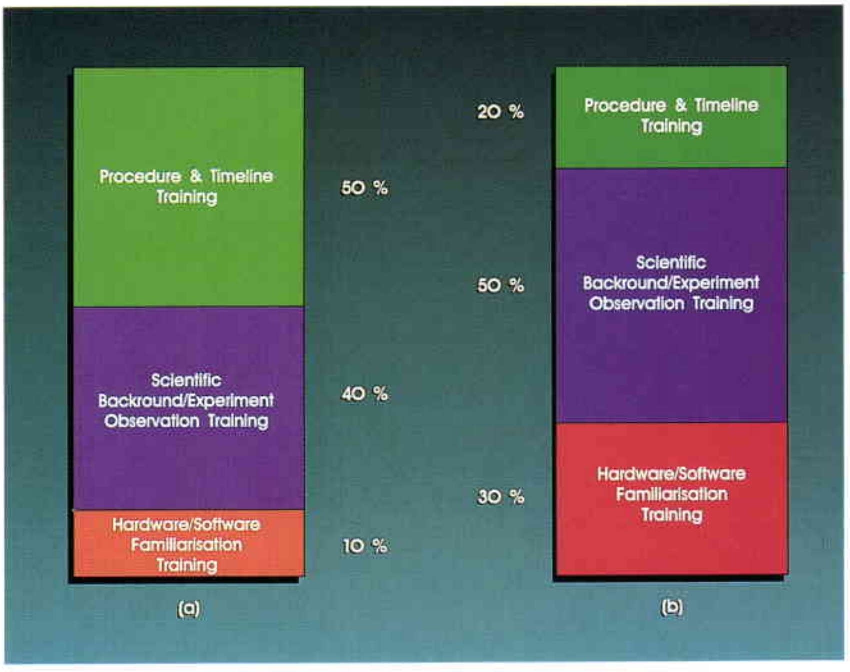


Figure 3. Crew training-time breakdowns for:
(a) a typical Spacelab mission
(b) a sample Space Station 'Freedom' mission

Crews would spend approximately 50% of their one and a half year mission-specific training period rehearsing procedures and timelines to the point where they got the most out of every minute in space. Their remaining training time was spent acquiring the scientific background and observational skills required to perform the experiments (40%), in addition to becoming familiar with the experiment hardware/software (10%).

The emphasis placed on rehearsing procedures and timelines and the lessened emphasis on scientific background observational skills made a lot of sense when the crew's time in space was very limited and thus the depth to which a crew member could become involved in an individual experiment was also limited (given the number of experiments to be performed in such a short period). Even on Spacelab, most tasks were considered time-critical and the training programme reflected it, being geared more to operating a space vehicle than working in a laboratory.

On the Space Station, however, crews will be expected to exercise far greater scientific judgement than during past missions, judgement based on their experimental observations, basic understanding of the principles and theories of their discipline, and understanding of the experiment in terms of its hypothesis, objectives, and the control flexibility built into it (Fig. 3b).

At the same time, the programme should put less emphasis on procedural training for those tasks that are not safety- or time-critical. Experimental procedures will be modified frequently (even in real time) to maximise the scientific return, and due to the longer mission duration and a correspondingly longer time being available for each experiment, the crew's performance on a minute-by-minute basis will be less important than during Spacelab missions.

Finally, there could be a considerable period of time between a crew member training for an experiment and its execution in space. Consequently, the ground-based training should focus more on techniques that promise the greatest retention, and less on those not as easily remembered. Procedures, by nature, are rarely predefined steps for executing a particular task. Why and when each step is performed is often a matter of individual preference, and as a result the sequence and rationale behind the ordering of the steps can be difficult to retain.

Thus, a heavy emphasis on procedural training may ultimately not be worth the time and effort invested by the crew member. Instead, the crews should be trained generically (i.e. familiarisation with format and nomenclature) on payload procedures and be familiar with all such procedures specific to their role, but they should not drill in them in an 'Olympic' mode.

On the other hand, experiment/observation/ scientific background training is more like the classical education that one receives for a job or profession on Earth. The background knowledge associated with a particular experiment can generally be linked to an overriding principle or theory, and is therefore much easier to retain. Similarly, the skills associated with performing a particular task, especially if they are psycho-motor skills (e.g. animal surgery or the operation of a robotic arm), are usually retained for much longer periods than procedures learned by rote.

2. Move towards more hands-on hardware/software familiarisation training

Less procedural training does not necessarily imply less hands-on training with the flight hardware and software, which is still a vital component of the crew's overall training. Although difficult to quantify, no matter how many hours the crew may spend reading textbooks or flight-procedures handbooks, nor how much time they spend studying schematics, they will not get a thorough operational understanding of a system or payload until they actually handle the real flight equipment (or a high-fidelity substitute).

This phenomenon is the direct result of a basic principle of learning: the more senses one uses in learning, the easier/faster one learns and the longer the information is retained. Handling the real flight hardware/software exercises almost all of the senses – sight, touch, hearing and sometimes even smell – and thereby allows the crew member to subsequently recall more easily the experiment's objectives and how to operate it.

3. Move towards more on-board training/ Principal Investigator interaction

Past programs have exhibited a very distinct division between the training for on-board activities and their execution. This distinct division was largely the result of the mission's short duration leaving no time for the crew to train on-board, but neither was there a driving need. Given that the average duration of past missions (Skylab excluded) was one to two weeks, the ability to maintain a high level of proficiency (i.e. skill, knowledge, attitude retention) was very high.

As a result, any on-board training that did occur on past missions was either the result of a contingency or emergency situation which was not foreseen (e.g. Palapa-Westar satellite recovery), or was sufficiently remote (i.e. had such a low probability of occurrence) that it did not warrant excessive training on the ground yet critical enough to warrant some formal means of training while on-board. The Shuttle, for example, carries videotapes on how to perform certain types of in-flight maintenance tasks should they become necessary.

Given the longer the generally longer periods between when ground training occurs and when the task has to be executed on-board the Space Station, which could be as long as six months, it is unrealistic to expect 'Freedom' crews to remain as proficient in the execution of certain tasks as they were in the Spacelab era. In the interests of productivity alone, therefore, they should be

Figure 4. ESA scientist astronaut Ulf Merbold training for the IML-1 mission

given some means of refreshing their task-related knowledge and skills. The key question is how best to achieve this, given today's fiscal environment and the need to reduce the amount of training time required on the ground.

The placing of more emphasis on background objective and hardware/software familiarisation training, and less on the strict execution of timelines and procedures, as suggested above, will not alone ensure success. It is also vital that the crews be given some time just prior to the execution of the task to refresh their knowledge/skills for that task. This will reduce both the amount of time needed on the ground to prepare the crew member, and the likelihood of error when the task is finally executed.

The mechanism for on-board training need not be sophisticated, excessively costly, or

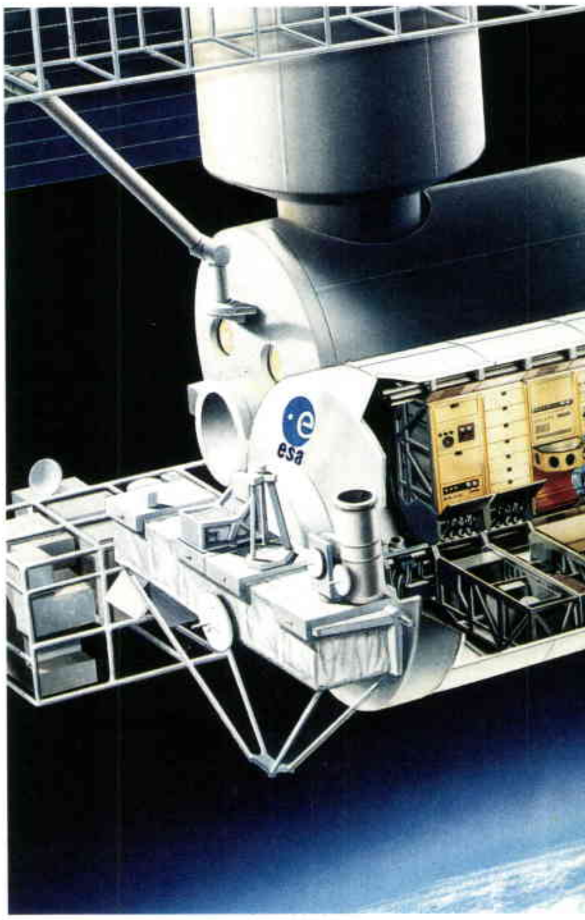


Figure 5. The Columbus Attached Laboratory

over-extend Station resources. One approach would be to just give the crew member enough time to review the experimental objectives, procedures, and any personal notes made in the course of the ground-based studies, together with the option of discussing matters with the experiment's Principal Investigator (PI).

The on-board training should not be restricted to audio communication between the crew and the ground. The ability to uplink/downlink and record video could greatly enhance crew productivity by reducing both on-board and/or ground training time, the time needed to perform a particular task, and the potential for error.

The need for such an on-board video capability was demonstrated during the first Skylab mission, when the crew had to make several EVA sorties to release a solar panel that had failed to deploy and to repair a sunshield damaged during launch. A number of the procedures were complex and therefore extremely difficult to describe in writing or in words, making the on-board training extremely tedious and time-consuming. The crew therefore spent an exorbitant amount of time in lengthy discussion with the ground and in studying the volumes of text uplinked to them, most of which could have been avoided had there been the possibility to uplink a video demonstration of the requisite procedures.

With cameras, videotape recorders, and a good audio and visual communication loop, effective and affordable training can be provided on-board comparatively cheaply.

In general, a substantial reduction in pre-flight training for contingencies can be expected through the provision of on-board training. Rather than training on the ground for all possible malfunctions, the crew can be instructed in real time in how to deal with the particular problem that has occurred.

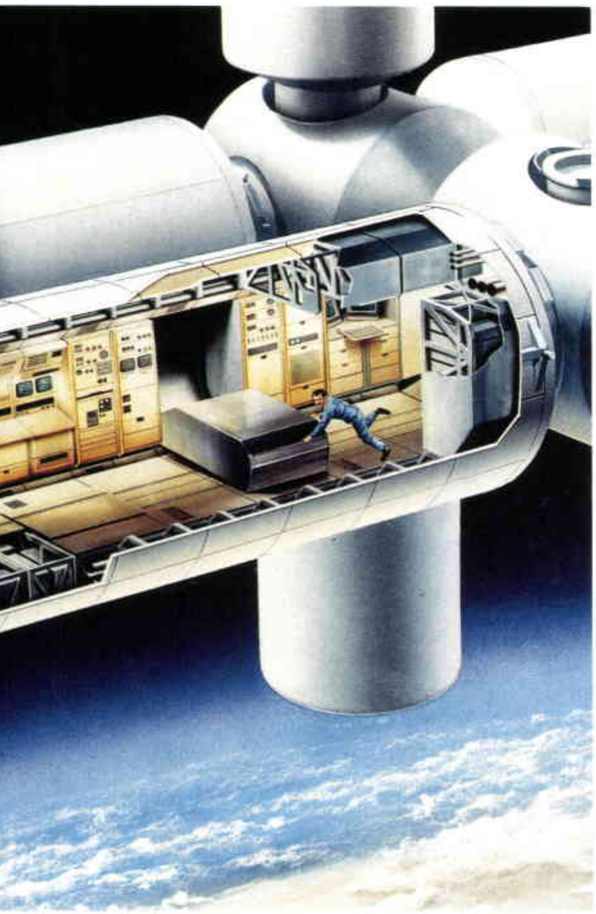
4. Move towards more discipline/facility specialisation and less cross-training

Another approach for alleviating excessive training time is to increase the degree of specialisation among crew members and reduce the degree of cross-training – whether discipline-oriented, e.g. systems (remote manipulator system, EVA, etc.), scientific (materials science, life sciences, etc.), or facilities-oriented, e.g. Anthrolab, health maintenance facility, etc.

Given the quantity and diversity of tasks to be performed on-board the SSF, it is not reasonable to expect a single crew member to be capable of performing all activities on-board to the same level of proficiency. It is also clear that specialisation improves the quality and effectiveness of the crew because it increases the knowledge and skills that the crew in toto is able to apply.

Specialisation is not new to the space industry. During past Spacelab missions, for example, Payload Specialists spent approximately 80% of their one- and a half-year training period learning how to conduct the scientific experiments to be flown, and only the remaining 20% on Spacelab and Shuttle subsystems. The Mission Specialists, on the other hand, spent a large percentage of their time learning how to operate Spacelab and Shuttle subsystems (~60%), and a smaller percentage on the scientific experiments (~40%).

In this way, the Payload Specialists were able to focus their efforts on experimental activities; their understanding of Spacelab subsystems was limited to the degree necessary to perform these experiments; their knowledge of Shuttle subsystems was limited to the degree required to be conversant and safe. On the other hand, the



Mission Specialists generally had a greater understanding of Shuttle and Spacelab subsystems, to the degree where they were able to independently trouble-shoot malfunctions, but their understanding of individual experiments was limited.

This type of specialisation, between scientific and systems expertise, has proved to be extremely effective, largely because the knowledge and skills required to operate systems differs in some respects from the knowledge and skills required to conduct scientific experiments.

Even among the Payload Specialists themselves there was a degree of specialisation, but to a lesser extent. Each one generally became an expert on a select set of scientific experiments, but in this case the division of responsibilities was based more on an equitable sharing of workload rather than by discipline. Given the shear number of experiments on the SSF, this approach may not be prudent, but it may prove more advantageous to specialise in a specific scientific discipline, thereby applying one's skills to a larger range of experiments.

Specialisation by scientific discipline can also be advantageous from the perspective that if the crew members' areas of specialisation are aligned with their educational backgrounds, considerable savings in scientific-background training can be realised.

There is nevertheless a need for some degree of cross-training due to the isolated nature of the Space Station and the limited number of crew members on-board, to ensure that appropriate knowledge/skills are available to handle contingency situations and to support those operations that require two or more crew members. Spacelab exceeded this basic requirement largely because, given the shortness of the mission, cross-training provided greater flexibility in rescheduling crew time if a particular experiment took longer than planned. The Space Station should not require as much flexibility because it will be easier to reschedule an activity for a later date, and the amount of cross-training needed should therefore be considerably reduced.

5. Employ more common crew equipment and procedures

One of the assumptions made during analysis of the amount of crew time required to train for SSF was that the operation of each module, and therefore the training associated with it, would be unique, i.e. each module would employ unique crew equipment and procedures. The reality is that many of the operations will be common to a number of modules, and as a result the training associated with these common areas does not need to be duplicated. There is thus a potential to significantly reduce the amount of training time required. This concept can also be extended to experiment operation.

Since the current concept does not limit a particular scientific discipline to one module, some of the training associated with a particular scientific discipline will overlap. Even if the facilities associated with that discipline are different (between modules), the scientific background training for each discipline should be the same.

Similarly, applying commonality between flight and ground equipment and procedures also has the potential to reduce the crew's training time. For example, the same set of tools used for maintaining equipment on the ground should also be used for performing maintenance on-board whenever possible, provided there is no unique requirement imposed by working in zero gravity.

6. Move towards more crew-friendly interfaces

One of the more effective ways of reducing training time both on the ground and on-board, in addition to increasing the crew's overall effectiveness and reducing the scope for error, is simplification of the crew interfaces. For example, the use of computer graphics that visually map the system or experiment for the crew, and which are interactive in the sense that the crew can actively control the system from the display, can dramatically reduce training time and reduce the chances of error.

7. Move towards more automated or tele-operated activities

Another means of reducing crew training time, both on the ground and on-board, is to re-allocate some tasks they would normally perform. Although automation and tele-operation offer the potential to reduce training time, it is not a one-to-one reduction. Rather, the use of automation and tele-science can reduce the crew's training time only to the degree that it minimises or eliminates the crew's involvement. Some 'automated' activities, for example, still require the crew's presence to actively monitor the system and to take over should the situation warrant.

The Shuttle's flight-control system, for example, although fully automated, is constantly monitored to ensure that it is functioning properly by the crew, who would take over if the vehicle finds itself in an environment outside its design capabilities. In this respect, the use of automation, although drastically reducing the crew's workload during routine operations, may even increase training time because the crew now has to be trained on how the automated systems works and when to override it.

Conclusion

The greatly increased size of Space Station 'Freedom' compared with Spacelab, a mode of operation that is more laboratory- than spacecraft-oriented, and the longer mission durations for crew members of three to six months, all strongly influence the structure and content of an optimum training programme. An environment that is more laboratory-oriented than past programs will obviously require knowledge and skills that are different from those trained for on past missions. More specifically, the crews will be asked to exercise more scientific judgement, based on experiment observation and a thorough understanding of basic scientific principles and experiment objectives. The training programme must therefore 'educate' the flight crews to the level where they can exercise this judgement, via more scientific-background, experiment-objective and observational training.

The longer duration mission of the SSF also means that there could be a considerable period of time between a crew member training for an activity and actually executing it. As a result, the programme needs to emphasise less that training which is difficult to retain, devise methods for retaining it longer, or allow crew members the opportunity to refresh their knowledge or skills on-board before executing a particular task.

The training programme should put less emphasis on procedural training for those tasks which are not safety- or time-critical, and more on familiarisation with flight hardware/software. Because there will be less emphasis on optimisation of the crew's performance on a minute-by-minute basis, there needs to be less 'drill-oriented' training for experiment procedures and timelines, and a greater understanding of the basic theory, experiment objectives, techniques and hardware involved.

The sheer size of the Space Station means that there will be more experiments to train for than on past missions, given a similar size of crew, and therefore anything that can be done to:

(i) reduce the crew's involvement in a particular activity, via discipline or facility specialisation and thorough automation or tele-operation
(ii) eliminate redundant or overlapping courses, by employing greater commonality), or
(iii) reduce the level of training required, via more crew-friendly interfaces

will substantially reduce the training time.

Finally, it should be noted that this article has only addressed the potential impacts on training of a longer duration mission, a change in the on-board mode of operation, and the increased size of the Space Station, in a qualitative sense. Each of the recommendations made needs to be examined quantitatively in order to determine how best to implement them within the current Space Station 'Freedom' training concept.

ESA's Future Operations System for Flight Dynamics – 'ORATOS'

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'ORATOS', the Agency's future orbit and attitude operations system, will be in use from the mid-nineties until well beyond the year 2000. Behind its design lies the experience gained in providing flight-dynamics support to all of ESA's earlier missions.

Introduction

Until recently, computing facilities were commonly based on large central computers, or 'mainframes', which were shared by many users. An example is the Comparex 8/92 computer currently used by ESOC's Orbit and Attitude Division (OAD) for both operational and non-operational flight-dynamics activities in a time-sharing mode with numerous other users at the Centre.

The advent of powerful small computers has brought about a trend towards distributed computing facilities. Within a distributed environment, most of the processing is performed by client workstations, which are powerful micro-computers, normally assigned to a single person or a specific task. Since data are frequently shared between client workstations, centralised data storage is provided by file servers, which are small computers with high-capacity disk units.

Several client workstations and one or more file servers are interconnected by a Local Area Network (LAN) to form a hardware platform. The network encompasses communications hardware and software which uses a standard protocol for inter-process communications. External connectivity and interconnectivity between different hardware platforms is provided by superordinate networks. ESOC's 'OPSLAN', for instance, provides for Centre-wide operational data exchange.

The transition from a mainframe to fully distributed hardware platforms implies a major upgrading of the software support system. The Orbit Attitude Operations System (ORATOS) described here is ESA's intended future, distributed flight-dynamics operations system.

Flight-dynamics operations systems at ESOC

The flight-dynamics discipline deals with the estimation and control of spacecraft orbits and attitudes. The expertise required encompasses mathematics (state estimation and optimal control), dynamics (orbital and attitude dynamics) and physics/engineering (modelling of the space environment and of spacecraft measurement and control systems). Due to the wide spectrum of missions supported by ESOC, which range from near-Earth (e.g. ERS-1) to interplanetary (Giotto, Ulysses), many flight-dynamics tasks are mission-specific. Flight-dynamics experts perform mission studies, prepare the mission-specific flight-dynamics support software, and operate the flight-dynamics system during critical mission phases.

Based on the experience gained from the flight-dynamics support to the earliest European spacecraft in the late sixties, the first dedicated flight-dynamics operations system was implemented in the early seventies in order to provide specialised software-development and operations-support tools and to ensure system safety and reliability during operations. An important objective of this early system was to augment the functionalities of the rudimentary mainframe operating system in use at that time.

Conversely, an objective of future flight-dynamics systems is to ensure homogeneous use of today's abundant and sophisticated commercially available software tools and to provide easy-to-use interfaces with the system which are tailored to the specific needs for flight-dynamics support. The other original objective, to guarantee operational safety and reliability, assumes even greater importance today in view of the high degree of flexibility and distributed architecture of modern computer systems.

ORATOS is intended to be ESA's standard flight-dynamics support system for the future. Once it is fully operational in the mid-nineties, it will be used in support of all future ESA missions, i.e. scientific, communications and manned-flight projects. ORATOS supports distributed processing within a UNIX operating system environment. Each hardware platform consists of several client work stations which are connected to one or more file servers to form a local network.

For development and operations support, the system features state-of-the-art Man/Machine Interface (MMI) capabilities, facilities for local and remote data access and dissemination (e.g. for spacecraft telemetry and telecommand) and tools for systems and configuration assurance and management. In the applications domain, ORATOS provides standard topical libraries of flight-dynamics functions, shells of recurrent software elements for project-specific adaptation, and standard multi-project applications facilities. Project-specific applications that cannot be based on shells will be implemented using the ORATOS development and operations support tools and the applications libraries.

The first step from the early, purely mainframe-based, flight-dynamics operations system of the seventies towards ORATOS was the so-called 'LEOP Automation System' (LEOP = Launch and Early Orbit Phase). This system was developed between 1986 and 1990 and was used to support the Meteosat-P2, MOP-1, Hipparcos, Italsat and MOP-2 missions. The level of support provided was increased from initial in-parallel operation of selected subsystems for validation purposes, to full operation of all subsystems for the later projects.

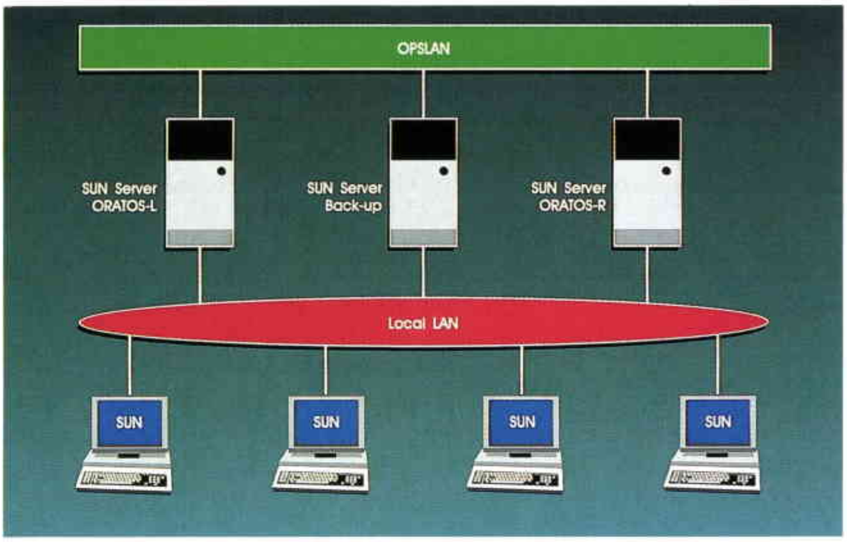


Figure 1. Hardware architecture of the ORATOS operational platform

The LEOP automation system has a centralised architecture based on a mainframe computer interconnected with workstations. The processing of applications (written in Fortran) is carried out on the mainframe. The workstations perform all graphical/alphanumeric data-display tasks (coded in C). The interfaces between applications and display tasks are via data files which reside on the mainframe and are accessed from the workstations via a communications link. The major drawback lies in the centralised architecture based on a multi-user mainframe which is not dedicated solely to flight dynamics, and whose operating system is now becoming outdated. After it was demonstrated in 1989 that workstations would have sufficient computing power to support even the (then) most demanding flight-dynamics applications, it was decided to implement, as a pilot development, a fully distributed flight-dynamics system based on a network of file servers and client workstations (currently Sun equipment).

The development of this Mark-1 version of ORATOS, known as the Pilot Navigation System (PNS), commenced with a study phase in 1990. The PNS was conceived in order to reduce the development risk associated with ORATOS by adopting an evolutionary approach. Since the move to a fully distributed workstation-based system implies a major change in the applications environment and in the interfaces between applications and data-display software, both the systems architecture and the support facilities have to be upgraded. As a proof of the new concept, the PNS provides a range of support facilities together with sample applications which will be used to partially support, for example, the Agency's ISO and Artemis projects.

Based on PNS, and making use of advanced software technologies, the ORATOS project will provide a complete range of support facilities and flight-dynamics applications. In its final setup, the system will be used to support ESA's future missions such as Cluster, DRS, the IOI, POEM-1 and XMM. ORATOS will not only be the result of an evolutionary process, but will also be designed for future evolution towards more advanced hardware and software technologies (e.g. expert systems, object-oriented techniques, and advanced database support tools).

ORATOS hardware

The ORATOS computer hardware consists of a network of powerful workstations running UNIX (Fig. 1). ORATOS will reside on several hardware platforms, each of which comprises one or more file servers, several client workstations, and the associated communications interface hardware. Client workstations and file servers within each platform are interconnected by a local network. The file servers are the focal points for mass-storage of shared data, and function as gateways for the external connectivity of the platform via ESOC's OPSLAN. Thus all external inputs/outputs (e.g. telemetry, tracking data and telecommands) will pass via the file servers. Operationally, each client workstation is dedicated to executing individual software subsystems. The overall processing power of the system can be easily adapted to changing needs by varying the number of client workstations.

Back-up of systems elements (client workstations, file servers, communications lines) is provided as necessary to ensure safe operations. The entire distributed system need not be duplicated for back-up (i.e. generally a single spare client workstation per hardware platform suffices), which results in a cost advantage over mainframe systems.

Some ORATOS platforms are dedicated to specific projects (e.g. ISO), while others will form a standard, multi-project flight-dynamics infrastructure at ESOC. The ORATOS infrastructure platforms are dedicated to development (ORATOS-D), systems integration (ORATOS-I), and launch/routine-phase operations (ORATOS-L/R). This separation between platforms for development, integration and operations is dictated by operational safety. It precludes development from interfering with on-going operations and guarantees a controlled transition of newly developed software modules into the operational suite of software.

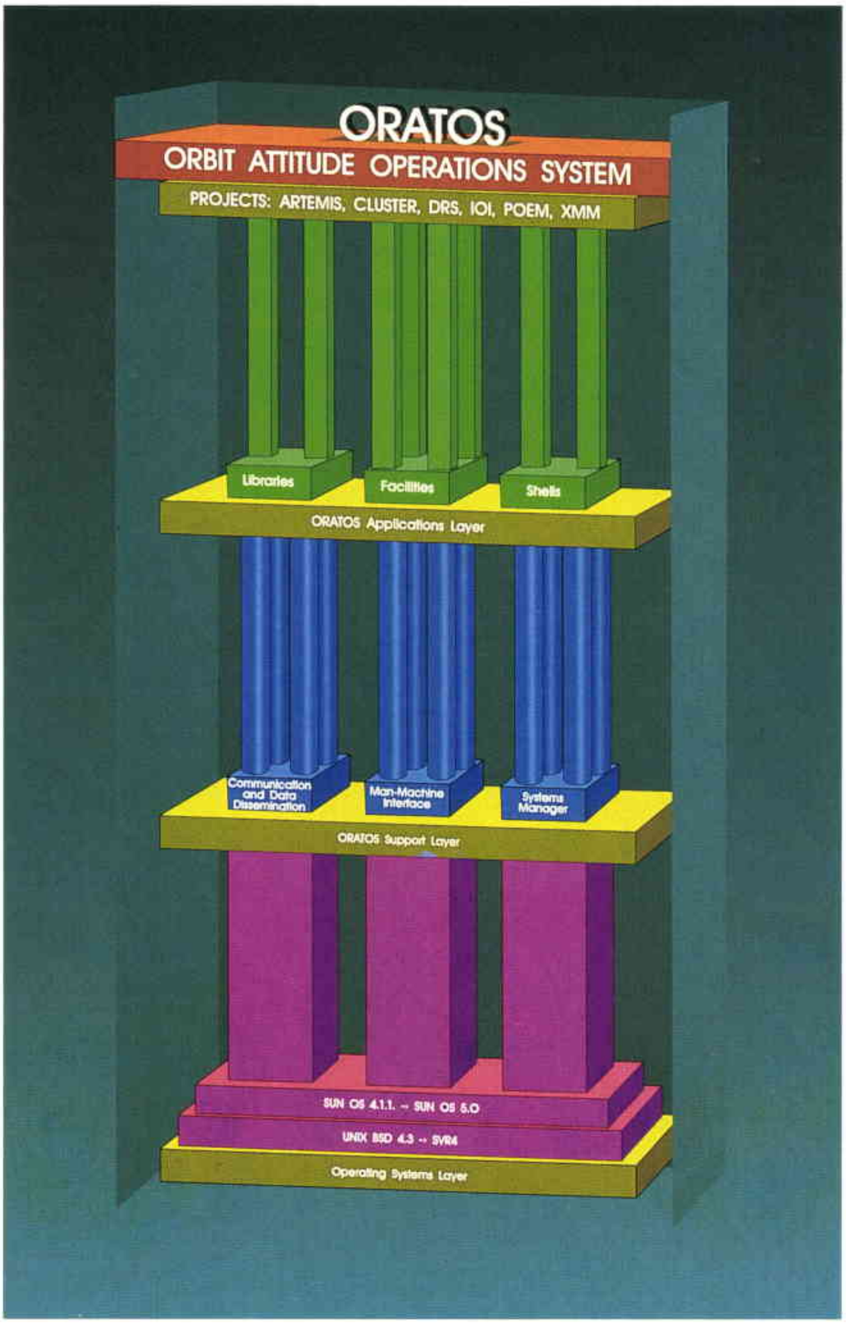
The operational ORATOS platform contains three file servers: one for critical single-mission support during launch and early orbit phases (ORATOS-L), one for multi-mission routine-phase support (ORATOS-R), and one back-up file server. Up to eight client workstations are currently foreseen within the ORATOS-L hardware subgroup, and three within ORATOS-R. The operational platform is adaptable to changing hardware requirements. ORATOS-I, the hardware environment for integration, independent testing and acceptance of new operational software, consists of a single file server and five client workstations.

ORATOS software

Architecture and implementation

The ORATOS software is structured into layers, thereby separating flight-dynamics application programs, support tools and operating-system facilities (Fig. 2). Each layer of the 'building' represents a layer of the system, and each building block represents a specific systems element (e.g. a support tool or an applications program). The layered systems architecture has been chosen to allow the upgrading or replacement of operating-systems-layer facilities with a minimum (or no) effect on the applications layer. Owing to the inherent evolutional ability of the layered architecture, the system will

Figure 2. Overview of the ORATOS software architecture



be able at a later stage to provide a more advanced and a richer set of tools and applications than are shown in Figure 2.

The software engineering for ORATOS is being derived in detail during the present Pilot Navigation System development. The current top-level assumptions are as follows:
- UNIX will be the unique operating system on all workstations.
- Remote inter-task communications will be via TCP/IP.
- The flight-dynamics applications software will be coded in Fortran 77. If another high-level language emerges as a general standard, conversion of the applications to this language will be required.

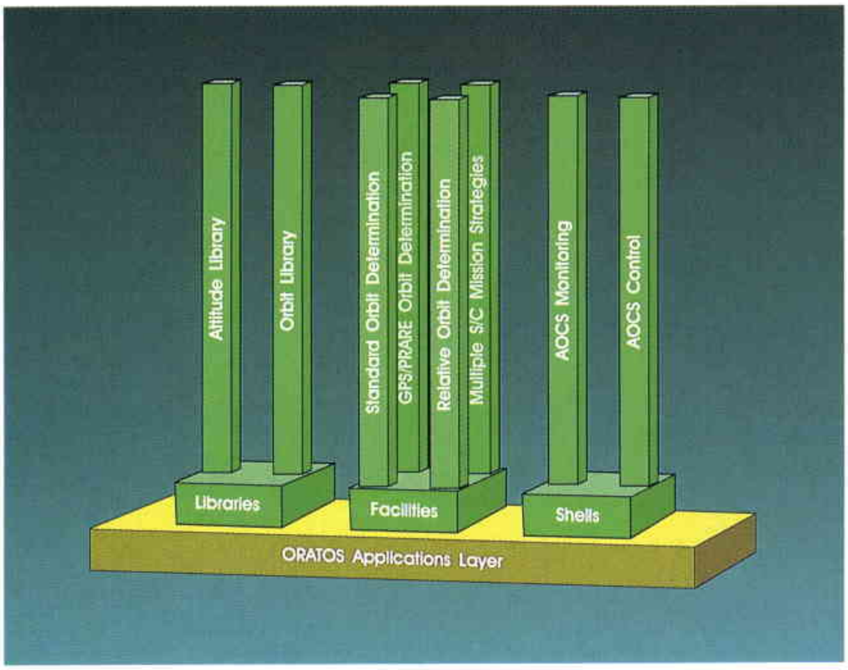


Figure 3. The ORATOS applications layer

- Lower-layer software within the support layer will be coded in C.
- The applications-software interface to the support layer will be via Fortran-callable subroutines and data files.
- The man/machine interface will be based on the X Window system, adhering to the Open Look standard implemented with the XView toolkit.

Applications layer

The applications layer, which contains flight-dynamics discipline-specific software, is the 'bel etage' of the ORATOS 'building', applications support being a central ORATOS objective. This layer contains three types of elements: *Libraries, Facilities* and *Shells.* Figure 3 shows examples of elements in each category.

Libraries contain standard applications subroutines which are reusable within and between projects and are therefore developed only once. These subroutines are grouped into topical libraries. Figure 3 shows the existing attitude and orbit libraries as examples.

Facilities are self-contained programs or program packages for multi-project re-utilisation. For these programs only the data environment differs between projects; no updates of the software are required. Figure 3 shows four example facilities:

- the Standard Orbit Determination facility, which is derived from the orbit-determination subsystem currently in use at ESOC, with the addition of an advanced man/machine interface
- the GPS+PRARE Orbit Determination facility, which supports the processing of novel measurements from the Global Positioning System (GPS) and PRARE (Precise Range and Range-Rate Equipment)
- the Relative Orbit Determination facility, which is based on measurements from relative state sensors (relative GPS, onboard CCD camera, or radar)
- the Multi-Spacecraft Mission Strategies facility, which supports coordinated orbital strategy planning and optimisation of cooperative orbital manoeuvres by several spacecraft, and is therefore applicable to missions involving formation-control of several spacecraft and rendezvous missions.

Shells are suitable for the implementation of software which is recurrent in terms of overall task structure and interfaces, but with project-specific algorithms. Unlike facilities, shells require updating of the source code for different projects. Each shell consists of a working program applicable to a specific project which is designed to localise and minimise all updates required for other projects. These updates are implemented interactively using a system which is provided as part of the shell.

Figure 3 shows two typical example shells:

- the Advanced Spacecraft AOCS Monitoring shell, which is based on the considerable hardware commonalities of the Attitude and Orbit Control Systems (AOCS) of modern three-axis-stabilised spacecraft
- the Advanced Spacecraft AOCS Control shell, which generates support parameters for modern, autonomous spacecraft AOCS systems.

A significant amount of project-specific flight-dynamics applications will still remain in the future which can neither exist as facilities nor can be based on shells. This software can also be implemented under ORATOS by making use of its applications libraries and support-layer facilities.

Support layer

The support layer, which is the 'ground floor' of the ORATOS 'building', provides all interfaces between the applications layer and the operating systems layer. Decoupling of the applications from the operating system ensures applications portability and ease of user access to systems tools. The support layer is structured into three topical sublayers: *Communications and Data Dissemination*, *Man/Machine Interface*, and *Systems Manager*. Figure 4 shows mainly those support tools in each sublayer which are prototyped within the Pilot Navigation System project.

The *Communications and Data Dissemination* sublayer encompasses all software for network-wide data access and routing. The applicable data types include telemetry, tracking, telecommand and external/internal databases (e.g. spacecraft parameters, orbital ephemerides). The applications interface to tools within this sublayer is via Fortran-callable subroutines. An evolution of the tools within this sublayer keeping pace with that of database access methods is foreseen. Figure 4 shows four examples of sublayer elements:

- the Circular Index Sequential (CISA) modules, which support read/write access to index sequential files across a network of workstations
- the Data Storage and Retrieval (DSR) system, which allows the user to store and retrieve items by name
- the Remote External Access to Circular History (REACH) files, which provide access to history files located on a remote host
- the General Data File (GDF) service, which provides a central database of rarely changing spacecraft and mission parameters. There is one such database per project, serving all the flight-dynamics applications of that project.

The *Man/Machine Interface* sublayer contains tools for controlling application programs and for the presentation of output data in alphanumeric and graphical form. Line art, block diagrams and three-dimensional/animated graphics are supported and Open Look facilities such as panels, menus and push buttons are available via the graphical window. All display or control windows are defined by an interactive tool which can be operated by the user without any prior systems knowledge. Figure 4 shows four specific tools within the MMI sublayer:

- the Applications Control Facility (ACF), which is a tool for the definition of interactive control windows and the controlling of user applications via these windows
- the Data Display Module Alphanumeric (DDMan), which is a tool for alphanumeric display of data on either form-filling or scrolling displays
- the Data Display Module Graphical (DDMg), which supports line graphics

Figure 4. The ORATOS support layer

- the Data Display Module 3D Graphical (DDM3d), which will allow three-dimensional display of a spacecraft in its actual attitude and dynamic state, as obtained from telemetry, or the display of a three-dimensional realistic view of a target spacecraft as a Hermes pilot would see it in real time.

The *Systems Manager* sublayer contains software tools for configuration and systems management and testing. Figure 4 shows four example tools within this sublayer:

- the Systems Monitoring and Control tool, which administers resources within the operational hardware platform
- the Advanced Test Harness, which automates and standardises software quality control and stores the test definitions, test inputs and reference outputs

– the Configuration Control tool, which supports security and integrity of the operational software and data
– the Scheduler, which is a tool for interactive scheduling of flight-dynamics tasks that have to be run routinely and do not necessarily require human intervention.

Operating-systems layer

A complex structure like ORATOS requires a solid foundation; currently this is SunOS 4.1.1. The next major change will be the migration to SunOS 5.0, Sun's implementation of System V Release 4 (SVR4), which is designed to be the first step towards the standard UNIX operating system of the future. Based on the operating system are three major 'pillars' of the ORATOS Support Layer: *X/Open Look*, *TCP/IP* and *NetISAM*.

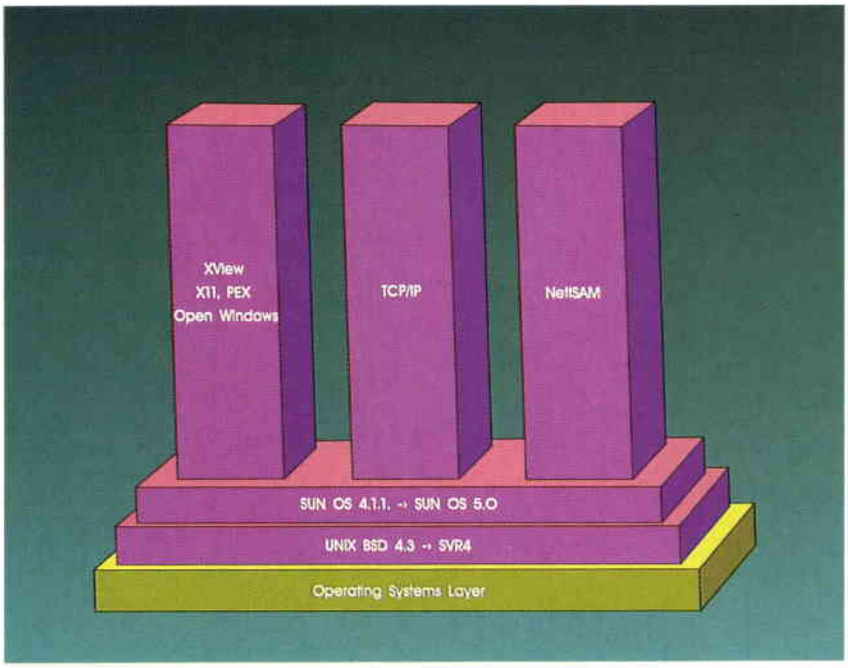


Figure 5. The ORATOS operating systems layer

X/Open Look is the backbone of the Graphical User Interface (GUI). X, which has become the industry's standard window system on workstations, is implemented on a wide variety of platforms and thus provides substantial vendor independence. The implementation of GUIs based on X is supported by the XView toolkit. This toolkit was chosen since it is a portable implementation of Open Look, which is a system-independent standard for GUIs. All of the ORATOS MMI tools are implemented in XView and conform to the Open Look standard.

The *Transmission Control Protocol/Internet Protocol* (TCP/IP), which is the basis of all data transfer and inter-task communication within ORATOS, is a standard protocol for inter-process communications on distributed network systems.

NetISAM (Indexed Sequential Access Method) handles internal low-level data access to the ORATOS platforms.

Conclusion

The ORATOS system exploits a combination of state-of-the-art computer hardware and modern software facilities and techniques. Its distributed hardware architecture, with file servers and client workstations, facilitates both adaptation to changing resource requirements and migration to future hardware.

The ORATOS prototype, known as the Pilot Navigation System, which is currently being implemented, has already validated the systems hardware architecture and software design.

Its high degree of flexibility, its ease of adaptability, and its rich and easy-to-use set of support tools, make ORATOS an extremely interesting product for implementation outside the Agency also.

Acknowledgement

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Comprehensive Satellite Operations

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A satellite is controlled by telemetry and telecommand signals both before and after its launch. The technologies used for pre- and post-launch control activities can be standardized if pre-launch operations follow a control and verification philosophy while post-launch operations primarily involve control and usage activities. Geostationary communication satellites are used to explain the concept.

Satellite operations

Satellites are launched and operated based on the requirements of their users. Satellite users can be scientists exploring the non-terrestrial environment or technologists engaged in the exploitation of space. The comprehensive satellite system that meets its users' requirements is composed of space and Earth segments; both need to be operated before and after a launch.

Following a successful launch, it may be necessary to operate a satellite in transitional orbits prior to the acquisition of the fully operational status. Such activities require operations associated with elliptical orbits and the firing of a rocket motor which transfers the satellite into an operational geostationary position. Satellite operations during launch and transfer orbits are necessary but they are ancillary to the fully operational status of an overall system that is composed of space and Earth segments. Similarly, satellite operations that occur before launch are part of the construction and test process of a comprehensive operational system and they are also ancillary. However, experiences gained from a pre-launch operation can make a significant contribution to post-launch operational activities. Before the overall system is operational, compatibility tests of the post-launch Ground Control Segment and the satellite are normally performed. This demonstrates that the methodologies associated with comprehensive satellite operations are being practiced and such activities could be extended.

Pre-launch operations

The majority of communication satellites that have been developed in Europe have been subjected to comprehensive assembly, integration and test programmes, including a simulation of all expected satellite operations for launch and orbital situations. These qualification and acceptance processes ensure that the satellite is ready for its launch and working life.

At each step in the construction of a European communication satellite, each component is thoroughly tested before it is integrated with other components. Firstly, each equipment unit is built and tested. In some cases, the units are then assembled into sub-systems, and the sub-systems are tested and then integrated on the satellite structure. In other cases, immediately after unit-level testing is completed, the units are mounted on the satellite structure, and then each sub-system is assembled and tested.

After the sub-systems are assembled and tested on the satellite structure, they are connected to form the operational satellite. The satellite then undergoes a pre-launch testing programme which simulates its launch and orbital life, including exercising on-board satellite redundancies and recoveries from emergency situations.

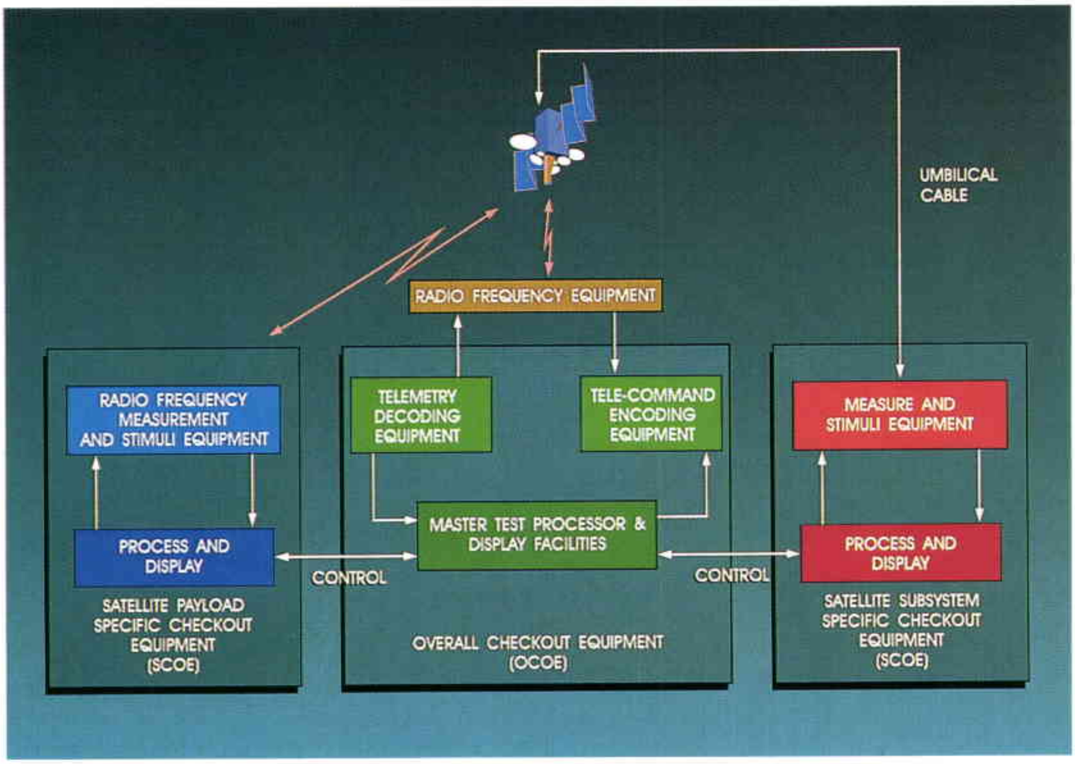
During the pre-launch testing, the launch and orbital environments must be simulated by test facilities and chambers. Electrical test equipment is used to enable and support satellite operations. (It is generally connected directly to the satellite by what is often called an 'umbilical cable'.) The electrical test equipment is deemed to be the 'checkout' equipment because it stimulates and measures satellite functions during testing operations, enabling the verification of both the satellite's operation and performance.

The 'checkout' equipment is the major component of the Electrical Ground Support Equipment (EGSE), the Earth segment that operates the satellite prior to launch.

The EGSE architecture (Fig. 1) is composed of satellite sub-system Overall Checkout Equipment (OCOE) and Specific Checkout Equipment (SCOE). The OCOE provides the overall control of pre-launch satellite operations: it initiates satellite telecommands, processes satellite telemetry data, and is the executive master of SCOE. The test conductor, a senior engineer, controls the testing of the satellite from the OCOE test conductor console, an executive work station.

Post-launch operations
After it has been launched, the satellite is controlled from the facilities of the Earth segment which are known as the Ground Control Segment. For European satellites, two facilities provide the ground control: Telemetry, Tracking and Command (TTC) stations and an Operations and Control Centre (OCC). The TTC stations make the radio frequency links between the Ground Control Segment and the orbiting satellite. The links allow the reception of satellite telemetry, the tracking of the satellite's orbit, and the commanding of the satellite. The TTC stations are operated under the executive control of the OCC. The OCC,

Figure 1. Earth segment for pre-launch operations



The EGSE configuration, or a simplified version of it, is used during all major construction activities, including the construction of most European-built communication satellites. It is also used at the launch site where, after analysis of satellite telemetry data, the EGSE gives a 'Go/No-Go' status reading that assists management in deciding to launch the satellite. From an engineering standpoint, the test equipment (i.e. the EGSE) must be more complex than the item being tested (i.e. the satellite) if comprehensive testing is to be performed before the satellite is launched.

Satellite pre-launch operations therefore primarily involve tasks that are control and verification oriented.

which houses the satellite control engineers, initiates telecommand transmissions and determines satellite orbits via the TTC station tracking facilities. The post-launch Earth segment architecture in Figure 2 shows the OCC and a single TTC station for on-station control activities associated with an overall communications system. The communication payload Test and Monitor Stations (TMS) are also shown. They enable the payload to be commissioned when the satellite reaches its on-station position. At that time , further In-Orbit Tests (IOT) can be conducted at regular periods, using the TMS facilities, to analyse payload performance.

However, the major activities associated with post-launch operations involve the control of the satellite's in-orbit position, condition and status. These tasks allow operations to be conducted to meet the user's requirements. In summary, satellite post-launch operations primarily involve control and usage tasks.

Operational commonalities

The similarities between the systems that are used to operate the satellite before and after its launch can be observed by comparing Figures 1 and 2. Conceptually, the operations should be almost identical for the control of the satellite's condition and status. Thus, common designs could be developed to suit pre- and post-launch control purposes. Realistically, the development schedules of both the satellite EGSE and the operational Earth segment may demand duplications. However, these duplications could be the result of one design and development process. The post-launch Ground Segment, which provides satellite control facilities, may need redundant equipment to be incorporated into system designs so that a continuous, 24-hour monitoring can be safely performed. This requirement for redundancy could be accomplished by technical duplications which should arise from a single design and development process. If the satellite is properly tested before its departure to the launch site, only a few engineers and pieces of test equipment would be required for launch preparations. If this is achieved, the overall 'checkout' equipment or a duplicate could be installed at the OCC.

The use of computer software that provides the same man/machine interface to the OCOE and OCC could enhance the manpower utilization. Equipment that was developed and used during satellite construction, and automatic satellite procedures could be used again for orbital operations. This methodology has been employed to some extent with the ESA Communication Satellite Monitoring Facilities (CSMF). The CSMF has employed pre-launch OCOE facilities to assist in orbit operations of all ESA communication satellites. In addition, some OCOE satellite telemetry monitoring tasks have been transferred to CSMF stand-alone workstations to aid OLYMPUS-1 operations. The co-ordination of activities associated with OLYMPUS-1 user requirements is centered at ESTRACK in Redu, Belgium, where a CSMF stand-alone workstation (Fig. 3a) is employed. This equipment receives the satellite telemetry as a pulse code modulated (PCM) signal and processes the data to give an output to users in synoptic form (Fig. 3b). Figure 4 shows a similar functional interface for operators in the control room of the Olympus-1 OCC at Fucino, Italy.

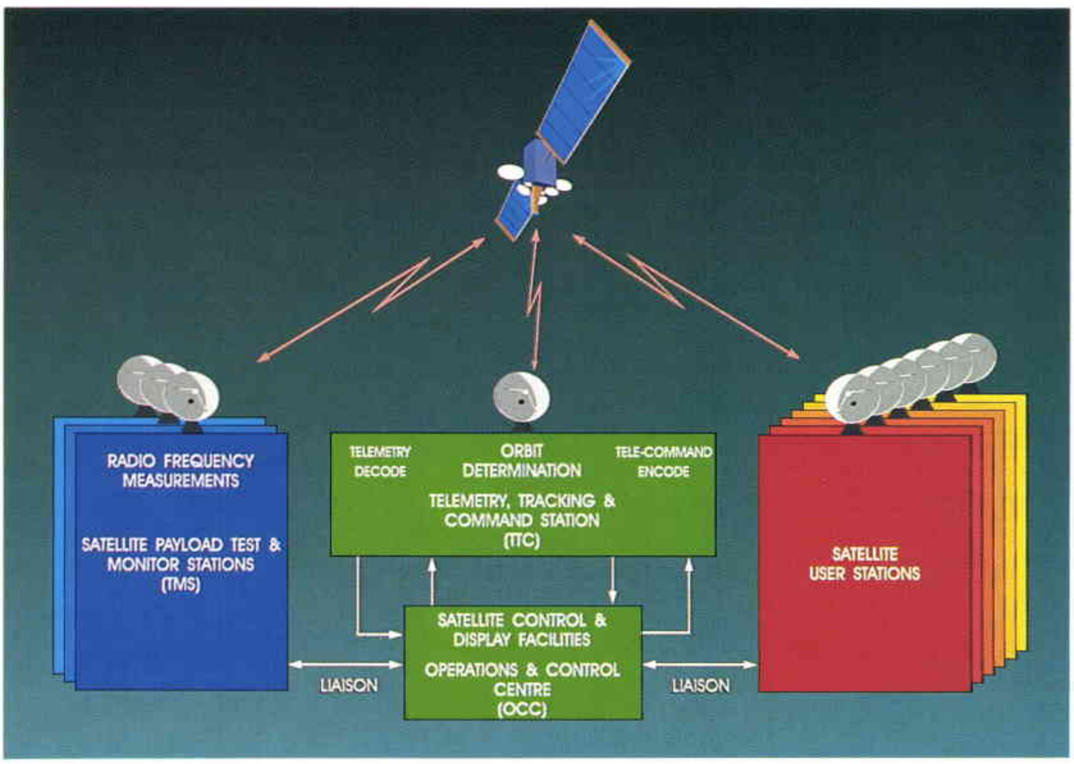


Figure 2. Earth segment for post-launch operations

In addition to the unit at Redu, the ESA CSMF and the CSMF stand-alone workstations, which are located at ESTEC, Noordwijk, have been used to support activities associated with bringing the Olympus-1 satellite back to an operational

Figure 3a. Complete CSMF stand-alone workstation

mode that satisfies user requirements. On 29 May 1991, this three-axis stabilized satellite attained an unintended spin around a single axis and moved from its geostationary position to a lower orbit in which it was drifting (for further details, see article on page 62). These changes in the satellite's orbit and attitude prevented the satisfactory operation of the on-board communication payloads and user requirements could not be met. When the satellite was returned to its geostationary position and correct attitude 76 days later, the In-Orbit Tests re-commissioned payload elements, enabling the user operations to also be re-started.

Operational teams

A common team for all spacecraft operational activities, both before and after the launch, could be set up. Members of the satellite construction team should be able to be transferred to orbital operations. This team should be supplemented by other experts who manage the TTC station operations and orbit determinations. Such action would ensure that the satellite operations experts, who gained their experience during spacecraft construction, transfer their knowledge to post-launch activities. The senior engineer responsible for satellite construction, often called the test conductor, could undertake the duties of the counterpart in the post-launch phase, the satellite controller. Even if this approach is only partially adopted, the test conductor could assist with orbital operations.

For geostationary communication satellites, the immediate post-launch activities are critical to the length of the life of the satellite. If the testing programme was properly formulated, the construction team will be familiar with the expected operations and should be able to handle effectively any unexpected in-flight condition. When the satellite is fully operational and at its geostationary location, satellite operational tasks will, if all operates satisfactorily, become routine.

Members of the Olympus-1 industrial construction team participated in the initial in-orbit tests that occurred immediately after launch. Furthermore, members of this team also participated in the recovery actions of Olympus-1. This team from European industry employed facilities for both of these activities which provided the same user interface as the ESA CSMF. Indeed, these Agency facilities employed elements that were developed by industry during satellite construction.

In summary, it should be possible for a 'core team' to be formed to handle spacecraft operations. The 'core team' must be supported by design experts during spacecraft construction and by flight dynamics experts after launch. The size of the 'core team' will depend upon the amount of expertise that is embodied in the OCOE and OCC computer software.

Comprehensive operations

The environments to which an exploitive geostationary satellite will be exposed can be closely simulated before its launch. This is especially true for a communication satellite of this type. It will be appreciated that all the conditions that an exploratory scientific satellite might meet cannot be simulated. If this was possible, the purpose of the mission

Figure 3b. CSMF synoptic picture of Olympus 20/30 GHz payload

Figure 4. Control room of Olympus-1 Operations and Control Centre

would be in doubt. Therefore the concept of developing operational techniques commencing with satellite construction for post-launch activities is more applicable to commercial application spacecraft than to those engaged in scientific exploratory missions.

Satellite pre-launch operations have been developed to enable technologies to be re-used between spacecraft development programmes. An extension of this methodology could enable the harmonization of satellite operations for pre- and post-launch activities. This would allow a significant amount of technical rationalization to be achieved for the pre- and post-launch ground control segment elements which are used for satellite control. In that case, the production of procedures could also be rationalized. This would result in comprehensive operational methodologies being established and provide a cost-effective method for satellite operations. The maximum amount of re-use of technologies for pre- and post-launch operations would reduce the need for the insular construction activities associated with pre- and post-launch ground segments. Furthermore, the requirement for verifying the performance of the post-launch ground control segment, the OCC in particular, would also diminish.

From a systems engineering standpoint, comprehensive satellite operations can produce standardization of equipment and methodologies. This would reduce duplications and enable comprehensive systems, which are composed of space and Earth segments, to be operated safely.

Acknowledgements
The author thanks colleagues who have made indirect contributions to this article through efforts emanating from CSMF activities. Such support has been from members of industry as well as ESA staff members.

The Legal Framework for the Use of ERS-1 Data

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The launch of the first European Remote-Sensing Satellite, ERS-1, has required the establishment of a special legal framework to ensure optimal management of the acquisition and dissemination of the wealth of data that it will provide. ERS-1 is currently the only spacecraft in orbit observing the Earth with a Synthetic Aperture Radar (SAR), performing global measurements and taking images irrespective of weather conditions. It is also measuring parameters not provided by any other satellite system.

The data produced by ERS-1

As provided for in the ERS-1 Programme Declaration, ESA had been entrusted with the execution of the ERS-1 Programme, including the operational responsibilities, for the in-orbit lifetime of the spacecraft, which is planned to last at least two years. During this period, the Agency itself will be responsible both for the satellite's operation and the distribution of its data, rather than leaving these activities to a user organisation once the technical development programme is complete.

Data generated by the ERS-1 payload and the products derived from them have been classified into two basic categories, based on the sensor producing them: the Low Bit Rate (LBR) and the Synthetic Aperture Radar (SAR) standard data and products.*

The SAR data cannot be recorded on-board the spacecraft due to the high data rate, and are therefore acquired only for areas within the coverage zone of a real-time ground receiving station. On the other hand, the less prolific LBR data from one complete orbit can be stored by an on-board tape recorder, before being down-linked to a ground receiving station.

As a result, ESA provides ERS-1 data to the user community on a global basis for the LBR instruments, and on a regional basis for the SAR. To expand the coverage zone of the ESA ground stations receiving SAR data (stations planned within the ERS-1 Programme), a number of ground receiving stations have been installed by operators outside the institutional framework of European space cooperation. Any such ground station operator has agreed terms of access under the ERS-1 Programme through a specific agreement with ESA.

ESA, through its own ground receiving stations and the Processing and Archiving Facilities (PAFs), performs the primary function of acquiring the global LBR data set. Some States participating in the Programme have set up, in parallel, national receiving ground stations, whose coverage may overlap that of the ESA stations, and which acquire LBR data on a 'non-interference basis'.

The ESA ERS-1 Programme therefore involves data reception, processing and distribution via the different elements of the ERS-1 ground system, namely the Earthnet ERS-1 Central Facility, the ESA ground stations, and the PAFs. In addition, any participating or non-participating State may set up ground facilities of its own and negotiate with ESA for direct access to the ERS-1 data.

The legal scenario

The ERS-1 spacecraft is owned by ESA in the name and on behalf of the States participating in the ERS-1 Programme. It has been registered by ESA under the provisions of the 'Convention on Registration of Objects Launched into Outer Space', opened for signature in New York on 14 January 1975, and which entered into force on 15 September 1976. General international law therefore recognises the Agency as the body entitled to maintain jurisdiction and control over the satellite and having the right to lay down rules for its utilisation. The ERS-1 Participating States have agreed to become responsible for ensuring the detailed implementation of

* For further details, see ESA Bulletin 65, February 1991.

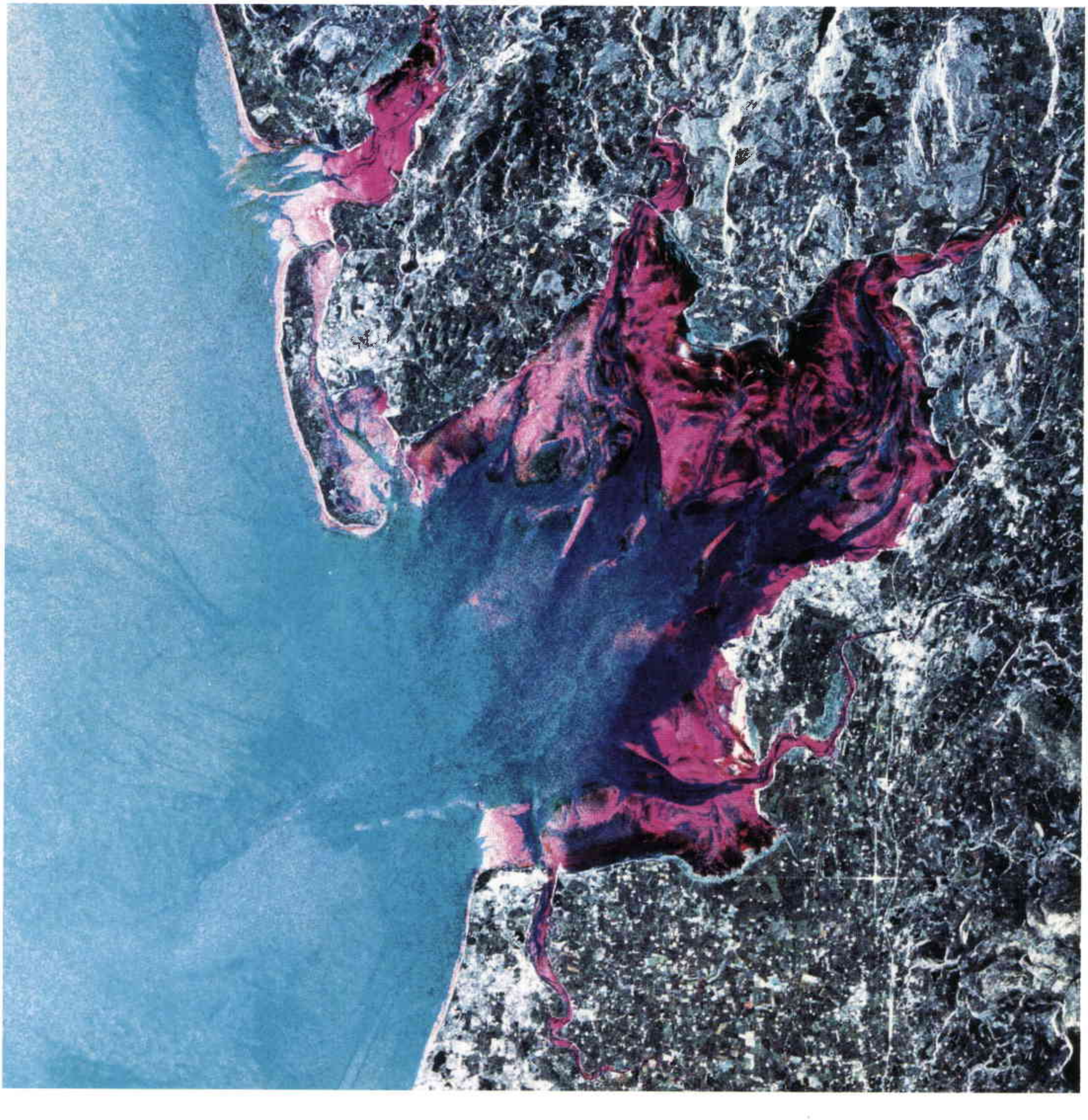
those rules through the ERS-1 Programme Declaration agreed by those States. This Declaration also spells out the conditions of access to the ERS-1 data and the method of distribution.

As these States have declared that the ERS-1 objectives are of both 'a scientific and an economic nature', the ERS-1 data policy is aimed at stimulating the broadest possible involvement of the earth-science community and, at the same time, promoting data application.

In order to fulfil its specific mandate, the Agency had to guarantee the legal basis and protection of these data. Such protection against unauthorised reproduction or copying, primarily at the distribution/commercialisation stage, must be assured for the complete range of ERS-1 primary data, processed data and derived products.

Since there is as yet no national or international piece of legislation or regulation that explicitly provides for the protection of the data and images originating from sensors on-board satellites observing the Earth, ESA has chosen to secure such protection contractually via direct agreements with its partners requesting access to the data.

Figure 1. ERS-1 Synthetic Aperture Radar (SAR) image of Morecambe Bay (UK), acquired at Fucino (I), and processed in Frascati by ESA/Earthnet Copyright © 1991 ESA



The Agency has based the ERS-1 data policy on two fundamental legal principles:

1. ERS-1 primary data will be available to all interested users on an open and non-discriminatory basis, consistent with the generally accepted 'Principles Relating to Remote Sensing of the Earth from Outer Space', approved in December 1986 under Resolution 41/65 of the UN General Assembly.

2. ESA retains full title and ownership as the holder of the intellectual property rights over the satellite-produced data. This is clearly stated and acknowledged under the terms of the various agreements that ESA has concluded with all major international agencies involved in remote-sensing activities.

The application of an ESA copyright on ERS-1 data provides the Agency with the broadest possible basis for the protection of that data, allowing it to negotiate the most advantageous terms for acquisition, reproduction, distribution and commercialisation.

The agreements

The international agreements concluded by ESA within the framework of the ERS-1 Programme represent legal commitments under which the Agency establishes a direct working relationship with each of its counterparts. ESA has identified a variety of situations corresponding to specific types of applicable agreement, depending upon the role/task of the partner:

- The non-ESA ground-receiving-station operators.
- The Processing and Archiving Facilities (PAFs).
- The Principal Investigators (PIs).

1. Non-ESA ground-receiving-station operators

A network of agreements with many ground-receiving-station operators constitute the backbone of the system (see Table 1), providing for the activities of acquiring, processing, archiving and distributing the ERS-1 SAR data for additional coverage in the interests of the operators concerned and for the benefit of the overall ERS-1 Programme.

Within this special legal framework conceived to allow a smooth implementation of the Programme objectives, the various agreements list the rights and obligations of both the Agency and the partner concerned. The general principle is that data reception, archiving and distribution activities are carried out by the ground-station operator under ESA's supervision and control, whilst all necessary technical information, instructions and in-situ assistance will be provided by ESA staff for the duration of the agreement.

At the same time, because of the pre-operational character of the ERS-1 satellite, ESA does not guarantee the suitability of the data for any particular purpose. Neither is it liable for consequential loss brought about by the use of such data, nor can it bear liability in the event of any damage or loss of revenue arising directly or indirectly from a malfunction or interruption in the data transmission for whatsoever reason.

A complete archive of all SAR data acquired outside ESA's own SAR coverage area is also requested by the Agency from the ground receiving stations. If this proves too onerous, the station must make its data holding available to ESA for possible inclusion in the PAF archive on a cost-reimbursement basis. This ensures that the Agency will have access to the maximum possible amount of data available from its satellite.

Table 1. Network of International Agreements allowing acquisition and distribution of ERS-1 data other than from ESA ground stations

Ground Station Operators	Station	Signed
Norwegian Space Centre	Tromsø, Norway	19 July 1991
Department of Energy, Mines and Resources of Canada	Prince Albert, Gatineau, Canada	5 August 1991
British National Space Centre	West Freugh, Scotland	30 August 1991
DLR	O'Higgins, Antarctica	Approved but not yet signed
Centre National d'Etudes Spatiales	Aussaguel, France	Approved but not yet signed
National Aeronautics and Space Administration	Fairbanks, Alaska	14 January 1986
Australian Centre for Remote Sensing	Alice Springs, Hobart, Australia	26 August 1991
National Remote-Sensing Agency of India	Hyderabad, India	26 June 1991
National Space Development Agency of Japan	Hatoyama, Kuamoto, Syowa, Japan	20 June 1991
Brazilian Commission of Space Activities	Cuiaba, Brazil	Approved but not yet signed

The ground-station operator can process the SAR primary data under the technical provisions of the Agency and extract, use and distribute the data from the station archive, only for the purposes of the licence for the production, reproduction, distribution and sale that is granted in the Agreement.

In that Agreement, each station operator is granted a non-exclusive licence for the reproduction, distribution and sale of the data to the users who are resident of the country hosting the station. The station operator must provide ESA with a copy of the model contract and conditions of sale it will use for the distribution of the data and analysed information.

All the packaging of ERS-1 data and analysed information distributed or sold must show: 'Distributed by (name of the station) . . . under an ESA Licence'.

2. Processing and Archiving Facilities (PAFs)

Each of the four Agreements concluded between the Agency and a national entity managing a PAF (Table 2) defines the tasks delegated by the Agency for the activities of archiving, retrieval, processing and distribution of data from the ERS-1 mission. These entities will follow the programmatic instructions, procedures and planning established by the Agency, which has also adopted a general scheme to harmonise the activities of the relevant British, French, Italian and German facilities.

The main undertaking of each PAF entity is to maintain and operate the equipment necessary to supply the Agency, and the users on behalf of the Agency, with ERS-1 data products and services on a timely basis. The ERS-1 data archived by the PAF will remain the property of the Agency while being accessible to all interested users on an open, non-discriminatory basis, in accordance with the general ERS-1 data policy adopted by the Agency. The users will request and agree on standard terms of access to data with the Agency, which will then establish procedures for the distribution and provision of data with the PAF concerned.

The PAFs will also provide the Agency with a catalogue of archived data and information relevant to the system implementation. The Programme objective is to maintain ERS-1 archived data at each PAF for at least ten years after the end of the ERS-1 spacecraft's active lifetime.

Table 2. Agreements concluded with national entities managing a Processing and Archiving Facility (PAF)

France	IFREMER	Brest
Germany	DLR	Oberpfaffenhofen
Italy	ASI	Matera
United Kingdom	BNSC	Farnborough

3. Principal Investigators

On 20 May 1986, the Agency issued an 'Announcement of Opportunity' for the submission of proposals for possible scientific or operational evaluation of ERS-1 data. Many valuable proposals were submitted by institutes and individuals responsible for related activities, and so far 267 of them have been granted 'Principal Investigator' (PI) status (Table 3).

A special form of Agreement is concluded on the acceptance of standard terms and conditions for the utilisation of ERS-1 data by the PI requesting data access (Fig. 2).

Table 3. Distribution by nationality of the Principal Investigators having access to ERS-1 data

Australia	21
Austria	2
Belgium	3
Brazil	1
Canada	26
Denmark	3
Finland	2
France	18
Germany	24
Iceland	1
India	7
International	4
Italy	7
Japan	13
New Zealand	1
Norway	9
Spain	2
Sweden	3
Switzerland	1
The Netherlands	7
UK	36
USA	76
TOTAL	267

TERMS AND CONDITIONS FOR THE UTILISATION OF ERS-1 DATA

BY THE PRINCIPAL INVESTIGATOR

All references herein to "the Agency" shall be deemed to mean the European Space Agency and a "Principal Investigator" (P.I.) is the user of data derived from the ERS-1 satellite payload selected in response to the Announcement of Opportunity for ERS-1 (A.O.), issued by the European Space Agency on May 20, 1986, as identified in the front page herein.

The P.I.'s activities shall be deemed to cover the total time period of use by the P.I. of ERS-1 data, herein defined as the "investigation", and the subsequent preparation of results concluding with the submission of a final report to the Agency.

The P.I. shall fulfill his commitments as herein specified without charge to the Agency and shall develop and provide results of his investigation using ERS-1 data in accordance with the A.O. and pursuant to the following terms and conditions which shall prevail in case of conflict with any other published document or correspondence :

1. For the purpose of this document, ERS-1 data refers exclusively to payload data originating from the Active Microwave Instrumentation (AMI) and Radar Altimeter, plus associated auxiliary information. Data originating from ERS-1 instruments selected through the A.O. (i.e. from ATSR and PRARE) shall be handled in accordance with the arrangements between the Agency and the Instrument provider.

2. The Agency will use its best efforts to provide the agreed amount of data free-of-charge to the selected P.I. for the successful completion of the investigation, taking into account scheduling and processing constraints both at the satellite and the ground segment level.

   The Agency will deliver the requested data sets to the P.I. in separate instalments, upon which the Agency reserves the right to decide.

3. All costs associated with the execution of the investigation shall be borne by the P.I.

4. The P.I. shall report without delay to the Agency on the following occasions :

   On delivery of data by the Agency, the P.I. shall report back that the data have been received and, within a delay of one month, that the data received were in a usable form, in the correct format, and could be correctly read at the P.I. facilities.

Figure 2

Each PI is granted a limited amount of data free of charge, for the exclusive purposes of the investigation agreed by ESA. They have to comply with the general legal requirements of the Programme in handling the data (ESA copyright policy, internal use only, no reproduction or distribution, reporting of results and submitting for wide publication, participation in ESA-organised workshops, etc.).

4. Other uses
Similar terms and conditions of access to ERS-1 data are also underwritten by different entities involved in other roles planned under the ERS-1 Programme:

- institutes implementing pilot/demonstration projects approved by the Agency
- nationally nominated centres for LBR fast-delivery services
- meteorological services in Participating States, including Eumetsat and ECMWF, cooperating with ESA in the assessment of the operational value of the LBR fast-delivery service, as well as in such activities as ice forecasting and pollution monitoring
- media companies wishing to publish ERS-1 data for public-information purposes.

ESA copyright and licences

In order to be able to enact a protection scheme, the copyright and licence concepts have been applied with the meanings known through legal experience. This implies that anyone signing an ERS-1 Data Agreement acknowledges ESA's copyright on all ERS-1-produced data, and commits to respect, and ensure the respect of, the Agency's rights.

The relevant provisions in the Agreements state that the ground-station operator will mark all ERS-1 data and analysed information with '© 'ESA (year of reception)'; the operator will display on all ERS-1 data and analysed information processed by the station, the mention of the trademark that ESA has registered 'ERS (R-)', plus the mention of the entity originating the final data product.

Of course, ESA's ownership and copyright does not prevent the recognition of copyright in favour of the ground-station operator or a third party in respect of original activities to add to and incorporate in the data product further sources of information, to produce analysed information that will result in a different and more elaborated product, thereby making the final product fall under their own copyright title.

In order to further guarantee ESA's right, users have agreed to the additional responsibility of informing ESA in writing whenever they learn that the Agency's copyright interests and trademark are being used unlawfully by a third party. ESA will then take the necessary legal action to protect the interests of the Participating States.

The overall philosophy of distribution envisages that ERS-1 data will be publicly available in a controlled way, through licence-to-use agreements granted by ESA, as the owner of the ERS-1 data. In particular, the Agency prefers to grant several non-exclusive licences in the belief that this will lead to more users ultimately having access to the ERS-1 data products.

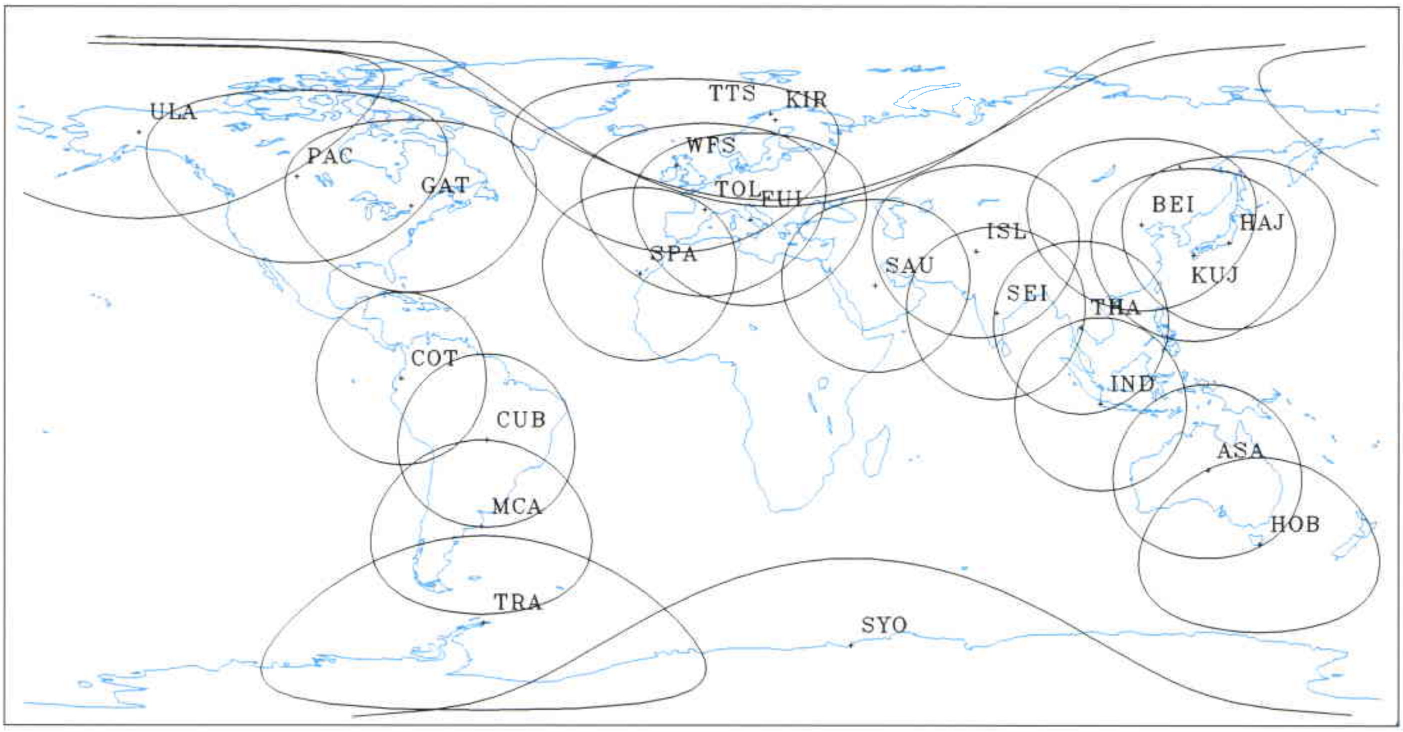
In view of the substantial capital cost of developing the ERS-1 system and the undoubted commercial/economic value of its data products in a variety of fields, ESA has decided on a uniform and consistent pricing policy for all ERS products from the outset, irrespective of the facility or supplier which generates them. This policy may change over time to reflect possible developments in the commercial values of the products.

The pricing policy also depends on another traditional legal concept used in the commercial environment, namely that of a royalty being associated with each unit produced. The basic idea here is that users from ERS-1 Programme Participating States will not be charged a royalty on the price of an ERS-1 standard product, in recognition of the fact that their country has financed the ERS Programme. On the other hand, foreign station operators will credit ESA with a royalty fee for each ERS-1 product item distributed or sold to a user from a non-Participating State.

As regards onward distribution, whenever the licensee of an ERS-1 primary or processed product wants to grant a sub-licence of use for that product to a third party, they must credit ESA with the royalty fee applicable for the standard product.

Distributorship

The Agency has also retained the right to distribute all ERS-1 data worldwide through a



ESA:	Fucino (I) Kiruna (S) Maspalomas (E)	Canada:	Prince Albert Gatineau	India:	Hyderabad
Australia:	Alice Springs Hobart	Ecuador:	Cotopaxi	Japan:	Hatoyama Kuamoto Syowa
Brazil:	Cuiaba	France:	Aussaguel	Norway:	Tromsø
		Germany:	O'Higgins	UK:	West Freugh

Figure 3. The ERS-1 data receiving stations and their coverages

commercial distributor specifically appointed under an ESA Contract. This distributor, engaged as an 'industrial partner', has the necessary infrastructure and commercial expertise to undertake all the marketing and promotional efforts necessary for optimal exploitation of the ERS-1 data products.

This idea of appointing a distributor is consistent with the aim of developing the commercial remote-sensing data market, which the ERS-1 data products should help to stimulate, and with the obligation to guarantee fair and open competition to all value-added industries interested in ERS-1 data distribution.

The ESA-appointed distributor is an international consortium of companies with skills in the marketing, promotion and distribution of space remote-sensing data, for worldwide reproduction, distribution and sale (SAR and LBR standard products). This consortium has been formed by Eurimage, Spot Image and Radarsat International. Each of these companies is also granted a non-exclusive sub-licence for data distribution at regional level, but in parallel with the rights awarded by ESA to ground-receiving-station operators for their respective territories.

Conclusion

Experience has shown that today an advanced earth-observation satellite programme such as ERS-1 makes sense only if supported by an infrastructure that allows efficient use to be made of the available data by all of the user communities concerned. Maximisation of the exploitation of the ERS-1 mission, the broadening of participation in it, and the strengthening of its effectiveness can be considered substantial achievements made possible by the establishment of the legal framework that has been described. This framework will undoubtedly be taken into consideration by the international community when preparing for multilateral remote-sensing activities and will also serve as a reference point when formulating a long-term policy for future generations of satellites observing the Earth.

In Brief

ESA Staff Member on Spacelab Mission in 1992

NASA recently appointed Dirk Frimout as payload specialist for the Atmospheric Laboratory for Applications and Science (ATLAS-1) Spacelab mission (STS 45), which is scheduled for flight in early 1992.

Frimout, an ESA staff member of Belgian nationality, will replace Michael Lampton of the United States, who has withdrawn for medical reasons. Frimout was named the alternate payload specialist in 1985, upon the proposal of the Belgian Institute for Space Aeronomy.

The ATLAS-1 Spacelab pallet-only mission, in which Frimout will participate, is the first in a series of Spacelab missions that will perform investigations in the fields of atmospheric science, solar physics, space plasma physics, and astronomy. The United States, Belgium, France, Germany and Japan will provide experiments for the mission. One of the main objectives of ATLAS investigators will be to study the Earth's interaction with the Sun over an 11-year solar cycle.

Frimout, 50, has been with ESA since 1978. Before his appointment to the Spacelab mission, he was Spacelab Mission Manager, responsible for the ESTEC Microgravity and Columbus Utilisation Division's Spacelab activities. He also participated in the development of the Microgravity Measurement Assembly, an experiment planned for the Spacelab D2 mission.

Since 1984, he has been responsible for ESA's support of four of the twelve experiments flying on the ATLAS-1 mission. He is also co-investigator for one of those four experiments, the Grille Spectrometer. All of the experiments are reflights from the Spacelab 1 mission of 1983.

From 1984 to 1989, he was involved with parabolic flights, sounding rockets (Texus and Maser), and with the Solution Growth Facility, an experiment to be flown on EURECA.

Frimout holds a Ph.D. in Applied Physics from the University of Ghent in Belgium.

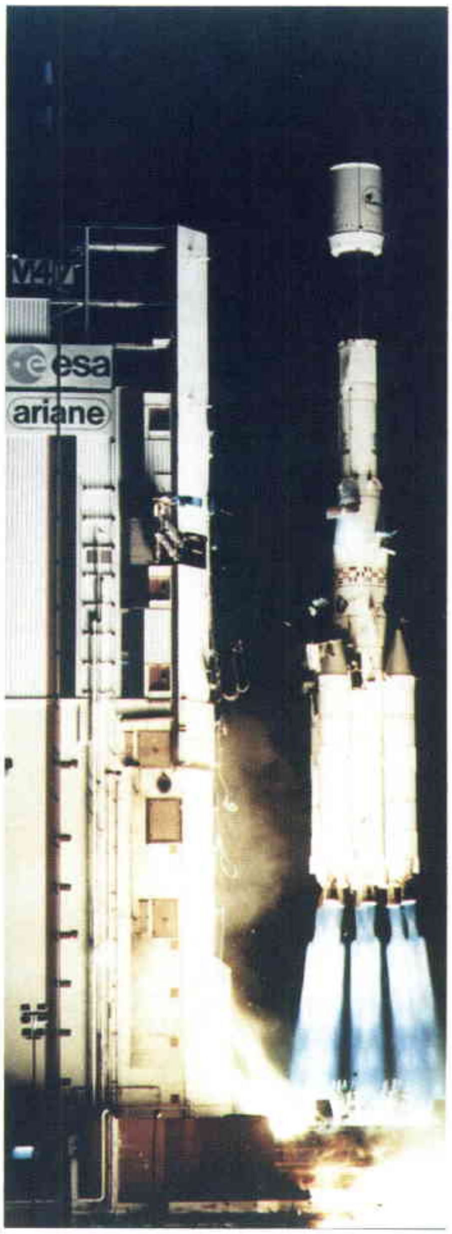
Dr. Dirk Frimout

Launch of 47th Ariane

The 47th Ariane vehicle was launched successfully from the Kourou Space Centre, French Guiana, on 29 October.

Its payload was the Intelsat VI telecommunications spacecraft, which weighed 4259 kg. The vehicle was an Ariane 4 type with the 44 L configuration, i.e. with four liquid strap-on boosters.

After a propulsion phase of 17 min 50 sec, and a smooth flight, the satellite was properly separated and injected into orbit.



New Biological Experiments in Space

The Biobox, a multi-user facility for performing a wide range of biological experiments under microgravity conditions, is currently being developed by a team of European companies for ESA.

This modular life-sciences payload consists of an incubator, which will contain the experiments, and an electronics unit. The environmental conditions within the incubator, such as the temperature profile (from 4° to 37°C) and the atmosphere, can be controlled. The conditions are continuously recorded and the results are stored on a 1-megabyte memory card. Unlike similar payloads developed for Spacelab, such as the Biorack and Biolabor, the Biobox permits for the first time complete control over environmental conditions throughout the experiment, from the placement of the biological material in the laboratory, through all transport operations and the space flight, to the return of the material to the laboratory.

From a biological point of view, space flight affects two environmental conditions: gravity is reduced and radiation is increased. The Biobox will be used to investigate the impact of these changes on biological systems. Two types of experiments will be conducted: experiments performed under microgravity conditions and increased radiation, and experiments performed in a 1-g centrifuge with increased radiation. The results of these flight tests will be compared with those of experiments conducted simultaneously on Earth under 'normal' conditions, i.e. 1-g and natural radiation.

In the Biobox's first mission, the behaviour of bone cells under microgravity conditions will be investigated. The results will be useful for extended space flights. During such flights, the astronauts' bone substance is drastically reduced because of the lack of stress on the bones.

The Biobox can also be used for experiments in other areas such as protein crystallisation, and the study of plant metabolism and genetics.

The Biobox will first be flown on board the Bion 10 mission which will be launched in November 1992 from Plesetsk, north of Moscow. The mission is part of the Soviet Biokosmos programme. The Biobox will be in a Soviet Photon-type recoverable capsule (Bion), and will remain in orbit for 14 days. It will be one of three major payloads; the other two are Soviet experiment units with monkeys.

ESA is undertaking the development of the Biobox's payload while the Soviets are responsible for the preparation of the space flight. Dornier (Germany) is the prime contractor for the development of the Biobox, and is supported by subcontractors from Italy, France, Belgium and the Netherlands. The experiments will be conducted by teams consisting of both Europeans and Soviets.

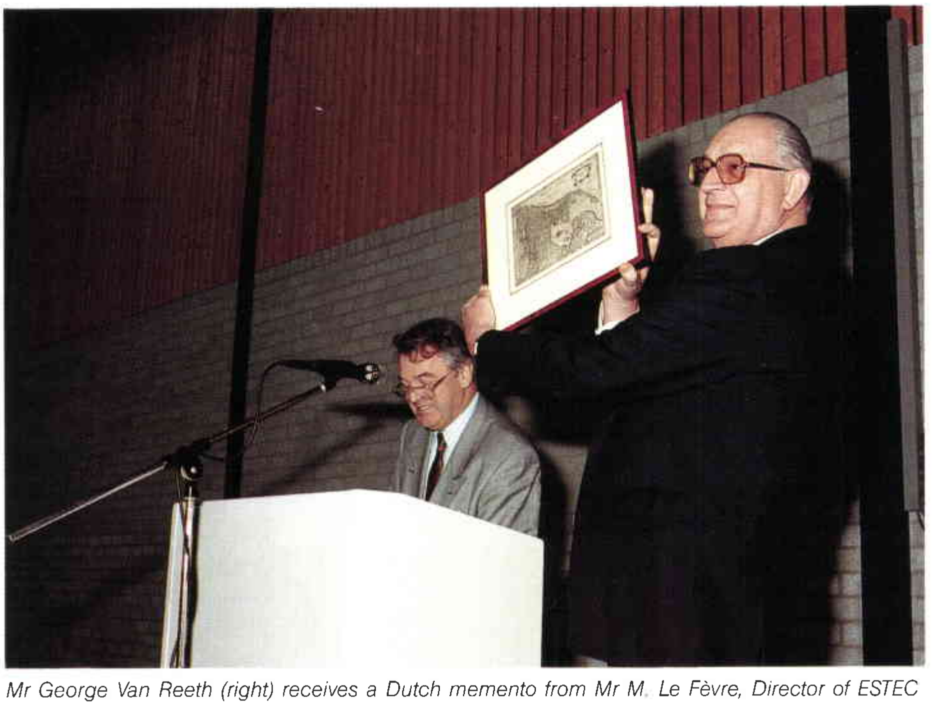
ESA's First Director of Administration Steps Down

George Van Reeth, ESA's longest serving director, is retiring at the end of November after 27 years with the Agency. His career has spanned the evolution of European cooperation in space, from the earliest days of ESTEC in the 1960s.

Mr Van Reeth joined the European Space Research Organisation (ESRO) in 1964 as the Head of the Contracts Division at ESTEC. He subsequently became ESTEC's Acting Head of Administration.

In 1972, he was appointed Administrative Director of the European Launcher Development Organisation (ELDO). When ELDO and ESRO merged in 1975 to form ESA, George Van Reeth became the Agency's first Director of Administration. He has held that position for the past 16 years thereby being ESA's only Director of Administration to date.

He is well known throughout the space industry for his negotiation skills. He has participated in negotiations with ESA's US partners on several cooperative programmes such as the Spacelab and the Space Station, and on fair rules of competition for launchers. He was also involved in the creation of international applications-oriented organisations such as EUMETSAT, EUTELSAT, and INMARSAT.



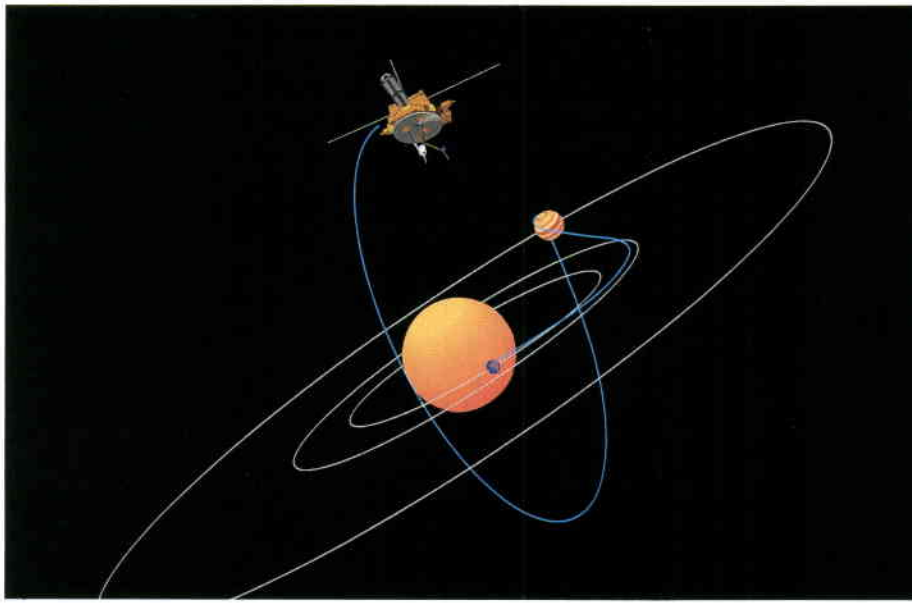
Mr George Van Reeth (right) receives a Dutch memento from Mr M. Le Fèvre, Director of ESTEC

He is considered to be the founder of the industrial consortia concept, an important tool for the proper distribution of industrial return to ESA's Member States. He also introduced the concept of incentives in ESA's development contracts, which has become a standard practice in European contracting.

In addition to his work at ESA, Mr Van Reeth served as the President of the International Astronautical Federation (IAF) from 1988 to 1990.

Ulysses: One Year into the Mission and on Target for Jupiter

On 6 October, with all subsystems and scientific instruments working nominally, ESA's Ulysses spacecraft completed the first year of its five-year mission to study the Sun and its environment in three dimensions. Since its launch, Ulysses has travelled more than 800 million km along the in-ecliptic leg of its heliocentric trajectory, acquiring valuable scientific data that will serve as a reference for the out-of-ecliptic phase of the mission (see ESA Bulletin No. 67).



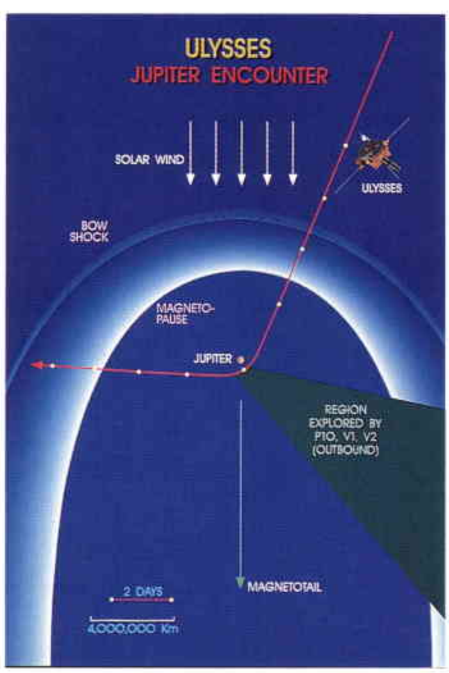
The attention of both the mission operations team and the scientific investigators is now being focused on the forthcoming encounter with Jupiter in the first half of February 1992, the next milestone in this unique, exploratory journey. During the fly-by, the gravitational field of the giant planet will change the trajectory of the space probe in such a way that it will leave the Jovian system heading back towards the Sun on an orbit that will take it firstly over the southern solar pole and subsequently over the northern pole.

This seemingly round-about manoeuvre is necessary because presently available launch vehicles are not powerful enough to inject even a spacecraft of Ulysses' modest dimensions directly into a solar polar orbit from the Earth.

Ulysses will be the fifth space probe to visit Jupiter, following in the footsteps of Pioneer 10 and 11 (1973/74) and Voyager 1 and 2 (1979). Spacecraft operations have been designed to minimise potential damage to the delicate equipment on board during the passage through the harsh environment of the gas giant. Although the scientific payload has not been designed specifically to perform detailed measurements at Jupiter, new discoveries are to be expected.

Of particular interest is the Jovian magnetosphere, created by the planet's powerful magnetic field holding the solar wind away from the planet. Jupiter's magnetosphere is so large (its average diameter is more than 50 times that of the Earth's magnetosphere) that if it could be seen from Earth it would occupy 2 degrees of sky (for comparison, the Sun occupies 0.5 degrees of sky). As a consequence, the Ulysses Jupiter encounter will last more than two weeks, in contrast to the Giotto cometary encounters with Halley in 1986 or Grigg-Skjellerup on 10 July 1992.

The closest approach to Jupiter will be on 8 February at 12:02 GMT, at which time the spacecraft will be at a distance of 378400 km (5.3 Jupiter radii) from the surface of the planet. Unlike most of the previous encounters, the Ulysses fly-by trajectory is retrograde, and the outbound leg will take the spacecraft through the unexplored dusk region of the Jovian magnetosphere at high latitudes.



Scientific topics that will be specifically addressed by the Ulysses payload during the encounter include the measurement of the Jovian magnetic field and plasma environment, the planetary radio emission at kilometre to decametre wavelengths, the energetic particle populations and the unique role played by the Jovian satellite Io, with its so-called plasma torus. Detailed scientific objectives will be discussed at a Ulysses Jupiter Workshop and Science Working Team meeting to be held in November.

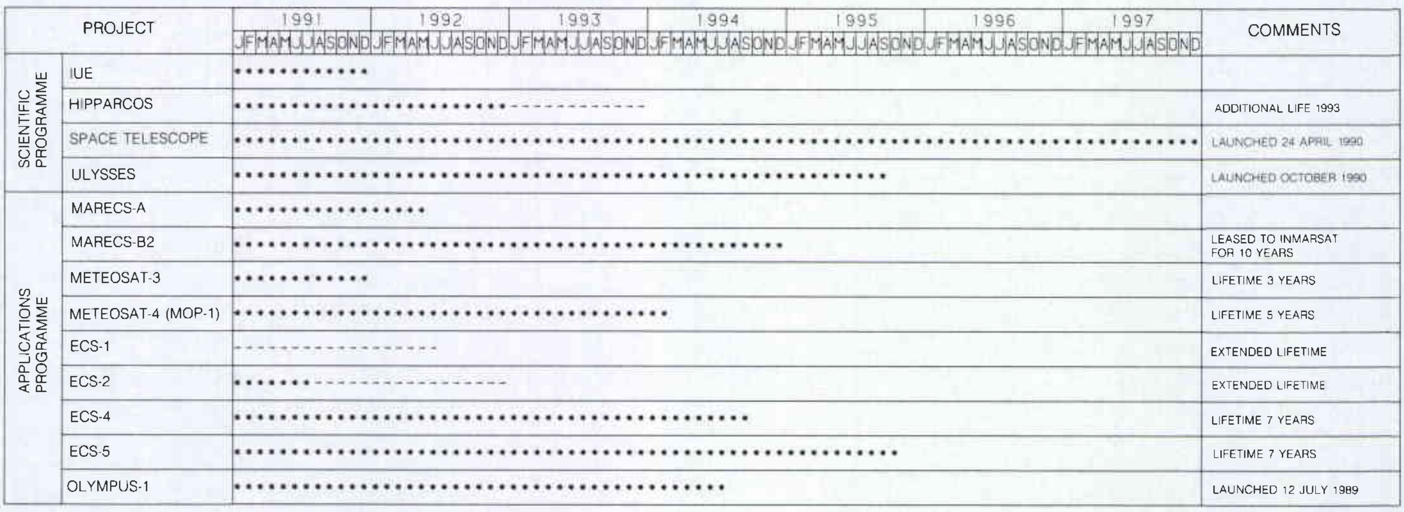
Continuous ground station coverage via the NASA Deep Space Network is planned for the 17 days around the closest approach, including one 70 m DSN pass per day.

Shortly after the fly-by, on 27 February 1992, Ulysses goes through its second opposition (the Sun, the Earth and the spacecraft are aligned). This will be the prime period for the search for gravitational waves using the telecommunications link with the spacecraft.

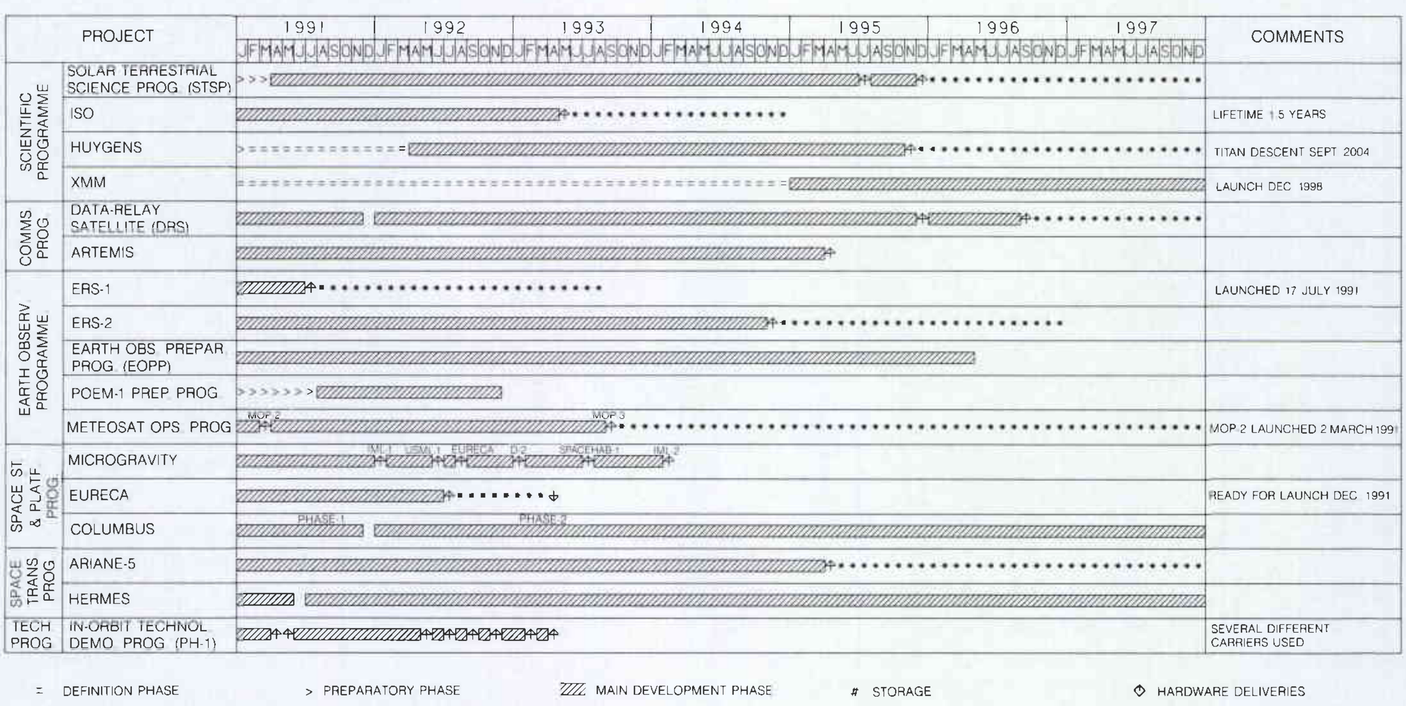
The Ulysses fly-by of the planet Jupiter will mark the beginning of the exciting out-of-ecliptic phase of the mission, leading to the first passage over the Sun's polar regions in mid-1994.

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

In Orbit / En orbite



Under Development / En cours de réalisation



Hipparcos

Le 8 août, le satellite d'astrométrie Hipparcos avait passé deux années en orbite et, à la fin novembre, il aura réuni des données scientifiques de haute qualité pendant deux ans. Le soutien continu fourni par les stations de l'Odenwald, de Perth et de Goldstone fait que, malgré son orbite de 10,6 heures, Hipparcos reste en contact avec le sol pendant 90% du temps et que des données scientifiques sont recueillies pendant 60 à 65% du temps.

Les activités se poursuivent désormais de façon plus ou moins routinière. L'énergie fournie par le réseau solaire et les réserves de gaz de la commande d'orientation font prévoir une durée de vie prolongée jusqu' à fin 1993.

Deux des gyroscopes embarqués ont occasionné des difficultés et le satellite fonctionne désormais sans gyroscopes de secours. Toutefois, les premiers essais menés à la mi-août sur un système de commande d'orientation en temps réel n'utilisant pas les informations fournies par le gyroscope de l'axe de rotation sont très prometteurs. Le signal gyroscopique a été remplacé par des informations fournies par un étalonnage précis des impulsions des propulseurs à jet de gaz et par un modèle des couples perturbateurs du satellite. Cela a permis de conserver une connaissance en temps réel de l'orientation du satellite au niveau d'une seconde d'arc RMS qui est nécessaire pour pointer le système de détection embarqué sur les étoiles programmées. Ce mode de fonctionnement de secours ne sera mis en oeuvre qu'en cas de nouveaux dysfonctionnement des gyroscopes.

Le traitement des données du satellite par les trois groupes de réduction des données — NDAC, FAST et TDAC — se poursuit conformément aux plans, la première 'solution de la sphère' sur la base d'une année complète de données du satellite devant être normalement terminée pour la fin de l'année. Tout porte à croire que la qualité du cadre de référence stellaire en résultant ainsi que des positions, mouvements propres et parallaxes des étoiles, sans oublier les informations sur la photométrie et les étoiles multiples, seront au niveau des attentes avant le lancement.

Marecs

Une nouvelle anomalie du réseau solaire de Marecs-A a été enregistrée en mars dernier lors d'une forte éruption solaire. L'énergie produite par le réseau solaire s'en est trouvée ramenée à un niveau qui ne permet plus d'assurer une capacité de télécommunications suffisante pour les objectifs opérationnels d'Inmarsat. Il a donc été décidé d'interrompre le service du satellite au-dessus de l'océan Pacifique et de le ramener à une position de l'orbite géostationnaire d'où il assure une couverture européenne. La manoeuvre s'est achevée à la mi-août et Marecs-A est désormais à poste à 20°E, où l'on espère pouvoir l'utiliser pour des expériences et des démonstrations de télécommunications du service mobile par satellite.

Marecs-B2 continue d'être exploité en tant que satellite principal d'Inmarsat dans la région ouest de l'Atlantique. Son fonctionnement a été sans histoire et la charge utile est toujours configurée en mode haute puissance, de capacité renforcée.

ECS

Les quatre satellites de la série ECS continuent de fonctionner normalement et, dans certains cas, au-delà des spécifications. Au total, 42 répéteurs sur les 54 qui ont été mis en orbite à bord de satellites ECS sont encore opérationnels.

La position actuelle des satellites est la suivante:

ECS-1	*16°E*
ECS-2	*2°E*
ECS-4	*7°E*
ERS-5	*21,5°E*

ECS-1 devrait rester opérationnel en 1991 et pendant une partie de l'année 1992. Il a déjà dépassé de plus de quinze mois sa durée de vie initialement prévue.

En juin 1991, ECS-2 est arrivé sans problèmes au terme de la durée de vie qui lui avait été fixée. Il devrait toutefois rester opérationnel au moins jusqu'à la fin de 1992.

Soho

La phase de réalisation principale (phase-C/D) dont Matra est le contractant principal se déroule sans problème particulier. Les questions d'ordre technique mises en évidence par la revue de conception système de la mission sont actuellement traitées.

Après la signature du contrat Matra le 11 juillet 1991, les négociations avec la plupart des sous-traitants devraient être achevées pour la fin de l'année.

Les impératifs techniques ont été rationalisés et les bilans de masse, de puissance et autres du système soigneusement étudiés afin de veiller à l'existence de marges suffisantes. Le bilan de masse s'est amélioré, mais l'on continue d'étudier la possibilité de mettre en oeuvre des mesures supplémentaires.

La réunion de démarrage lanceur avec la NASA (approvisionnement d'un lanceur Atlas IIAS) et General Dynamics s'est tenue à la mi-juin. La plupart des paramètres d'interface ont fait l'objet d'un accord et il ne reste pas de problème majeur à résoudre.

Les spécifications de l'enregistreur sur bande (Odetics, USA), de l'amplificateur haute puissance (Cubic, USA) et du suiveur solaire de pointage fin (Adcole, USA) ont été passées en revue et devraient être signées à l'automne. Les travaux sur les activités en vol et sur la mise en place du secteur sol ont fortement progressé; des réunions rassemblant l'industrie et les expérimentateurs sont programmées à intervalles réguliers afin d'assurer une mise en place harmonieuse des éléments des secteurs spatial et terrien.

La charge utile de Soho est en avance sur son programme de développement. La sixième réunion du Groupe de travail scientifique s'est tenue à l'ESTEC du 5 au 7 juin; l'accent a été mis principalement sur la propreté et la qualité de pointage. L'incidence sur la stabilité de pointage (à court, moyen et long terme) de l'interaction des éléments structurels et thermiques fait l'objet d'une attention soutenue car elle constitue un élément déterminant de la conception du satellite.

Hipparcos

On 8 August, the Hipparcos astrometry satellite completed its second year in orbit, and by the end of November it will have been accumulating high-quality scientific data for two years. Continuous support from the Odenwald, Perth and Goldstone stations means that, despite its 10.6 h orbit, Hipparcos remains in contact with the ground for 90% of the time, and scientific data is accumulated for some 60—65% of the time.

Operations now continue on a more-or-less routine basis. Solar-array power and gas supplies for attitude control are consistent with a lifetime extending to the end of 1993.

Two on-board gyroscopes have given problems, and the satellite is now operating without redundant gyros. However, first tests carried out in mid-August on a real-time attitude-control system running without information from the spin-axis gyro were very promising. Replacing the gyro signal with information from an accurate calibration of the gas-jet thruster impulses and a model of the satellite perturbing torques, serves to preserve a real-time knowledge of the spinning satellite's attitude to the 1 arcsec rms level necessary to point the onboard detection system to the programme stars. This contingency mode will only be implemented in the event of further gyro malfunctions.

The processing of the Hipparcos satellite data by the three data-reduction groups — NDAC, FAST and TDAC — is proceeding to schedule, with the first full-scale 'sphere solution' using one complete year of satellite data expected to be completed by the end of 1991. All indications are that the quality of the resulting stellar reference frame, and the resulting positions, proper motions and parallaxes, as well as information on photometry and multiple stars, will now meet the pre-launch expectations.

Marecs

Marecs-A suffered another solar-array anomaly in March of this year, during a time of high solar-storm activity. The power available from the solar array was thereby reduced to a level where it is no longer possible to sustain sufficient communications capacity for Inmarsat's operational purposes. It was therefore decided to remove the spacecraft from service above the Pacific Ocean and to move it back to a geostationary orbital position providing European coverage. The manoeuvre was completed in mid-August and Marecs-A is now located at 20°E, where it is hoped to use it for satellite mobile communications experimentation and demonstrations.

Marecs-B2 has continued to be operated as the Inmarsat prime spacecraft in the Atlantic West Region. Operations have been uneventful and the payload is still configured in enhanced-capacity, high-power mode.

ECS

All four spacecraft in the ECS series continue to function satisfactorily, and in some cases beyond specification. A total of 42 of the 54 transponders put into orbit aboard ECS spacecraft are still operational.

The present spacecraft locations are:

ECS-1	16°E
ECS-2	2°E
ECS-4	7°E
ECS-5	21.5°E

ECS-1 is now expected to remain operational for the rest of 1991 and part of 1992. It has already exceeded its design lifetime by fifteen months.

ECS-2 successfully completed its design lifetime in June 1991, but is expected to remain operational at least until the end of 1992.

Soho

The main development phase (Phase-C/D) with Matra as the Prime Contractor, is proceeding without major problems. The technical issues identified by the Mission System Design Review are being tackled.

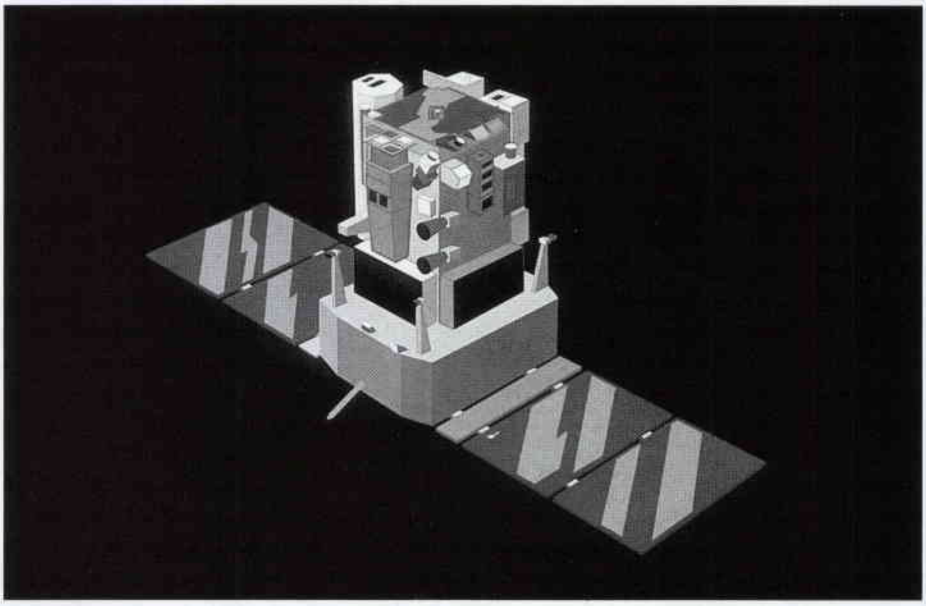
Following signature of the contract with Matra on 11 July, negotiations with most subcontractors are scheduled to be completed by the end of 1991.

The technical requirements have been streamlined and the mass, power and other system budgets have been carefully scrutinised to ensure that there are sufficient margins. The mass budget has improved, but the implementation of some further measures is still being pursued.

The launcher kick-off meeting with NASA (procuring the Atlas IIAS launcher from General Dynamics) and General Dynamics was held in mid-June. Most interface parameters were agreed and no major problems remain.

The Soho spacecraft

Le véhicule spatial Soho



Toutes les expériences sont à un stade avancé de mise au point technique et quelques expérimentateurs ont déjà procédé à des essais sur des modèles structurels.

Cluster

Depuis le début de la phase C/D, on a fait des progrès sur la consolidation de la conception technique de référence au niveau du véhicule spatial et du segment sol ainsi que sur la finalisation de la conception détaillée.

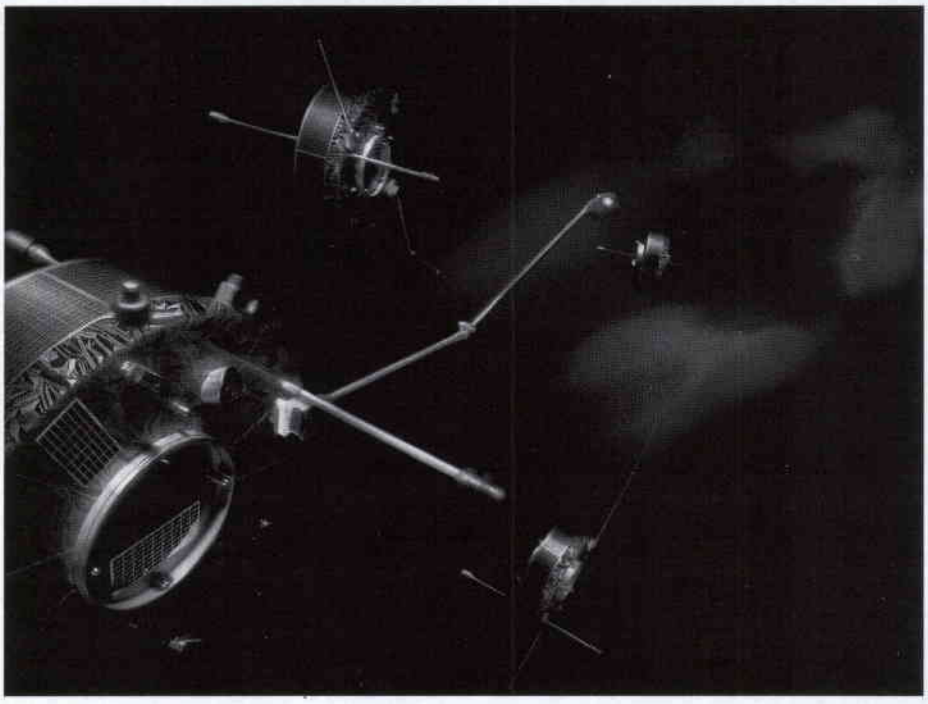
Les travaux sur le modèle de structure ont bien avancé avec un programme d'essais qui doit démarrer au début du mois de mars 1992. L'industrie a déployé des efforts importants pour maintenir le calendrier en dépit du démarrage tardif de la phase C/D (mi-avril au lieu du 1er février comme prévu dans le planning).

On est en train d'examiner de près le modèle technologique pour assurer la livraison en temps voulu de tous les sous-systèmes. Le programme suit actuellement le planning établi.

La réalisation des instruments scientifiques progresse selon le calendrier, la livraison des modèles technologiques correspondants devant avoir lieu à la mi-1992. Les instruments du modèle technologique réalisés dans la cadre du Consortium de l'expérience sur les ondes ont subi ensemble, avec succès, les essais en juillet 1991.

La décision de faire voler Cluster sur Ariane-5 Apex (vol V502) a été annoncée en juillet. Cette configuration comprend le satellite Amsat PSD comme passager et les négociations sont en cours pour décider de l'interface finale entre les deux projects.

La réunion de démarrage formel pour le Système de données scientifiques de Cluster s'est tenue récemment en présence de représentants de tous les Centres de données nationaux sélectionnés. A la suite d'une conception plus détaillée au niveau système, commencera la phase de mise en oeuvre à la mi-1992 pour s'assurer que le système sera disponible pour la date de lancement de Cluster prévue pour la fin de 1995.



The Cluster mission

La mission Cluster

ISO

Les travaux sur les quatre instruments scientifiques progressent correctement. Les modèles de vol en sont à l'essai final et à l'étalonnage. Des modèles de vol de rechange sont en cours d'assemblage pour trois instruments scientifiques tandis que l'équipe ISOCAM évalue la possibilité d'utiliser son modèle de qualification comme rechange de vol.

Le modèle de développement du module de charge utile a été livré au contractant principal et assemblé depuis lors au modèle structurel/thermique du module de servitude. Ce modèle du système de satellite complet contient des éléments électriques inertes, avec les caractéristiques de masse et de propriétés thermiques. Il sera soumis en octobre à des essais de qualification mécaniques, acoustiques et en vibration.

Toutes les unités du sous-système électrique en sont aux essais de qualification finale. Les unités du modèle de vol seront livrées pour intégration au cours des mois qui viennent. L'électronique des gyroscopes a posé un certain nombre de problèmes de conception de détail au cours des essais de qualification; ils sont en cours de solution. Sur le modèle de vol, les vannes d'hélium du cryostat du module charge utile ne présentent pas une étanchéité suffisante et ont été endommagées après avoir été actionnées un certain nombre de fois. Les essais ont également montré que la peinture noire spécialement mise au point n'adhérait pas correctement aux jambes du trépied du télescope qui porte le miroir secondaire lors des cyclages thermiques aux températures de l'hélium liquide. Ces trois problèmes techniques ont été attentivement étudiés et certains progrès ont été déjà faits, mais le souci demeure de trouver des solutions qui évitent de trop grands retards de calendrier.

Des revues de qualification ont été systématiquement menées sur tous les sous-systèmes du satellite et les instruments scientifiques après les essais de qualification. Ces revues devraient être achevées dans leur totalité avant la revue de conception du matériel au niveau système de décembre, prochaine revue officielle de l'Agence qui permettra d'évaluer l'état de qualification du satellite complet et le bien fondé de la conception du modèle de vol.

La réalisation du secteur sol progresse de façon satisfaisante et la constitution de l'équipe opérationnelle scientifique s'accélère. L'équipe de projet continue de travailler dans la perspective d'un lancement toujours fixé en mai 1993.

The specifications for the Tape Recorder (Odetics, USA), the High-Power Amplifier (Cubic, USA) and the Fine-Pointing Sun Sensor (Adcole, USA) have been reviewed and are planned to be signed in the Autumn. Work on the flight operations and on implementing the ground segment has progressed considerably; meetings including Industry and Exprimenters are scheduled at regular intervals to ensure a smooth buildup in the designs of the space and ground segments.

The Soho payload is well ahead in its planned development. The sixth Science Working Group meeting took place in ESTEC (NL) on 5—7 June; major emphasis was directed to cleanliness and pointing performance. The effect on pointing stability (short-, medium- and long-term) of the interaction of structural/thermal elements is a source of continued attention as it constitutes a design driver for the spacecraft.

All experiments are in an advanced stage of engineering and a few experimenters have already conducted tests on structural models.

Cluster

Progress since the start of the main development phase (Phase-C/D) has concentrated on the consolidation of the technical baseline for the spacecraft and ground segment and the finalisation of detailed design.

The structural-model programme is well underway with the test programme expected to commence in early March 1992. There has been extensive effort in industry to maintain the original planned dates despite the later start of Phase-C/D (mid-April compared with the original plan of 1 February).

The engineering-model programme is under scrutiny to ensure timely delivery of all subsystems. Currently the programme is being maintained as planned.

The development of the scientific instruments is proceeding on schedule with engineering models due for delivery in mid-1992. The engineering-model instruments within the Wave Experiment Consortium group were successfully tested together in July 1991.

The formal selection of Cluster for Ariane-5 Apex flight V502 was announced in July. The V502 configuration includes Amsat PSD as a passenger, and discussions are taking place to finalise the detailed interfaces between the two projects.

The formal kick-off meeting for the Cluster Science Data System took place recently, with representatives present from all of the selected National Data Centres. Following a more detailed system-level design, the implementation phase will commence in mid-1992 to ensure that the system will be ready for the Cluster launch date in late 1995.

ISO

The four scientific instruments are making good progress. Flight models are in final testing and calibration. Flight-spare models are being assembled for three scientific instruments and the ISOCAM team is evaluating the possibility of using its qualification model as a flight-spare.

The payload-module development model has been delivered to the Prime Contractor and has since been mated with the service module structural/thermal model. This model of the complete satellite system contains mass/thermal dummies for the electrical units. It will be submitted to mechanical, acoustic and vibration qualification testing in October.

All electrical subsystem units are in final qualification testing. The flight-model units will be delivered for integration over the coming months. The gyroscope electronic control units revealed a number of detail design problems during qualification testing which are presently being resolved.

The flight-model helium valves of the payload-module cryostat showed excessive leakage and also exhibited damage after many actuations. Tests also showed that the specially developed black paint does not adhere properly to the telescope tripod legs holding the secondary mirror when cycled down to liquid-helium temperatures. These three technical problems have received considerable attention and some progress towards solving them has already been made. A major concern is to identify solutions that will avoid excessive schedule delays.

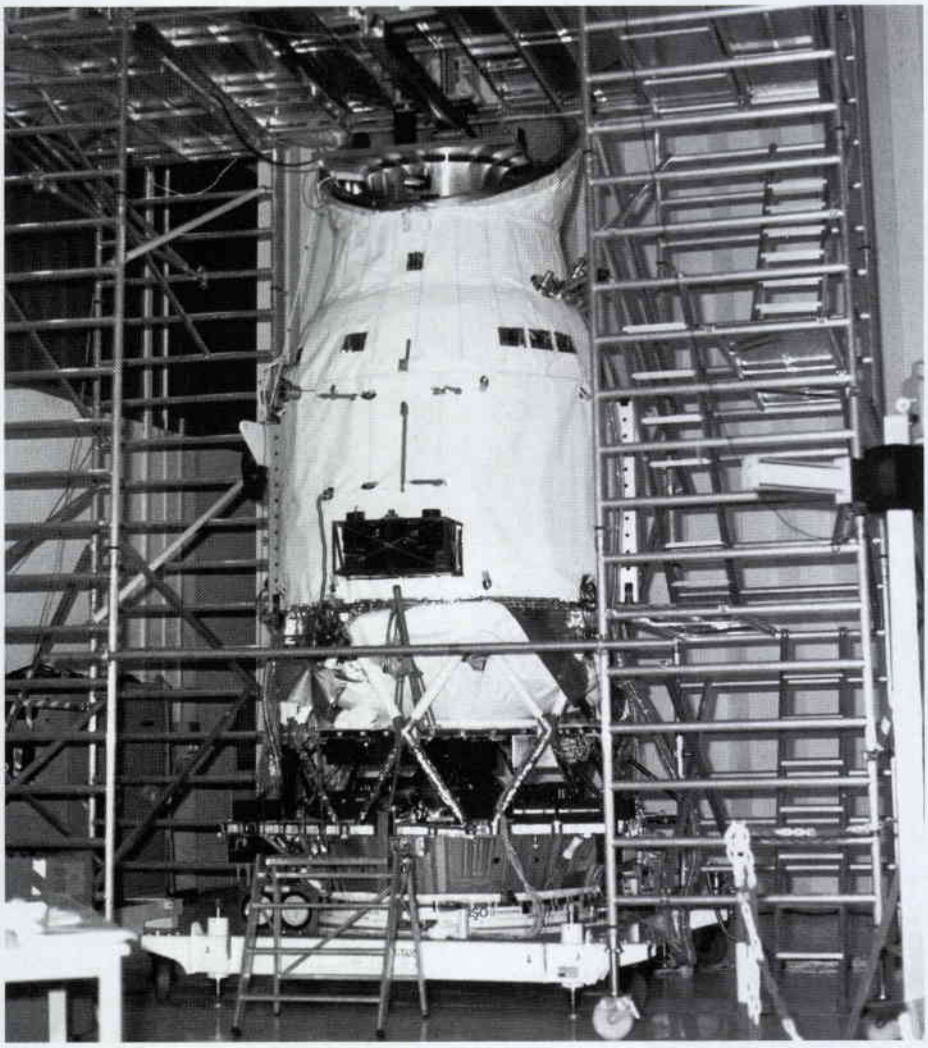
Qualification reviews for all satellite subsystems and scientific instruments are being held systematically after completion of the qualification tests. All such reviews should be completed before the System Hardware Design Review in December, the next formal ESA review, which will assess the qualification status of the complete satellite and the adequacy of the flight-model design.

Progress on the ground segment is satisfactory and the build-up of the science operations team is accelerating. The project continues to work towards a planned May 1993 launch date.

Huygens

The Huygens detailed-definition phase (Phase-B1) was concluded late April with a System Requirements Review. The Review Board agreed, in general, with the findings of the specialist review panels that the ESA requirements for the Probe system and experiment accommodation had been satisfactorily interpreted by industry and that a sound technical baseline had been established. Phase-B2, which concentrates upon detailed subsystem specification and the formation of the potential industrial team for the development and manufacturing phase, was subsequently authorised to start.

Whilst system design core activities have continued at a determined pace, the efforts to form the full industrial team have overshadowed other work. The documentation to enable subsystem procurement has been distributed to potential subcontractors, inviting either competitive or direct-negotiation bids, as appropriate, to be submitted to the Prime Contractor for evaluation. Successful bidders will be progressively included in the industrial team and, depending on the exigencies of their work, be awarded formal contractual subcontractor status with authority to start detailed definition, and in some cases advanced Phase-C/D, tasks. By the time the Probe system Preliminary Design Review (PDR) is held in mid-October, to evaluate the technical baseline upon which the Phase-C/D



ISO development model at Aerospatiale in Cannes (F)

Modèle de développement d'ISO à l'Aérospatiale, Cannes

septembre. Les revues ont donné des résultats variables, exigeant dans certains cas des mesures de la part de l'Agence, de l'industrie et des groupes 'Expériences' compétents.

Nous sommes dans l'attente d'une décision qui pourrait avoir de lourdes conséquences pour la mission Huygens/ Cassini. Nul n'ignore que les crédits attribués par le gouvernement US aux programmes de technologie ont été fortement amputés en 1992, ce qui aura inévitablement des incidences sur la NASA et le Jet Propulsion Laboratory. Différents scénarios sont à l'examen à la NASA afin d'atténuer le plus possible les conséquences de ces réductions, mais il semblerait que les missions Cassini/ CRAF devront subir certains ajustements. La situation sera plus claire en octobre lorsque les comités US compétents se seront réunis.

Huygens

La phase de définition détaillée (phase B1) s'est achevée fin avril par une revue des impératifs système. La commission de revue a rejoint dans l'ensemble les conclusions des groupes de revue spécialisés selon lesquelles les impératifs de l'Agence concernant le système de sonde et le logement des expériences avait été interprétés de façon satisfaisante par l'industrie et une base de référence saine était ainsi posée. Autorisation a donc été donnée de lancer la phase B2, ayant principalement pour objet la spécification détaillée des sous-systèmes et la constitution de l'équipe industrielle qui mènera la phase de développement et de fabrication.

Alors que les activités centrales de conception système se sont poursuivies à un rythme soutenu, il semble que le travail fourni afin de constituer l'équipe industrielle complète ait rejeté dans l'ombre d'autres travaux. La documentation devant autoriser l'approvisionnement des sous-systèmes a été communiquée aux sous-traitants potentiels, leur demandant de soumettre au contractant principal pour évaluation des offres concurrentielles ou de gré à gré, selon le cas. Les soumissionnaires retenus entreront progressivement dans l'équipe industrielle et pourront, selon les exigences de leurs travaux, se voir attribuer un statut de sous-traitant contractuel avec autorisation de démarrer la définition détaillée et, dans certains cas, des tâches anticipées de phase C/D. Lorsque la revue de conception préliminaire (PDR) du système sonde se tiendra à la mi-octobre afin d'évaluer la base de référence technique sur laquelle sera fondée l'offre industrielle de phase C/D, les sous-traitants des sous-systèmes et les fournisseurs d'équipements seront connus dans leur majorité.

Les travaux menés sur les expériences ont suffisamment progressé pour que des PDR soient conduites au sujet de toutes les expériences en août et

XMM

Les résultats des travaux de développement menés sur les technologies en concurrence pour la fabrication de l'optique rayons X très ambitieuse de la mission XMM ont fait l'objet en juin dernier d'une revue de conception de la base de référence. La commission de revue a recommandé le choix de la technologie 'nickel monolithique' au lieu de celle du CFRP provisoirement envisagée comme base de la poursuite des travaux en vue de la production d'un modèle de dévelop- pement de miroir. Il s'est avéré que la technologie du nickel monolithique présentait les meilleures propriétés et que son procédé de fabrication était moins complexe, bien qu'entraînant un accroissement de la masse. L'étude de certaines autres technologies sera poursuivie à titre de solutions de repli possibles.

La mise au point des instruments se poursuit comme prévu, les montages sur table devant être livrés fin 1992 pour les essais aux rayons X du modèle de développement du miroir.

industrial offer will be founded, the majority of subsystem subcontractors and equipment suppliers will have been identified.

Work on the experiments has progressed to the point where PDRs have been conducted for all experiments during August and September. The reviews produced mixed results, requiring some actions from ESA, industry and the experiment groups concerned.

Looming on the horizon is a decision that could have important consequences for the Huygens/Cassini mission. It is well known that US Government funding for technology programmes in 1992 has been drastically reduced, with unavoidable impacts for NASA and Jet Propulsion Laboratory (JPL). Various scenarios are being rigorously assessed by NASA to mitigate the effects of the cuts as much as possible, but it would seem that the Cassini/CRAF missions will be faced with some adjustment. The situation will become clearer in October after the relevant US Committees have met.

XMM

The results of the development activities on the competing technologies to be used to manufacture the very demanding X-ray imaging optics for the High-Throughput X-Ray Mission (XMM) were subject to a Baseline Design Review in late June. The Review Board recommended selection of the monolithic nickel technology instead of the previous CFRP technology as the technological basis on which to proceed further with the production of a Mirror Development Model. The monolithic nickel technology demonstrated the best performance and has a less complex manufacturing process, although at the expense of greater mass. Some of the other technologies will continue to be pursued for the time being as potential back-ups.

Development of the instruments continues as planned, with optical breadboard units due to be delivered in late 1992 for X-ray testing with the Mirror Development Model.

ERS

ERS-1

Following the agreement between the Project and Arianespace on the new launch date of 17 July, the second launch campaign was carried out within the planned 19 days. The satellite re-testing programme was complicated by its fuelled state and corresponding safety restrictions, but virtually all functions and redundancies were re-checked.

The Ariane V44 launch carrying ERS-1 and four microsatellites, took place as planned at the first attempt on 17 July 1991, with a lift-off 0.65 s after the opening of the launch window at 01 h 46 min 31 s (Universal Time).

Early-orbit operations were complicated by several unexpected events, including loss of contact with the NOAA Fairbanks Ground Station, blocking of one of the Wind-Scatterometer's antenna movements, blinding of the earth horizon sensor, and failure of the attitude-control system to converge to fine-pointing mode. All major problems were, however, overcome within the first 48 h after launch.

Following successful initial orbit-correction manoeuvres and full checkout of all spacecraft functions, a two-week period of payload switch-on and functional verification was started on 22 July. This confirmed that all instruments were performing satisfactorily in all modes.

Initial products from the RA (ocean and ice), AMI (SAR, Wave, Wind) and ATSR/M instruments show very good quality, even though several instrument parameters have not yet been optimised.

All the ESA ERS-1 ground stations and most of the 'external' SAR stations have been 'phased-in' and are producing initial data products.

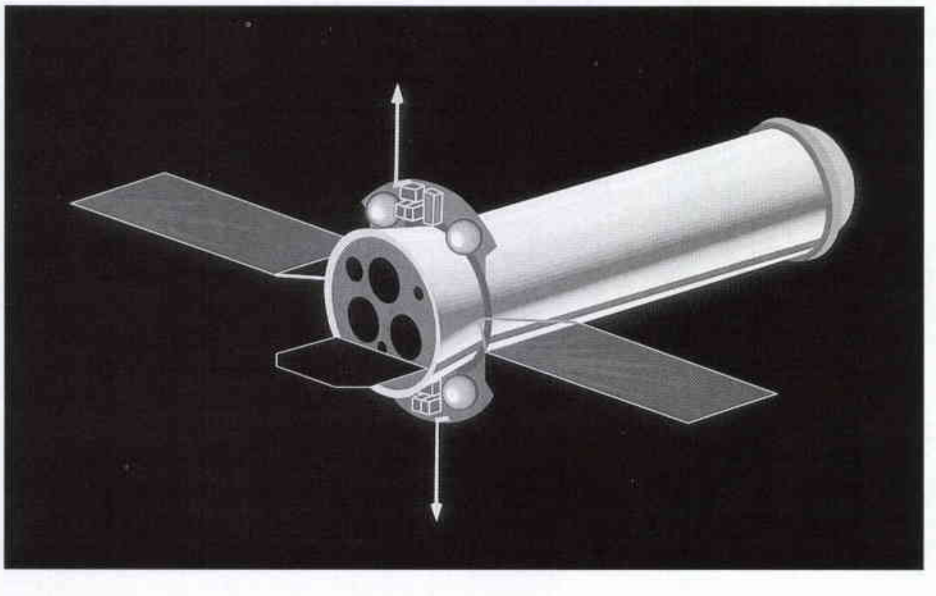
Engineering calibration activities have been initiated using the SAR and Scatterometer ground transponders. These will be followed by the geophysical calibration and validation campaigns planned to begin by mid-September.

ERS-2

ERS-2 has progressed well, with the manufacture of most platform and payload units and subsystems close to schedule. Delays have occurred with some units due to quality defects in certain batches of hi-rel components, but this has not had any impact on the overall programme schedule.

Contract negotiations with the Prime Contractor are expected to be concluded shortly.

The Request for Quotation (RFQ) for development (Phase-C/D) of the GOME instrument was issued to Industry at the beginning of July, and offers are expected by end-September.



The XMM spacecraft

Le véhicule spatial XMM

ERS

ERS-1
L'équipe de projet et Arianespace s'étant mis d'accord sur la nouvelle date de lancement du 17 juillet, la seconde campagne de lancement a été menée comme prévue en 19 jours. Le nouveau programme d'essais du satellite a été compliqué du fait que ses réservoirs étaient pleins et des restrictions de sécurité en résultant, mais pratiquement toutes les fonctions et redondances ont été soumises à une deuxième vérification.

Le lancement V44 emportant ERS-1 et quatre microsatellites a eu lieu comme prévu à la première tentative, le 17 juillet 1991, le décollage intervenant 0,65 s après l'ouverture de la fenêtre de lancement à 1h 46mn 31s (temps universel).

Les opérations de début de fonctionnement en orbite ont été compliquées par plusieurs événements fortuits, notamment la perte de contact avec la station sol de la NOAA à Fairbanks, les difficultés rencontrées lors du déploiement de l'une des antennes du diffusiomètre-vents, l'occultation du détecteur de l'horizon terrestre et l'incapacité du système de commande d'orientation à passer en mode de pointage fin. Tous les problèmes majeurs ont toutefois été résolus dans les 48 heures qui ont suivi le lancement.

Après la bonne exécution des premières manoeuvres de correction d'orbite et la vérification de l'ensemble des fonctions du satellite, une période d'activation de la charge utile et de vérification fonctionnelle de 2 semaines a commencé le 22 juillet. Elle a confirmé que tous les instruments fonctionnaient correctement en tous modes.

Les premiers produits des instruments RA (océans et glaces), AMI (SAR, vagues, vents) et ATSR/M sont de très bonne qualité bien qu'il reste à optimiser certains paramètres des instruments.

Toutes les stations sol ESA d'ERS-1 et la plupart des stations SAR 'extérieures' ont été progressivement mises en service et sortent les premiers produits de données.

Les premières activités d'étalonnage technique ont été conduites avec les répéteurs sol du SAR et du diffusiomètre. Elles seront suivies par les campagnes d'étalonnage et de validation géophysiques dont le démarrage est fixé à la mi-septembre.

ERS-2
Le projet ERS-2 avance bien et la fabrication de la majeure partie des unités et sous-systèmes de la plate-forme et de la charge utile respecte de très près le calendrier. Des retards ont été enregistrés sur certaines unités du fait des défauts de qualité que présentaient certains lots de composants à haute fiabilité mais cela n'a eu aucune incidence sur le calendrier global du programme.

Les négociations avec le contractant principal devraient se conclure prochainement.

La demande de prix (RFQ) relative à la réalisation (phase C/D) de l'instrument GOME a été envoyée dans l'industrie début juillet et les réponses sont attendues d'ici fin septembre.

EOPP

Aristoteles
Un contrat d'étude système a été passé en préparation de la phase B d'Aristoteles, qui devrait commencer en 1992. L'équipe industrielle dirigée par Alenia a pour principaux co-contractants Matra, l'ONERA et Dornier.

Un contrat a été attribué à l'ONERA pour la poursuite du prédéveloppement de l'accéléromètre Gradio. Cet instrument revêt une importance capitale pour la précision des résultats de la mission Aristoteles.

L'université de Bologne, l'ETH de Zurich, l'IPG de Paris ainsi que l'université de Santa Barbara (USA) se sont vu confier une étude ayant pour objet d'élargir l'évaluation des domaines potentiels de recherche géophysique au sein du programme Aristoteles.

La planification et la préparation de l'Atelier ESA/NASA sur Aristoteles qui aura lieu à Anacapri (Italie) les 23 et 24 septembre sont terminées. Depuis les premiers projets d'Aristoteles, mission commune ESA/NASA, cette réunion sera la première occasion de présenter à la communauté scientifique élargie la mission, ses objectifs scientifiques ainsi que sa mise en oeuvre.

Météosat deuxième génération
L'appel d'offres relatif à l'étude de phase A du secteur spatial a été lancé en mai. Les propositions industrielles doivent être remises au plus tard la deuxième quinzaine de septembre. L'étude de phase A de l'imageur a été confiée à Matra en juin.

En juillet, quatre propositions ont été reçues au sujet de la charge utile scientifique ou préopérationnelle des satellites de deuxième génération. Elles ont fait l'objet d'une évaluation technique, l'évaluation complète (y compris les aspects scientifiques) devant être achevée en septembre.

POEM-1
Les activités préparatoires de l'EOPP ayant trait à POEM-1 se sont achevées en août par la passation du contrat de phase B. Les autres activités s'inscrivent dans le cadre du nouveau programme préparatoire de POEM-1(voir ci-dessous).

Les travaux accomplis par le consortium maître d'oeuvre au cours de la deuxième extension de la phase A ont consisté à définir les bases de référence de chaque instrument pour la phase B, élaborer des plans de montage sur table et étudier les variantes envisageables pour la composition de référence de la charge utile M1.

Campagnes
Des experts ont été sélectionnés à l'issue d'une offre de participation pour prendre part à l'analyse des résultats de la Campagne européenne de détection par lidar aéroporté (ELAC).

La définition et la planification d'une campagne aéroportée dénommée SAREX-92, qui a pour objet d'améliorer l'interprétation des données radar et optiques enregistrées au-dessus des forêts tropicales humides d'Amérique du Sud, ont été mises en route. Les vols devraient avoir lieu en avril 1992. Cette campagne se déroule en coopération avec la campagne TREES de la Commission des Communautés européennes (JRC).

EOPP

Aristoteles

A system study contract has been initiated in preparation for the Aristoteles Phase-B, which is foreseen to start in 1992. The industrial team, led by Alenia, has Matra, Onera and Dornier as key co-contractors.

A contract has been initiated with Onera for the continuation of Gradio Accelerometer pre-development. This instrument will be a key factor in the accuracy of the final results obtained from the Aristoteles mission.

A study has been initiated with the University of Bologna, ETH Zurich, IPG Paris and the University of Santa Barbara (USA) to extend the evaluation of potential geophysical research areas with the Aristoteles mission.

Planning and preparation have been completed for the ESA/NASA/Aristoteles Workshop taking place on 23/24 September in Anacapri (I). It will provide the first opportunity since Aristoteles was planned as a joint ESA/NASA undertaking, to present the mission, its scientific objectives and its planned implementation to the wider scientific community.

Meteosat Second Generation

The Invitation to Tender (ITT) for the space-segment Phase-A study was issued in May. The industrial proposals are due in the second half of September. The Imager Phase-A study was initiated with Matra in June.

Four proposals were received in July for the scientific or pre-operational payload on MSG. They have been evaluated technically and the full assessment, including scientific aspects, is due to be completed in September.

POEM-1

The EOPP preparatory activities for POEM-1 were completed with the kick-off of the Phase-B contract in August. The further activities are covered by the new POEM-1 Preparatory Programme (see below).

Work completed by the prime consortium during the second Phase-A Extension has included the establishment of Phase-B baselines for each instrument, the establishment of breadboarding plans, and the investigation of a number of variants of the baseline M1 payload complement.

Campaigns

Via an Announcement of Opportunity (AO) procedure, investigators have been selected to participate in the analyses of the results of the European Lidar Aircraft Campaign (ELAC).

Definition of and planning for an aircraft campaign called SAREX-92 have been initiated, the objectives of which are to improve the interpretation of radar and optical data on the South American tropical rain forests. The flight activities are planned to take place in April 1992. This campaign is a cooperative venture with the CEC's TREES Campaign (JRC).

POEM-1 Preparatory Programme

The Project Team to manage this new Preparatory Programme has been set up and the mission's Phase-B was initiated in August. The baselines for the instruments and for variants of the payload complement have been established during the EOPP POEM-1 Phase-A Extension, which has now been completed.

The MIMR Phase-B proposal has been received and evaluated and the Phase-B kick-off is now imminent.

The Ground-Segment Phase-B RFQ has been prepared for formal issue.

Polar Platform

The Polar Platform Phase-C/D activities have continued in order to implement the technical and development baseline. A significant milestone was reached with the Baseline Consolidation Review, during which the PPF design baseline was consolidated and the majority of the top-level industrial documents (specifications and plans) were approved by the Agency.

Detailed design of the structure and Mechanical Ground-Support Equipment (MGSE) has progressed in phase with the Polar Platform's structural-model schedule.

Long-lead item and component procurement has been initiated for the Service Module units in order to match its protoflight model's schedule.

For the structure, a number of development models for panels and the central tube of the payload carrier have been manufactured.

In parallel, price and contractual negotiations have been taking place which are now in their final stages.

Meteosat

MOP-2, now known as Meteosat-5, is now stationed at 4°W as the in-orbit spare. A small image instability is under investigation. Meteosat-4 is presently being used as the operational unit.

Meteosat-3 has reached its new position of 50°W, where it is being operated for Eumetsat for the Atlantic Data Coverage mission.

The third and last satellite for the Meteosat Operational Programme, MOP-3, is scheduled for launch in September 1993. The intervening period is being used for upgrading the ground-support equipment and correction of the blackbody calibration mechanism which showed indications of improper operation on Meteosat-4. Detailed analyses and metallurgical examinations indicated a tendency for contacting surfaces in the mechanism to 'stick'. A new set of surfaces have now been space-qualified and are being installed in MOP-3's radiometer.

Earthnet

Acquisition, archiving, processing and distribution of data from the Landsat, Spot, MOS and Tiros satellites have been regularly carried out at the network stations.

Following NOAA-12's successful launch in May and NOAA-10's retirement, Earthnet's handling of the Tiros mission will be based on a morning acquisition from NOAA-12 and an afternoon acquisition from NOAA-11. The Earthnet Tiros Coordinated Network, including

Programme préparatoire de POEM-1

L'équipe de projet chargée de gérer ce nouveau programme préparatoire a été constituée et la phase B de la mission lancée en août. Les bases de référence des instruments entrant dans la composition de la charge utile et de leurs variantes ont été établies au cours de l'extension de la phase A de POEM-1, qui est maintenant terminée.

La proposition de phase B portant sur le radiomètre imageur hyperfréquences multifréquences (MIMR) a été reçue et évaluée. Le lancement de la phase B est imminent.

La demande de prix relative à la phase B du secteur sol a été préparée en vue de son envoi officiel.

Plate-forme polaire

Les activités de phase C/D de la plate-forme polaire se sont poursuivies en vue de la mise en oeuvre de la base de référence technique et du développement. Une étape importante a été franchie avec la revue de consolidation de la base de référence, au cours de laquelle la conception de référence de la plate-forme a été consolidée et la majorité des documents industriels de haut niveau (spécifications et plans) ont été approuvés par l'Agence.

La conception détaillée de la structure et des moyens sol mécaniques (MGSE) a progressé en phase avec celle du modèle structurel de la plate-forme.

L'approvisionnement des articles à long délai de livraison et des composants du module de servitude a été lancé conformément aux impératifs du calendrier du prototype de vol.

En ce qui concerne la structure, il a été fabriqué un certain nombre de modèles de développement correspondant aux panneaux et au tube central de l'élément porteur de la charge utile.

Les négociations tarifaires et contractuelles menées en parallèle sont en voie d'achèvement.

Météosat

MOP-2, désormais dénommé Météosat-5, est maintenant placé à 4°O en tant qu'unité de réserve en orbite. On recherche actuellement les causes de la légère instabilité d'image. Météosat-4 sert actuellement d'unité opérationnelle.

Météosat-3 a atteint son nouveau poste à 50°O où il est exploité pour le compte d'Eumetsat dans le cadre de la mission 'Couverture des données de l'Atlantique'.

Le lancement du troisième et dernier modèle de vol du Programme Météosat opérationnel, MOP-3, est fixé à septembre 1993. D'ici-là, on procède à la mise à hauteur des équipements de soutien au sol et à la correction du mécanisme d'étalonnage sur le corps noir, celui de Météosat-4 ayant montré des signes de dysfonctionnement. L'analyse détaillée et l'examen métallurgique ont fait apparaître que les surfaces de contact du mécanisme avaient tendance à 'coller'. Après avoir subi les essais de qualification pour l'espace, un nouveau lot de surfaces est en cours d'installation sur le radiomètre de MOP-3.

Earthnet

Les stations du réseau procèdent régulièrement à l'acquisition, à l'archivage, au traitement et à la diffusion des données des satellites Landsat, SPOT, MOS et Tiros.

Le satellite NOAA-12 ayant été lancé avec succès en mai et le NOAA-10 ayant été retiré du service, la gestion de la mission Tiros par Earthnet se fera sur la base de l'acquisition des données NOAA-12 le matin et celles de NOAA-11 l'après-midi. Le réseau coordonné Tiros d'Earthnet, avec la station de Dundee (Ecosse) a continué à acquérir et à archiver régulièrement les données HRPT de la NOAA. Le transfert des données des stations de Nairobi, de l'Agrhymet de Niamey et de La Réunion vers Frascati pour archivage et redistribution se fait maintenant régulièrement.

Un dialogue s'est engagé avec la Commission européenne (DG VIII/CCE) au sujet du soutien que pourrait apporter la CCE à la gestion des stations Tiros de la NOAA en Afrique — notamment pour l'acquisition des données à Maspalomas et pour l'archivage de données, la production de données à visualisation rapide et la mise à jour de catalogues à Maspalomas, Niamey, Nairobi et la Réunion. Cette coopération pourrait également s'étendre à la mise à hauteur de la Station de Cotopaxi pour que celle-ci puisse recevoir, archiver et distribuer les données AVHRR de la NOAA. L'établissement d'une installation de traitement des données AVHRR et ERS-1 qui serait analogue à celles qui sont proposées pour le projet TREES est également à l'examen.

Dans le cadre du projet TREES, un poste de travail AVHRR/SAR a été installé et inauguré en juillet au Centre régional de télédétection de Nairobi. Un deuxième système sera envoyé au Centre INPE de Cachoeira Paulista (Brésil).

A la suite de la définition des impératifs techniques et financiers d'un Réseau européen de données sur l'environnement à l'échelle du globe, un contrat sera bientôt conclu avec un consortium dirigé par la Swedish Space Corporation. En même temps, des activités communes avec la CCE se poursuivent pour veiller à ce que cette initiative soit conduite sur la base d'une association en coopération.

Des contrats d'approvisionnement en récepteurs, synchroniseurs de séquences, etc. ont été passés pour la mise à hauteur du réseau en vue de la réception des données du satellite japonais J-ERS-1 et de Landsat-6. Des négociations sont en cours sur la mise au point de logiciels et l'intégration des diverses installations.

Le contrat Eurimage relatif à la distribution des produits Earthnet (autres que ceux d'ERS-1) a été reconduit.

En ce qui concerne la mission SeaWifs de la NASA, dont le lancement est prévu en août 1993, la participation d'Earthnet à la gestion de ses données en Europe est proposée à la NASA au titre d'un programme conjoint ESA/CCE.

Les premiers résultats d'ERS-1 ont été présentés par le Directeur général de l'ESA, M. J.-M. Luton, et par le Sous-secrétaire d'Etat italien, M. L. Saporito, au cours d'une conférence de presse organisée le 4 septembre à l'ESRIN (Frascati, Italie).

Dundee in Scotland, has continued with regular acquisition and archiving of NOAA HRPT data. Data transfer from the Nairobi, Niamey-Agrimet and La Reunion stations to Frascati for archiving and redistribution is now routine.

A dialogue has been initiated with the European Commission (CEC DG VIII) concerning possible CEC support for the handling of the NOAA Tiros stations in Africa — in particular, data acquisition at Maspalomas, and data archiving and quick-look/catalogue generation at Maspalomas, Niamey, Nairobi and La Reunion. This cooperation could also be extended to include the upgrading of the Cotopaxi station to receive, archive and distribute NOAA AVHRR data. The establishment of an AVHRR and ERS-1 data-processing facility similar to those proposed within the TREES Project is also being considered.

As part of the TREES Project, an AVHRR/SAR work station was installed and inaugurated in July at the Nairobi Regional Remote-Sensing Centre. A second system will be shipped to Brazil's INPE Facility at Cachoeira Paulista.

The definition of the technical and financial requirements for a European Global Environmental Data Network has led to a contractual action now being finalised with a consortium led by the Swedish Space Corporation. In parallel, a joint effort with the CEC is continuing to ensure that this initiative is carried out on a cooperative-partnership basis.

Contracts have been placed for receivers, frame-synchronisers, etc. for upgrading the network for the Japanese J-ERS-1 and Landsat-6 satellites. Negotiations are in hand for software development and for integration of the various facilities.

The Eurimage contract for the distribution of Earthnet (other than ERS-1) products has been renewed.

Within the framework of the NASA SeaWifs mission, foreseen for launch in August 1993, Earthnet involvement to handle the data in Europe is being proposed to NASA as a joint ESA/CEC programme.

The first ERS-1 results from Earthnet were presented by ESA's Director General, Mr J-M. Luton, and the Italian Under-Secretary of State, Mr L. Saporito, at a Press Conference at ESRIN in Frascati (I) on 4 September.

The Earthnet ERS-1 Central Facility (EECF)

The Central User Service at ESRIN came into operation in July, and the interface between the EECF and the Mission Management and Control Centre (MMCC) at ESOC has been established. All of the ESA ground stations were fully operational by August. The links with the German, French and British Processing and Archiving Facilities (PAFs) are also now operational.

The first acquisition report from a 'foreign' station arrived at the EECF from the Alaska SAR Facility in Fairbanks on 25 August. August also saw the establishment of the links with the Italian and British Meteorological Offices for the distribution of ERS-1 LBR (Low-Bit-Rate) Fast-Delivery (FD) Products via the Global Telecommunication System network.

Activities at the Product Control Service (PCS) became especially intense after launch, ensuring routine monitoring of the LBR FD products and in-depth checking of anomalies during each orbit cycle. In particular, the PCS Verification Mode Processor was used extensively to validate the AMI's Image Mode and as a 'calibration sensor'. The generation of multi-temporal SAR images which allow the detection of variations such as tides etc., has already demonstrated the excellent orbital stability of the satellite and the very encouraging capabilities of the SAR instrument.

The ERS-1 ground-station network

The ESA network

The Fucino and Maspalomas stations started SAR data acquisition shortly after ERS-1's launch.

Acquisition of LBR tape-recorder dumps has been regularly carried out at the Fucino, Maspalomas, Gatineau and Prince Albert stations. The Fast-Delivery Processors have been operated at Fucino, Maspalomas and Gatineau.

A first optical disk containing LBR telemetry data was generated at Fucino using the Low Rate Data Transcription Facility and forwarded to both the UK and French PAFs.

National and foreign stations

The following stations were operational by the end of September: Tromsø, Gatineau, Prince Albert, Alaska SAR Facility, Hatoyama, Kumamoto, Hyderabad, West Freugh, Alice Springs, and O'Higgins. Tests were also carried out with Cuiaba (Brazil) and Cotopaxi (Ecuador).

The ERS-1 PAF activities

The collection of ERS-1 laser tracking data commenced at the German PAF in July and has continued on a routine basis thereafter. The first preliminary orbit was generated from the laser quick-look data and distributed to the EECF and to the PAFs in early August through the ERS-1 network. The ability to generate SAR Precision Image products and Geocoded Ellipsoid Corrected Products has been successfully demonstrated.

Real fast-delivery LBR test data ingested via the EECF-PAF link has demonstrated the good performance of the French PAF system. The processing chains for the French-PAF-specific LBR products have been tested using satellite raw data and AMI-wind FD products at the same time. Radar Altimeter precision products have also been made available.

At the UK PAF, the LBR product generation of Along-Track Scanning Radiometer (ATSR) products has commenced, with Radar-Altimeter product generation foreseen for October. The SAR fast-delivery archiving and distribution subsystem has also become operational.

Microgravity

The launch date for the IML-1 Spacelab mission is now January 1992, and preparation of the two ESA payloads for this mission, namely Biorack and the Critical Point Facility, is proceeding well. All flight hardware is at NASA/KSC and installed in Spacelab.

The flight model of the Glove Box developed by ESA for the USML-1 Spacelab mission (launch June 1992) has been successfully tested and was delivered to NASA/KSC in September.

All five multi-user facilities developed by ESA for Eureca (representing approx.

Installation centrale ERS-1 d'Earthnet (EECF)

Le Service utilisateur central de l'ESRIN a commencé à fonctionner en juillet et l'interface entre l'EECF et le Centre de Contrôle et de Gestion de la Mission (MMCC) à l'ESOC a été mise en place. L'ensemble des stations sol de l'ESA était pleinement opérationnel en août. Les liaisons avec les Installations de traitement et d'archivage (PAF) allemande, française et britannique sont également devenues opérationnelles.

Le premier rapport d'acquisition d'une station 'étrangère' est arrivé à l'EECF le 25 août. Il provenait de l'installation SAR d'Alaska à Fairbanks. C'est également en août qu'ont été établies les liaisons avec les Offices météorologiques italien et britannique pour la distribution des produits LBR (faible débit) à livraison rapide (FD) d'ERS-1 via le réseau du système mondial de télécommunications.

Les activités du Service de contrôle des produits (PCS) sont devenues particulièrement intenses après le lancement; ce service devait en effet procéder au suivi régulier des produits LBR FD et à la vérification approfondie d'anomalies pendant chaque cycle orbital. En particulier, le processeur PCS de validation a largement été utilisé pour la mise au point de l'AMI en mode imageur et pour le soutien des activités d'étalonnage. La production des images multi-temporelles du SAR, qui permettent de détecter des variations temporelles causées par les marées, les activités humaines, etc., a déjà démontré que la stabilité orbitale du satellite était excellente et que l'instrument SAR présentait des possibilités très encourageantes.

Réseau de stations sol d'ERS-1 Réseau ESA

Les stations de Fucino et de Maspalomas ont commencé à acquérir les données SAR peu de temps après le lancement d'ERS-1.

Les stations de Fucino, Maspalomas, Gatineau et Prince Albert ont régulièrement procédé à l'acquisition des données LBR des enregistreurs embarqués. Les processeurs des données à livraison rapide ont été utilisés à Fucino, Maspalomas et Gatineau.

Un premier disque optique contenant les données de télémesure LBR a été produit à Fucino au moyen de l'installation de transcription des données à faible débit et transmis aux PAF britannique et française.

Stations nationales et étrangères

Les stations suivantes sont devenues opérationnelles à la fin septembre: Tromsø, Gatineau, Prince Albert, Installation SAR de l'Alaska, Hatoyama, Kumamoto, Hyderabad, West Freugh, Alice Springs et O'Higgins. Des essais ont également été conduits à Cuiaba (Brésil) et Cotopaxi (Equateur)

Activités des PAF d'ERS-1

La collecte des données de poursuite laser d'ERS-1 a commencé à la PAF allemande en juillet et s'est poursuivie de façon régulière depuis lors. Le premier calcul d'orbite préliminaire a été fait à partir des données laser à visualisation rapide et diffusé à l'EECF et aux PAF début août par le réseau ERS-1. La possibilité d'élaborer des produits d'image SAR de précision et des produits corrigés et géocodés a été démontrée.

Les jeux de données à livraison rapide des instruments LBR qui ont été injecté en temps réel dans la PAF via la liaison EECF-PAF ont montré que la PAF française fonctionnait bien. Les chaînes de traitement des produits LBR spécifiques de la PAF française ont été soumises à des essais avec des données brutes du satellite ainsi qu'avec des produits FD de l'AMI en mode vents. Des produits de précision de l'Altimètre radar sont désormais disponibles également.

A la PAF britannique, l'élaboration de produits du Radiomètre à balayage dans le sens de la trace (ATSR) a commencé et celle des produits de l'Altimètre radar est prévue pour octobre. Le sous-système d'archivage et de distribution des données SAR à livraison rapide est également devenu opérationnel.

Microgravité

Le lancement de la mission Spacelab IML-1 est désormais prévu en janvier 1992 et la préparation des deux charges utiles de l'Agence pour cette mission, à savoir le Biorack et l'installation Point critique, progresse normalement. Tout le matériel de vol se trouve au Kennedy Space Center et est installé dans le Spacelab.

Le modèle de vol de la boîte à gants réalisé par l'Agence en vue de la mission Spacelab USML-1 (lancement en juin 1992) a fait l'objet d'essais satisfaisants et a été livré au Kennedy Space Center en septembre.

Toutes les installations à utilisateurs multiples réalisées par l'ESA pour Eureca (représentant environ 60% de la charge utile totale) ont été intégrées sur la plate-forme et ont subi avec succès les essais du système intégré.

Les charges utiles de l'Agence destinées à la mission Spacelab-D2 (lancement en janvier 1993) sont le module de physique des fluides de pointe (AFPM), l'Anthrorack et différentes expériences en sciences des matériaux montées dans des installations à utilisateurs multiples du DLR. Le modèle de vol de l'AFPM a été mis à niveau à l'ESTEC avant d'être intégré sans difficulté dans le bâti double de sciences des matériaux. La préparation des expériences et l'entraînement des équipages sont bien avancés. Le modèle de vol de l'Anthrorack a été expédié par l'Aérospatiale chez MBB/ERNO où a lieu l'intégration de la charge utile D2. Les essais d'interface entre l'Anthrorack et le Spacelab ont été menés à bien. Des efforts particuliers ont été faits pour remédier à certaines défaillances de matériel qui se sont produites pendant les essais de fonctionnement, l'objectif visé étant leur remise complète à la gestion de la mission Spacelab-D2 en octobre 1991. Les activités relatives aux quatre expériences individuelles montées dans des installations du DLR, qui représentent un volume de travail notable en essais et vérifications, progressent conformément aux plans.

Les charges utiles ESA de la mission Spacelab IML-2 (lancement en 1994) sont l'installation 'Bulles, Gouttes et Particules' (BDPU), le Biorack, le dispositif Point critique (CPF) et l'installation de cristallisation des protéines de pointe (APCF). Les travaux sur l'APCF progressent normalement. La BDPU a subi sans difficulté sa revue critique de conception. Les activités à mener sur le Biorack et le CPF, qui feront l'objet

60% of the total payload) have been integrated into the platform and have successfully completed integrated system testing.

The ESA payloads on the Spacelab-D2 mission (launch January 1993) are the Advanced Fluid-Physics Module (AFPM), Anthrorack, and individual material-sciences experiments mounted in DLR multi-user facilities. The flight model of the AFPM, having been upgraded at ESTEC, has been successfully integrated into the Material-Sciences Double Rack. The preparations for the experiments and crew training are well underway. The flight model of Anthrorack was shipped by Aerospatiale to MBB/ERNO, where the D2 payload is being integrated. Interface testing between Spacelab and Anthrorack has been performed successfully. Special efforts are being made to remedy some hardware failures which occurred during performance testing, the aim being to achieve a complete handover to the Spacelab-D2 mission management in October 1991. The work on the four single experiments in DLR facilities is progressing according to plan, which involves a substantial verification and testing effort.

The ESA payloads for the IML-2 Spacelab mission (launch 1994) are the Bubble, Drop and Particle Unit (BDPU), Biorack, the Critical Point Facility (CPF) and the Advanced Protein Crystallisation Facility (APCF). Work on the APCF is progressing well. The BDPU has successfully completed its Critical Design Review. Activities on Biorack and CPF, both being re-flights from the IML-1 mission, are presently limited to preparatory studies, awaiting completion of IML-1.

An additional flight opportunity for the APCF on Spacehab, a commercial venture sponsored by NASA, in July 1993 is being negotiated.

The thirteenth ESA parabolic-flight campaign with the CNES/CEV Caravelle aircraft was conducted in June. The next flight is planned for September. A scientific workshop was organised to present the results from the seventh to the eleventh campaigns.

Maxus-1, the first sounding-rocket planned to provide 15 min of microgravity, was launched in May, by a German/Swedish consortium. A failure investigation is in progress as the rocket did not achieve its correct apogee.

Work on the Swedish Maser-5 sounding-rocket programme (launch Spring 1992) has been initiated. Five ESA payload modules will be accommodated.

The next launch (Texus 28) in the German Texus sounding-rocket programme, carrying one ESA payload, is scheduled for Autumn 1991.

The implementing arrangement with Glavkosmos (USSR) for flying biological experiments in a 'Biobox' on Biokosmos-10 on a cooperative basis (no exchange of funds) has been presented to the Agency's IRC, AFC and Microgravity Programme Board. The development phase (Phase-C/D) has been initiated, with the flight planned for the end of 1993.

Agreement has been reached with the German Space Agency, DARA, to fly the Otolith Test Device developed by ESA on the German MIR mission in late 1991. This experiment will investigate the human body's reflexes and the behaviour of its complex physiological orientation system.

Eureca

The supplementary test programme recommended by the ESA Board that reviewed the acceptability of Eureca flight hardware in May was completed satisfactorily by the end of July.

These tests revealed, however, that the data flows between the flight unit and the ESOC ground segment need adjustment to avoid critical onboard-computer load conditions.

As a result of tests on the resistivity of the material Vespel to hydrazine contamination, a decision was made to exchange all Vespel seals in the He-gas pressure system of Eureca's Orbital Transfer Propulsion Assembly.

Having been given the Agency's consent to ship, the flight unit is now being prepared by MBB/ERNO for transport to the USA. The Eureca launch is now planned by NASA for 2 July 1992 on Shuttle flight STS-46, with retrieval foreseen for 22 April 1993 on STS-57.

Space Station Freedom/Columbus

Manned laboratories

After several rounds of discussion with the Delegations and in-house analysis of the implications for the programme of imposed budget restrictions, a modified scenario was presented to the Delegations at the end of August as part of the overall In-Orbit-Infrastructure (IOI) scenario. This revised scenario is the proposed basis for the Ministerial Conference in November.

The scenario for the Attached Laboratory is unchanged and launch is still scheduled for September 1998, driven by the Space-Station Freedom Assembly Sequence.

The launch date and development schedule for the Free-Flyer is linked to the date when Hermes will be able to perform its first full servicing mission. The Hermes development schedule foresees such a mission in mid-2004, and consequently launch of the Free-Flyer is foreseen for the second half of 2003. An initial joint system-definition effort is planned in the 1992—1994 time frame. The subsystem developments that were supposed to be common with one of the two other Columbus elements and managed by the Free-Flyer contractor, have been moved to Attached Laboratory or Polar-Platform responsibility, as appropriate, as the full Free-Flyer development will only start in 1995. A strong coherence will be maintained between the Free-Flyer and the Hermes developments.

On the NASA side, after a difficult initial budget-approval situation for fiscal-year 1992 Space-Station funding, in June the House of Representatives finally voted the 1992 Space Station funding at essentially the 1991 level. This vote was confirmed in July by the Senate. During this process, ESA strongly supported the Space Station Programme in the light of the international commitments associated with it.

The System Architect Support Contract for the operations ground segment has *d'un nouveau vol après IML-1, se limitent pour le moment à des études préparatoires.*

On négocie actuellement une occasion de vol supplémentaire pour l'APCF sur Spacehab, opération commerciale patronnée par la NASA, en juillet 1993.

La treizième campagne de vols paraboliques de l'Agence a été conduite en juin sur la Caravelle du CNES/CEV. Le prochain vol est prévu en septembre. Un atelier scientifique a été organisé afin de présenter les résultats obtenus de la septième à la onzième campagne.

Maxus-1, première fusée-sonde capable de fournir 15 mn de quasi-impesanteur, a été lancée en mai 1991 par un consortium germano-suédois. La fusée n'ayant pu atteinare son apogée correct, une enquête est en cours pour analyser la cause de la défaillance.

Le programme suédois de fusées-sondes Maser-5 (lancement au printemps 1992) a été engagé. Cinq modules de charge utile de l'ESA y seront embarqués.

Le prochain lancement (Texus 28) du programme allemand de fusées-sondes (Texus) emportant une charge utile de l'ESA est programmé pour l'automne 1991.

L'accord d'exécution conclu avec Glavcosmos (URSS) pour l'emport sur une base coopérative (sans échange de fonds) d'expériences biologiques dans un 'Biobox' à bord de Biocosmos-10 a été présenté à l'IRC, à l'AFC et au Conseil directeur du programme de recherche en microgravité de l'Agence. La phase de développement (phase C/D) a été engagée, le vol étant prévu pour la fin 1993.

Un accord a été conclu avec la DARA, l'Agence spatiale allemande, pour l'emport fin 1991, sur la mission allemande MIR, du dispositif d'expérimentation 'Otolith' réalisé par l'Agence. Cette expérience étudiera les réflexes du corps humain et le comportement de son complexe système physiologique d'orientation.

Eureca

Le programme d'essais supplémentaire recommandé par la commission ESA qui a procédé en mai 1991 à la revue du matériel de vol Eureca avant expédition a été mené à bonne fin en juillet.

Ces essais ont toutefois fait apparaître que les flux de données entre l'unité de vol et le secteur sol de l'ESOC devait être ajusté afin d'éviter une surcharge critique du calculateur embarqué.

A la suite d'essais sur la résistance du matériau 'Vespel' à l'action de l'hydrazine, il a été décidé de remplacer tous les joints en Vespel du système de pressurisation à l'hélium de l'ensemble propulseur de transfert orbital d'Eureca.

L'Agence ayant donné son accord au transport, l'unité de vol est en préparation chez MBB/ERNO en vue d'être acheminée au Etats-Unis. Le lancement d'Eureca est désormais prévu par la NASA le 2 juillet 1992 sur le vol de la Navette STS-46, sa récupération étant prévue le 22 avril 1993 par STS-57.

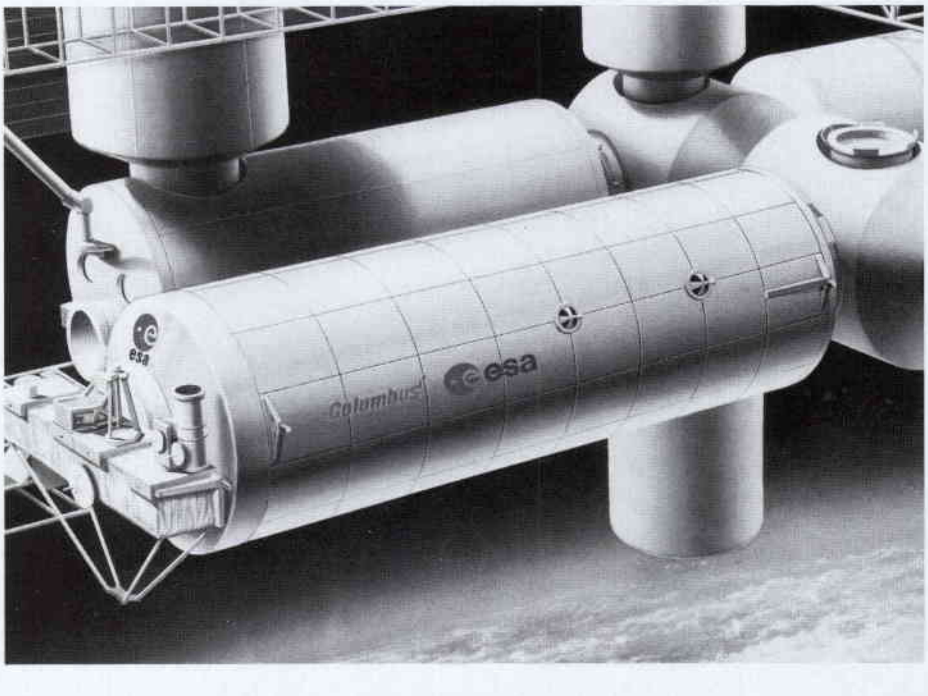
Station spatiale Freedom/Columbus

Laboratoires habités

Après plusieurs séries de discussions avec les délégations et à l'issue d'une analyse interne des incidences sur le programme des restrictions budgétaires imposées, un scénario modifié a été présenté fin août aux délégations dans le cadre du scénario général de l'Infrastructure orbitale (IOI). Ce scénario révisé constitue la base de la proposition qui sera soumise aux ministres en novembre.

En ce qui concerne le laboratoire raccordé, le scénario est inchangé et son lancement demeure fixé à septembre 1998, date imposée par la séquence d'assemblage de la station spatiale Freedom.

Le calendrier de développement et la date de lancement du laboratoire autonome sont liés à la date à laquelle Hermès sera en mesure d'exécuter sa première mission de desserte complète. Le calendrier de développement d'Hermès prévoit que cette mission sera exécutée à la mi-2004, ce qui conduit à un lancement du laboratoire autonome au deuxième semestre de 2003. Un premier effort de définition commune au niveau système est prévu au cours de la période 1992-1994. Les travaux de développement des sous-systèmes présumés communs avec l'un des deux autres éléments Columbus et gérés par le contractant du laboratoire autonome ont été transférés à la responsabilité des contractants du laboratoire raccordé ou de la plate-forme polaire, selon le cas, la réalisation proprement dite du laboratoire autonome ne devant débuter qu'en 1995.



The Columbus Attached Laboratory

Le laboratoire raccordé Columbus

been completed and all central facilities have been designed and specifications established. Work on the Laboratory Control Centres has progressed.

On the utilisation side, the precursor flights have been retained as they provide unique access, prior to exploitation of the Infrastructure, to scientific users, and increase European experience in manned space flight in preparing for Columbus exploitation. However, budget constraints mean that only three precursor flights are now proposed – two Eureca and one Spacelab – in the 1995–97 time frame.

Among the 'Long-Term Programme' activities, the EXEMSI experimental campaign has been defined and should be conducted in mid-1992. A crew of three will be confined for two 28 day periods in a volume corresponding to the living space of Hermes plus the Free-Flyer.

Ariane

The main aims of the Ariane-5 Programme for 1991 have been achieved from the technical and timetable viewpoints. In particular:

- the programme for tests on the Vulcain engine has been adhered to;
- the major subassemblies making up the first P230 booster have been delivered;
- the production and test facilities have been commissioned in Guiana.

Vulcain engine
In a little over a year, five Vulcain engines have been accepted at SEP and tested on the engine teststands at Vernon (France) and Lampoldhausen (Germany). In a programme of forty-eight tests, the following key objectives have been achieved:

- definition of the ignition and shutdown sequences;
- short burn at 10% above nominal thrust;
- steady-state operation for 885 s (flight duration is 600 s);
- cumulative operation of 3200 s, including 2300 s on a single engine.

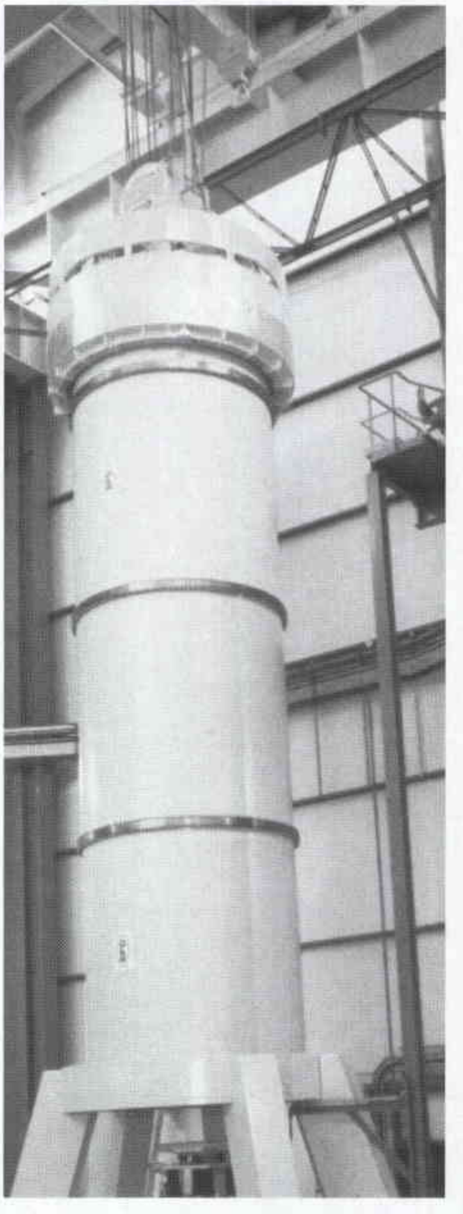
Progress is thus well in line with the Vulcain-engine development plan.

P230 stage
The following very important milestones have been achieved in the last few months:

- The first burst test of a booster casing representative of a flight structure was performed by MAN (Germany). Results confirm the validity of the inter-segment joint configuration and the dimensioning of the structure.
- The barrel sections (with internal thermal cladding) for the first B1 booster were delivered to Guiana by BPD.
- The first full-scale nozzle was accepted by SEP. This nozzle will be used on the B1 booster, hot-testing of which is now scheduled for March 1992.

Facilities in French Guiana
The grain plant facilities in French Guiana have been validated. These facilities, developed with SNPE-Engineering as prime contractor, have now been released to the company Regulus, which has the responsibility for running the plant.

A full-scale segment weighing 100 t, representative of the flight segments, was used to validate the fabrication and control process. 12 t inert and active mixes have been produced by the two mixers.



Process validation mockup of Ariane-5's P230 stage

Modèle de validation du processus de fabrication de l'étage P230 d'Ariane

Toute la cohérence possible sera assurée entre les travaux de développement du laboratoire autonome et ceux d'Hermès.

Du côté de la NASA, après une période de négociation délicate, la Chambre des Représentants a finalement voté au mois de juin le budget de la Station spatiale pour 1992 à un niveau à peu près identique à celui de 1991. Ce vote a été confirmé en juillet par le Sénat. Tout au long de ce processus, l'Agence a apporté un soutien énergique au programme de Station spatiale en se fondant sur les engagements internationaux qui y sont liés.

Le contrat de soutien architecte système pour le secteur sol opérationnel a été mené à bonne fin, toutes les installations centrales ont été conçues et les spécifications établies. Les travaux relatifs au Centre de contrôle des laboratoires ont progressé.

Côté utilisateurs, le principe de vols précurseurs a été retenu car il s'agit d'un moyen unique d'accès à l'espace pour les utilisateurs scientifiques, antérieurement à l'exploitation de l'infrastructure, et c'est un moyen d'accroître l'expérience européenne en matière de vols spatiaux avec équipage en préparation de l'exploitation de Columbus. Toutefois, les contraintes budgétaires font que trois vols précurseurs seulement sont désormais proposés — deux vols Eureca et un vol Spacelab — au cours de la période 1995-1997.

Parmi les activités du 'programme à long terme', la campagne expérimentale 'EXEMSI' a été définie et devrait être menée à la mi-1992. Un équipage de trois personnes restera enfermé pendant deux périodes de 28 jours dans un volume correspondant à l'espace vital offert par Hermès plus le laboratoire autonome.

Ariane

Les principaux objectifs du programme Ariane-5, prévus en 1991, sont respectés du point de vue technique et calendaire; citons notamment:
- *respect du plan d'essais du moteur Vulcain*
- *livraison des gros sous-ensembles constitutifs du premier booster P230*
- *recette des installations de production et d'essais en Guyane.*

Moteur Vulcain
En un peu plus d'un an cinq moteurs Vulcain ont été recettés à la SEP et essayés sur les bancs moteur de Vernon (F) et de Lampoldshausen (A). 48 essais sont réalisés et les objectifs importants suivants sont atteints:
- *définition des séquences d'allumage et d'arrêt*
- *fonctionnement du moteur, en courte durée, 10% au delà de la poussée nominale*
- *fonctionnement du moteur, en continu, pendant 885 s (le temps de vol est de 600 s)*
- *durée de fonctionnement cumulée de 3200 s dont 2300 s sur un seul moteur.*

Le plan de développement du moteur Vulcain est donc respecté.

Etage P230
Au cours de ces derniers mois, des étapes très significatives ont été atteintes dont:
- *la réalisation chez MAN (A) du premier essai d'éclatement d'une structure nue représentative d'une structure de vol. Les résultats obtenus permettent de confirmer la validité de la configuration des liaisons intersegments et le dimensionnement de la structure*
- *la livraison en Guyane par BPD des viroles du premier booster B1 équipées de leur protection thermique interne*
- *la recette par la SEP de la première tuyère à échelle 1. Cette tuyère équipera le booster B1 dont l'essai à feu est maintenant programmé en mars 1992.*

Installations en Guyane
Les installations de l'usine de poudre en Guyane ont été validées. Ces installations, développées sous la maîtrise de SNPE-Ingénierie, sont désormais mises à disposition de la société Regulus chargée de l'exploitation de l'usine.

Un segment, échelle 1 de 100 t, représentatif des segments de vol a permis de valider le processus de fabrication et de contrôle. Des coulées inertes et actives de 12 t ont été réalisées sur les deux malaxeurs.

Publications

The documents that are listed here have been issued since the last publications announcement in the ESA 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. 15, No. 3/4:

THE CHALLENGE OF SAMPLE ACQUISITION IN A COMETARY ENVIRONMENT
EIDEN M J & COSTE P

A NEW MECHANISM FOR PAYLOAD JETTISONING
PANIN F

ANALYSIS MODELLING AND SPACE-SPECIFIC ANALYSES USING 'ESABASE'
DE KRUYF J

SENSITIVITY CHANGES IN THE CNRS ULTRAVIOLET SPECTROMETER ABOARD OSO-8
LEMAIRE P

ASSESSMENT OF THE CATHEDRAL-II SILICON COMPILER FOR DIGITAL-SIGNAL-PROCESSING APPLICATIONS
BOLSENS I ET AL.

A METHOD OF SIMULATING DISCONTINUOUS SIGNALS
LO PRESTI L & MONDIN M

ESA Special Publications

ESA SP-1143 // 290 PAGES
REPORT OF THE EARTH-OBSERVATION USER CONSULTATION MEETING, ESTEC, NOORDWIJK (NL), 29-31 MAY 1991 (OCTOBER 1991)
READINGS C, BARRON C & BATTRICK B (EDs)

ESA SP-1131 REVISION 1 // PRICE 25 DFL
CATALOGUE OF ESA PATENTS (JULY 1991)
KALLENBACH P A (ED. BATTRICK B)

ESA SP-320 // PRICE 150 DFL
PROCEEDINGS OF THE EUROPEAN SPACE POWER CONFERENCE, FLORENCE, ITALY, 2-6 SEPTEMBER 1991 (VOLS 1 & 2)
HUNT J (EDITOR)

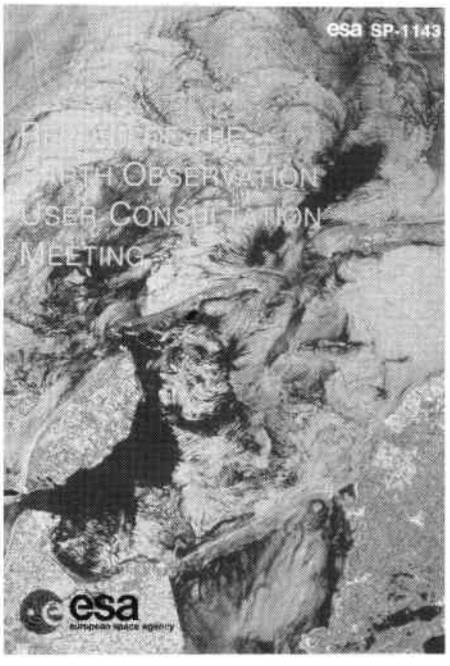
ESA SP-316 // PRICE 75 DFL
PROCEEDINGS OF THE SYMPOSIUM SPACE PRODUCT ASSURANCE FOR EUROPE IN THE 1990S, ESTEC, NOORDWIJK, 15-19 APRIL 1991 (AUGUST 1991)
HUNT J (EDITOR)

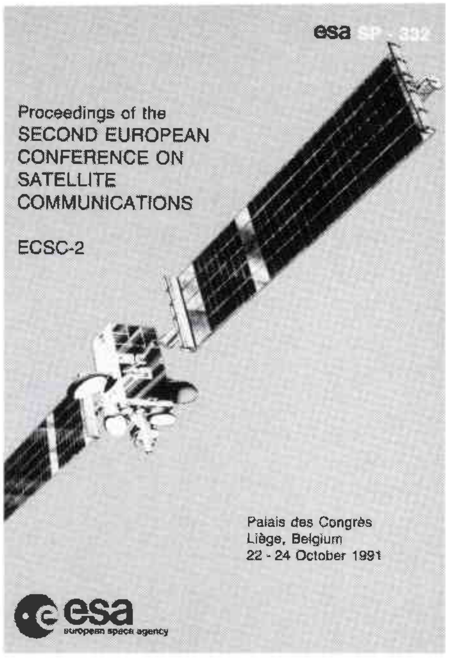
ESA SP-332 // PRICE 90 DFL
PROCEEDINGS OF THE SECOND EUROPEAN CONFERENCE ON SATELLITE COMMUNICATIONS (ECSC-2), LIEGE, BELGIUM, 22-24 OCTOBER 1991
KALDEICH B (EDITOR)

ESA SP-321 // PRICE 150 DFL
PROCEEDINGS OF AN INTERNATIONAL CONFERENCE ON SPACECRAFT STRUCTURES AND MECHANICAL TESTING (VOLS. 1 & 2)
BURKE W R (EDITOR)

ESA SP-342 // PRICE 90 DFL
PROCEEDINGS OF IVTH EUROPEAN AEROSPACE CONFERENCE ON LAUNCH BASES AND CONTROL INFRASTRUCTURES FOR SPACECRAFT, PARIS, 13-16 MAY 1991
KALDEICH B (EDITOR)

ESA SP-345 // PRICE 35 DFL
PROCEEDINGS OF INTERNATIONAL WORKSHOP ON SALYUT-7/KOSMOS-1686 REENTRY
FLURY W & BATTRICK B (EDITORS)





ESA Brochures

ESA BR-76 // NO CHARGE
PROMOTION OF INDUSTRIAL DEVELOPMENT AND UTILISATION OF MICROGRAVITY IN SPACE. THE 'RADIUS' REPORT (JUNE 1991)
GUYENNE T D (EDITOR)

ESA BR-71 // NO CHARGE
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BURKE W R (EDITOR)

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AOS HANDBOOK — A USER'S GUIDE TO THE CCSDS STANDARDS FOR ADVANCED ORBITING SYSTEMS (JULY 1991)
STANTON D (ED. BURKE W R)

ESA Scientific and Technical Reports

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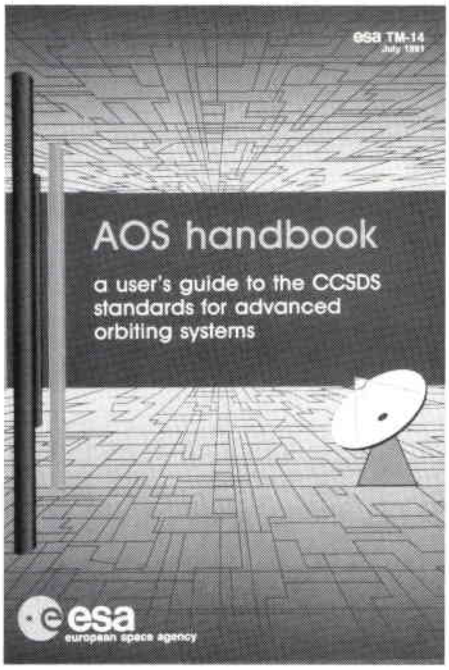
THE PHYSICS AND INSTRUMENTATION OF PASSIVE ATMOSPHERIC SOUNDING (JULY 1991)
INGMANN P (ED. BURKE W R)

ESA Procedures, Standards and Specifications

ESA PSS-01-612 ISSUE 1 // PRICE DFL 35
CAPABILITY APPROVAL PROGRAMME FOR MICROWAVE HYBRID INTEGRATION CIRCUITS (MHICs) (NOVEMBER 1990)
ESTEC PRODUCT ASSURANCE AND SAFETY DEPT.



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THE CRIMPING OF HIGH-RELIABILITY ELECTRICAL CONNECTIONS (DEC. 1990)
ESTEC MATERIALS AND PROCESSES DIVISION

ESA PSS-01-728 ISSUE 2 // PRICE 35 DFL
THE REPAIR AND MODIFICATION OF PRINTED-CIRCUIT BOARD ASSEMBLIES FOR SPACE USE (MARCH 1991)
ESTEC MATERIALS AND PROCESSES DIVISION

ESA PSS-01-21 ISSUE 2 // PRICE 25 DFL
SOFTWARE PRODUCT ASSURANCE REQUIREMENTS FOR SPACE SYSTEMS (APRIL 1991)
ESTEC PRODUCT ASSURANCE AND SAFETY DEPT. AND ESA FRACTURE CONTROL BOARD

ESA PSS-01-730 ISSUE 1 // PRICE 35 DFL
THE WIRE WRAPPING OF HIGH-RELIABILITY ELECTRICAL CONNECTIONS (MARCH 1991)
ESTEC PRODUCT ASSURANCE AND SAFETY DEPT.

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SPACE DATA COMMUNICATIONS (MARCH 1991)
ESA STANDARDS APPROVAL BOARD (STAB) FOR SPACE DATA COMMUNICATIONS

ESA PSS-04-104 VOLUME 1 ISSUE 2 // PRICE 25 DFL
RANGING STANDARD. VOLUME 1: DIRECT GROUND TO SPACECRAFT RANGING (MARCH 1991)
ESA STANDARDS APPROVAL BOARD (STAB) FOR SPACE DATA COMMUNICATIONS

ESA PSS-03-210 ISSUE 1 // PRICE 75 DFL
ADHESIVE BONDING HANDBOOK FOR ADVANCED STRUCTURAL MATERIALS (FEBRUARY 1990)
ESTEC STRUCTURES AND MECHANISMS DIV.

ESA PSS-01-20 ISSUE 2 // PRICE 35 DFL
QUALITY ASSURANCE REQUIREMENTS FOR ESA SPACE SYSTEMS (FEBRUARY 1991)
ESTEC PRODUCT ASSURANCE AND SAFETY DEPT.

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Microgravity News from ESA (English with French summaries)	3	Europe's microgravity research programme	,,	,,
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