esa bulletin

number 56

november 1988

COLUMBUS

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr H. Grage.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie

Président du Conseil: M H. Grage.

Directeur général: Prof. R. Lüst.

esa bulletin

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

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Assistant Editor
Erica Rolfe

Layout
Carel Haakman

Montage
Keith Briddon

Advertising
Brigitte Kaldeich

Printed in The Netherlands
ISSN 0376-4265

european space agency
agence spatiale européenne

Corrigendum
The caption to Figure 20b on page 27 of ESA Bulletin No. 54 should have read:
(b) Docking/berthing latching subsystem being developed by Dornier System (Germany) and Sener (Spain)

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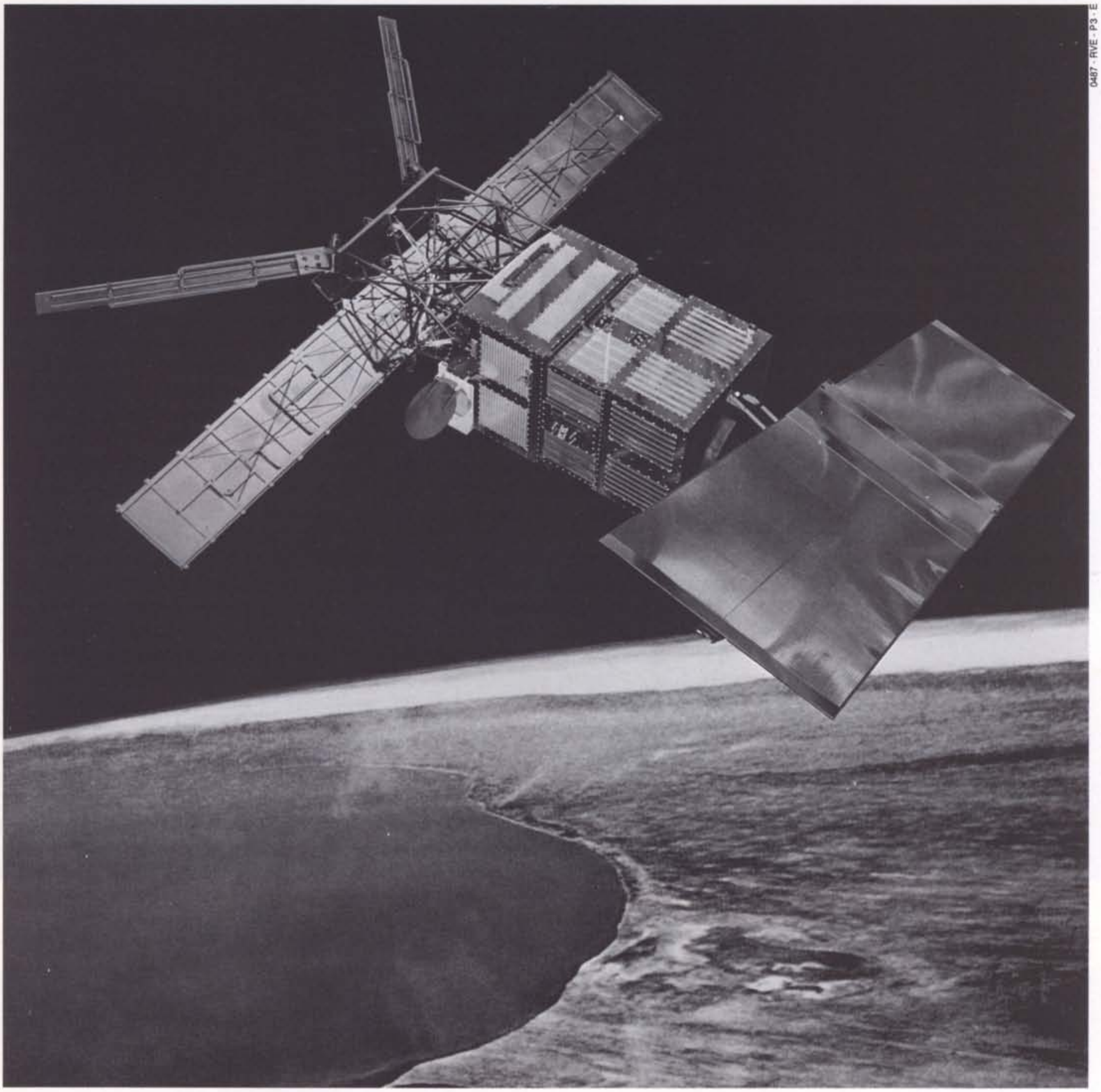

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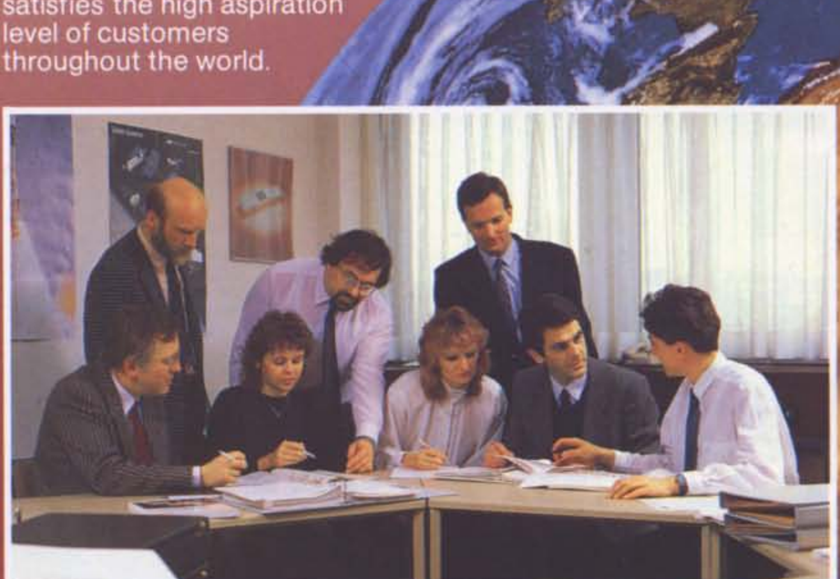

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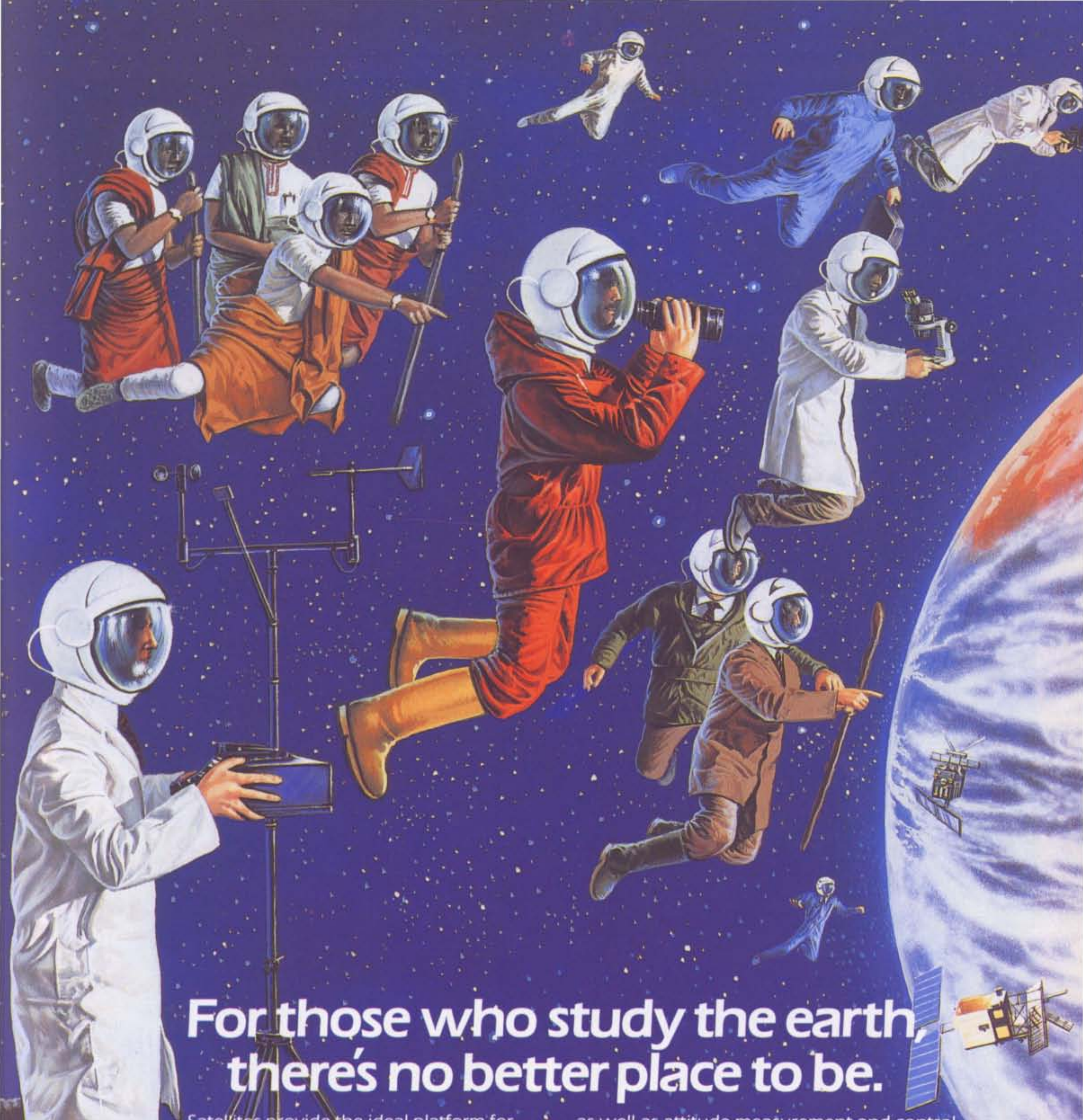

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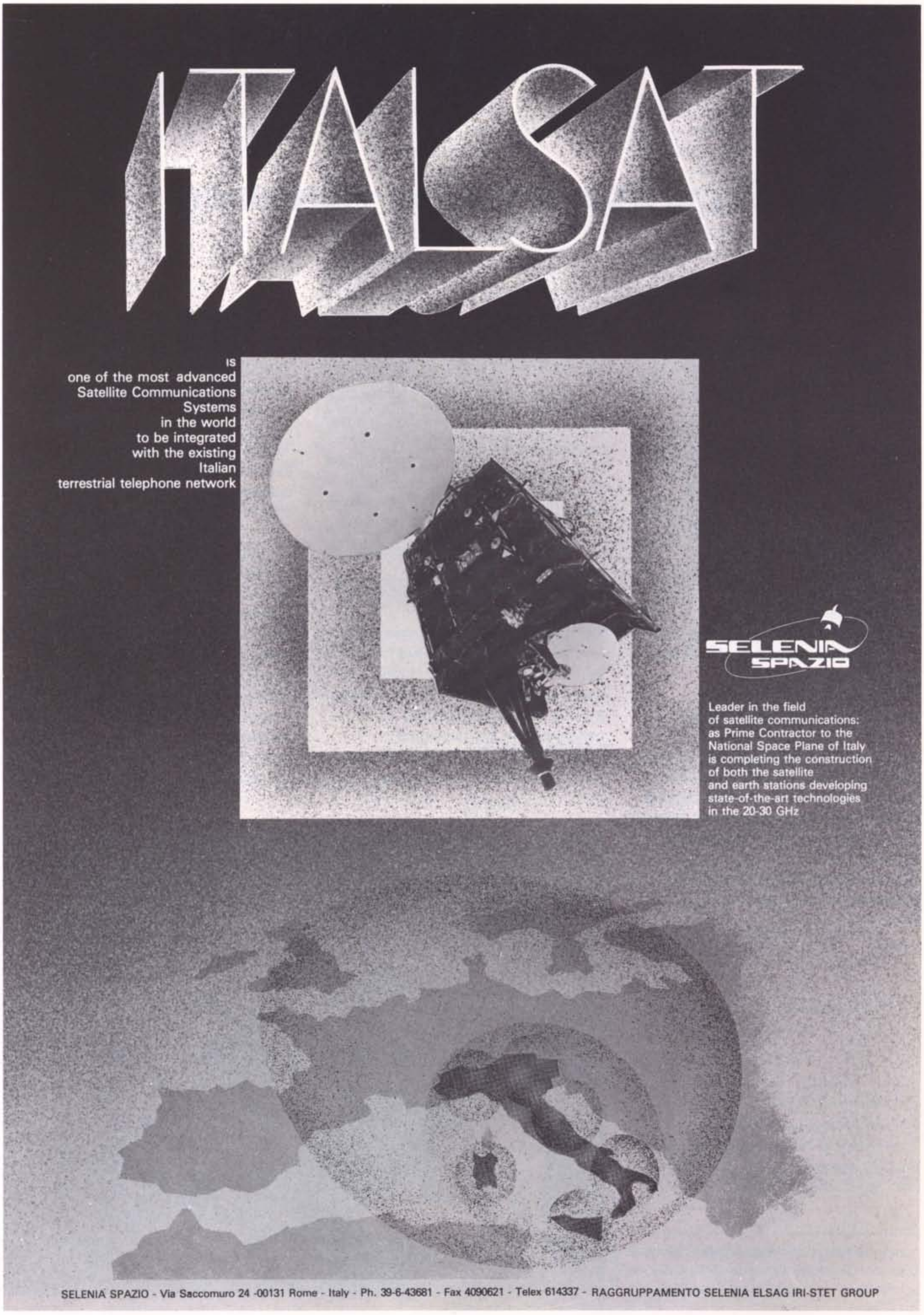
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Europe Signs Space-Station Agreement

On 29 September 1988, in Washington DC, representatives of the nine ESA Member States participating in the Agency's Columbus Programme — Belgium, Denmark, France, Federal Republic of Germany, Italy, The Netherlands, Norway, Spain, and the United Kingdom — together representing the 'European partnership', signed a multilateral Intergovernmental Agreement (IGA) with the United States, Canada and Japan for the International Space-Station Programme. The IGA provides the policy framework and contains the basic principles for this unprecedented, long-term cooperative endeavour in space.

On the same occasion, Prof. Reimar Lüst, ESA's Director General, and representatives from Canada signed Memoranda of Understanding (MOU)* with NASA covering 'Cooperation in the Detailed Design, Development, Operation and Utilisation of the Permanently Manned Civil Space Station'.

The international agreements

The agreements signed in Washington — a multilateral Intergovernmental Agreement (IGA) between Europe, the USA, Japan and Canada, complemented by three subordinate Memoranda of Understanding (MOUs) between their cooperating agencies (including that between NASA and ESA) — are the product of three years of negotiations in which ESA has pursued its aspiration of being a strong partner in the International Space-Station endeavour.

The IGA's signature establishes the long-term international cooperative framework between the Government of the United States of America, the Governments of the nine ESA Member States participating in the Columbus Programme, the Government of Japan and the Government of Canada, the so-called 'Four Partners'. Based on the IGA, these Partners will now cooperate in the detailed design, development, operation and utilisation of a permanently manned civil Space Station for peaceful purposes, in accordance with international law. The IGA also defines the nature of that partnership, including the rights and obligations of the respective partners.

The bilateral Memorandum of Understanding between ESA and NASA, signed by Prof. Lüst on 29 September, develops the principles laid down in the IGA. This MOU covers in great detail the management, procedural and technical questions that need to be settled before entering into such a joint high-technology enterprise. It recognises NASA's role as the main infrastructure supplier for the Space Station, but ESA retains design and management authority over the

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Signature of the Memorandum of Understanding by Mr Dale Myers, NASA's Deputy Administrator, and Prof. Reimar Lüst, ESA's Director General

* Japan's Constitution requires that it formally ratify the IGA before signature of the MOU. It will therefore sign the MOU at a later date.

European flight elements. The agreement includes not only the development of this complex orbital infrastructure, but also its operation and its utilisation, which will last for several decades.

The European contribution
Europe's contribution to the International Space Station through the Columbus Programme (decribed in detail in the next article in this issue), is based on three major ESA-developed elements:

— The Columbus Attached Laboratory

Statement by Prof. Reimar Lüst, ESA's Director General

In German we have a saying *'Ende gut, alles gut'*, which means 'all is well that ends well' and indeed as a representative of the Executive of the European Space Agency I want to thank everyone who has contributed in reaching the Intergovernmental Agreement and the Memorandum of Understanding. I want to thank all our Governments and all our partners.

Of course this is not the end but the beginning of a great undertaking. There is no parallel in the past. The agencies to which our Governments have entrusted the management of this large cooperative project have accepted this great responsibility and I very much hope that we will be able to carry it out successfully.

I am confident that this will be the case. Each partner is to contribute to the Space Station in a specific way. In the Intergovernmental Agreement and the Memorandum of Understanding the principle of consensus is a cornerstone. I believe that we in Europe know from experience that to achieve consensus is not always easy, but it can be achieved if there is a will to succeed and a spirit of trust in each other.

Today we have signed an Agreement for cooperation which should lead us beyond the year 2000. Modern technological projects have a long lead time before they reach final fruition. A lot can happen in that time but we trust that whatever changes occur, we, the four Partners in this challenging new venture, will forge ahead and succeed in our endeavour to conquer space together.

Signatories at the IGA/MOU Ceremony

IGA

Belgium
Signatory: The Honorable Hugo Schiltz, Vice Prime Minister and Minister for Science Policy

Canada
Signatory: The Honorable Robert de Cotret, Minister for Regional Industrial Expansion and Minister of State for Science and Technology

Denmark
Signatory: His Excellency Ambassador Eigil Jørgensen

France
Signatory: The Honorable Paul Quiles, Minister for Telecommunications and Space

Federal Republic of Germany
Signatories: His Excellency Ambassador Jürgen Ruhfus
The Honorable Heinz Riesenhuber, Chairman of the ESA Council at Ministerial Level and Federal Minister for Research and Technology

Italy
Signatory: Senator Leargo Saporito, Undersecretary for Scientific and Technological Research

Japan
Signatory: His Excellency Ambassador Nobuo Matsunaga

The Netherlands
Signatory: His Excellency Ambassador Richard Fein

Norway
Signatory: His Excellency Ambassador Kjell Eliassen

Spain
Signatory: His Excellency Ambassador Julian Santamaria

The United Kingdom
Signatory: The Lord Glenarthur, Minister of State, Foreign and Commonwealth Office

The United States
Signatory: The Honorable George P. Shultz, Secretary of State

MOUs

Canada
Signatory: The Honorable Frank Oberle, Minister of State (Science and Technology)

ESA
Signatory: Prof.Dr. Reimar Lüst, Director General, European Space Agency

The United States
Signatory: The Honorable Dale Myers, Deputy Administrator, National Aeronautics and Space Administration

Signatories of the Intergovernmental Agreement, from left to right: Secretary of State George Shultz, USA; Ambassador Nobuo Matsunaga, Japan; and Minister Robert de Cotret, Canada

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(APM), which, once assembled in orbit, will become an integral part of the manned base and will accommodate the European experiments to be performed there.
- The Columbus Free-Flyer Laboratory (MTFF), which will fly close to the manned base and will operate autonomously. It will, however, dock with the manned base, or with the European space plane Hermes, at regular intervals for inspection and servicing by astronauts.
- The Columbus Polar Platform (PPF), which will perform Earth-observation and space-science missions from a higher-inclination, near-polar orbit.

The basis of the Columbus philosophy is to provide Europe with expertise in manned, man-assisted and fully automatic operations in space, as a foundation for future autonomous European missions. The Columbus Development Programme was endorsed in this light during the ESA Council Meeting at Ministerial Level in The Hague in November 1987 as an important part of the European Long-Term Space Programme. The development of the various Columbus space elements and associated ground infrastructure is therefore closely linked to that of the other large ESA programmes now in preparation such as Ariane-5, Hermes and the European Data-Relay Satellite.

The Columbus space-segment elements will be supported by a sophisticated ground segment, in which the Columbus Central Mission Control Centre will play a pivotal role. This Centre, to be sited at ESOC in Darmstadt (Germany) will coordinate and control the preparation of mission activities, and will monitor the missions themselves and control the communications network.

There will also be centres for payload integration, engineering support and logistics services in Germany and Italy for the Columbus Free-Flyer (MTFF) and the Attached Laboratory (APM), respectively. Further centres, primarily for user familiarisation and support, the number of which will be determined by users' needs, will be provided by national agencies in the ESA Member States. All of these centres and their projected roles are described in detail in the next article.

Signatories of the Intergovernmental Agreement: Ambassador Jürgen Ruhfus (left) and Dr Heinz Riesenhuber, Federal Republic of Germany

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Benefits to Europe

Europe's participation in the Columbus/Space-Station Programme will:

- provide access to long-duration manned space flight using the largest and most advanced facilities available;
- offer the European user community an unprecedented quantity and quality of microgravity mission opportunities;
- enable Europe to maintain and develop the technological knowhow in manned space flights that it initially acquired with Spacelab;
- enable Europe to take part, using the Polar Platform, in the initial steps of a future international Global Earth-Observation Programme.

Last, but by no means least, this international cooperative endeavour will allow Europe to acquire expertise in the complex operational techniques associated with manned space flight.

In the words of Prof. Lüst, speaking after the signing ceremonies:

'Today we signed an Agreement for cooperation which should lead us beyond the year 2000. Modern technological projects have a long lead time before they reach final fruition. A lot can happen in that time, but we trust that whatever changes do occur we, the 'Four Partners' in this challenging new venture, will forge ahead and succeed in our endeavour to conquer space together'.

Concluding remarks by Dr Heinz Riesenhuber, German Federal Minister*

In signing this Intergovernmental Agreement today, European Governments' members of ESA have responded definitively to the invitation extended by President Reagan in 1984. This invitation was first taken up positively by European Ministers meeting in ESA Council in Rome in 1985. Then Ministers decided not only to prepare Europe's own capabilities for the support of man in space, but also to establish a partnership with the United States in the International Space Station Programme.

European Governments have felt very strongly that cooperation in the development and use of a civil space station should be based on the principle of genuine partnership. They made this clear in the two ESA Council Meetings at Ministerial Level — in Rome in January 1985 and in The Hague in November 1987.

With the conclusion of the Agreement, which we have just signed, we will set the scene for Western efforts in space. The West herewith sets up a genuine partnership in a permanently manned civil space station for peaceful purposes. This cooperation is unique. The challenges, and the funds involved, are enormous; our cooperation is meant to last for a long time.

The impact of this cooperation will not be limited to space only. By concentrating their technical and scientific efforts and means, and by securing a free flow of information and technical data among all partners, the nations of the Free World can exploit the enormous potential of advanced and new technology.

This Agreement is the result of a compromise. In the course of a long negotiation there have certainly been many compromises.

But it is a compromise with which every partner can live. The Europeans want to make our joint venture, they want to make our partnership a living exercise of true, equal and productive cooperation in a field which presents a great challenge: Europe, the United States, Canada and Japan associated in the first space venture expanding the Western horizon into space for the benefit of all.

*In his capacity as Chairman of the ESA Council Meeting at Ministerial Level in The Hague in November 1987.

The Columbus Development Programme

F. Engström, J-J. Dordain, R. Barbera, G. Giampalmo & H. Arend, Directorate of Space Station and Platforms, ESA, Paris

The Columbus Development Programme, started in January 1988, represents Europe's major contribution to the cooperation with the United States, Japan and Canada in the International Space-Station Programme. It covers the development, manufacture and delivery to orbit of three space elements — an Attached Pressurised Module (APM), a Man-Tended Free-Flyer (MTFF), and a Polar Platform (PPF), buildup of the related ground infrastructure, and preparation for intial operations and subsequent utilisation.

Introduction

The successful first flight of Spacelab in November 1983 represented an important milestone in the European commitment to manned space flight. The Spacelab missions, however, were never seen as a final goal for Europe. Several years before the first Spacelab flight, a parallel programme of mission and system studies was conducted which evolved, during the period 1982-84, into a number of study investigations (so-called 'Phase-A' studies). These were performed under ESA and national aegis, in concert with the initial NASA studies of a manned Space Station.

These studies, which covered both systems and utilisation aspects, were all completed by mid-1984. Then, in the context of President Reagan's proposal for an international partnership in the Space-Station Programme, the Columbus Programme was proposed for Europeanisation by Germany and Italy and became the focal point for future related ESA activities.

After a programme bridging phase in late 1984/early 1985, Columbus definition activities were officially given the go-ahead at the Rome Council Meeting at Ministerial Level in January 1985 and the Columbus Preparatory Programme was born.

The main objectives of this Preparatory Programme, implemented in mid-1985 and finalised industrially in April 1988, were the definition of the Columbus space segment, the development of critical technologies, and the preliminary investigation of the user requirements and of the operations infrastructure.

Based on the results of these Phase-B studies and the progress achieved in the negotiations with NASA, at The Hague Council Meeting at Ministerial Level in November 1987 Europe approved the Columbus Development Programme. This provides for the manufacture and delivery to orbit of the three Columbus space elements, build-up of the associated ground infrastructure, and preparations for initial operations and utilisation.

The primary objectives of the Programme, which started in January 1988, are to:
- provide an in-orbit and ground infrastructure compatible with European and international user needs from the mid-1990s onwards
- continue, and further develop, Europe's capabilities in manned space flight
- cooperate with the United States and other partners in the International Space-Station (ISS) Programme
- ensure European autonomy in the longer term, in particular through cooperation in the International Space-Station Programme
- ensure the establishment within Europe of the key technologies required for manned space flight and for a wide spectrum of in-orbit operations, both manned and automated.

The Programme content

The Columbus Development Programme

covers:
- the development, manufacture and delivery-to-orbit of three space elements — Attached Pressurised Module (APM), Polar Platform (PPF) and Man-Tended Free-Flyer (MTFF).
- the buildup of the related ground infrastructure
- the initial preparational activities for operations
- the preparatory activities for utilisation.

The Programme is being conducted in two phases. Phase-1 (1988—1990) is a detailed design, definition and initial-development phase. Its aim is to optimise technical, operational and programmatic coherence and cooperation with the other three European space-infrastructure programmes — Hermes, Ariane-5 and the European Data-Relay Satellite — and to establish the related interfaces with the International Space-Station Programme. This first phase will be followed by a Phase-2 dedicated mainly to the full development, manufacture and integration of the space-segment elements, their initial launches, the setting up and validation of the ground infrastructure, and preparations for Columbus utilisation, culminating in flight opportunities on Spacelab, Eureca, etc.

Major Phase-1 milestones on the space-segment side are: the Preliminary Requirements Review (PRR-1 December 1988, PRR-2 February 1989), the System Requirements Review (second half of 1989), the Programmatics Review (June 1990), and the APM Preliminary Design Review (second half of 1990).

The current target launch dates for the space elements are:

APM	October	1996
PPF	April	1997
MTFF	April	1998.

As far as the trans-Atlantic cooperation is concerned, the negotiations between ESA and NASA on a bilateral Memorandum of Understanding (MOU) for cooperation in the design, development, operation and utilisation of the permanently manned civil International Space-Station complex were successfully completed in January 1988. This MOU was adopted by a unanimous vote by all ESA Member States in March 1988, authorising the Agency's Director General to proceed with the signature of the Agreement, which took place in Washington DC on 29 September 1988.

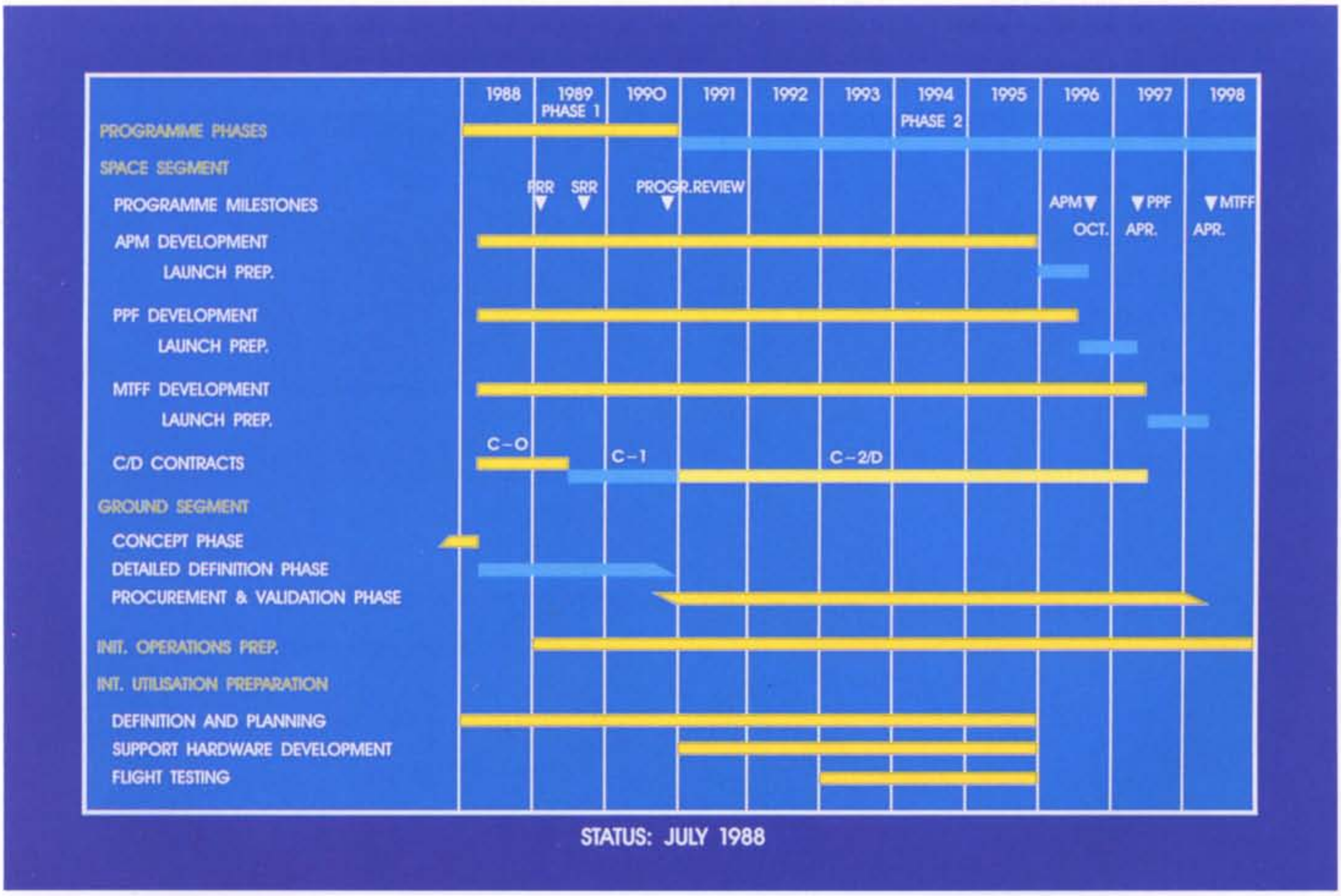


Figure 1 — Scheduling for the Columbus Development Programme

Space-segment development

The Columbus space segment is designed to provide Europe from the late 1990s onwards with a comprehensive space infrastructure that initially can fulfil the terms of the cooperation with the United States and other international partners, and later can form the basis of a completely autonomous European capability.

To satisfy the anticipated user needs in the late 1990s and beyond, the space segment consists of three elements with dedicated mission scenarios in low-Earth and polar orbits:
- The APM, a laboratory dedicated to payloads and experiments requiring the permanent presence and interactive capability of man.
- The MTFF, for payloads that require a long, undisturbed microgravity environment, but need manned intervention at the beginning or end of the experiment.
- The PPF, supporting automated payloads in Sun-synchronous polar orbit.

Both the APM and the MTFF are designed to be serviced by manual intervention. The PPF, on the other hand, will be an expendable platform, due to the limited servicing capabilities available in polar orbit, and overall system-cost considerations.

The APM

The APM is a pressurised cylindrical laboratory module, which will be permanently attached to the International Space Station manned base. It has a diameter of about 4 m, and is the length of four standard Spacelab segments (12.8 m). It will be used primarily for materials-science, fluid-physics, and compatible life-sciences missions.

The APM will be launched from Kennedy Space Center on a dedicated Shuttle flight, unloaded in orbit from the Shuttle's payload bay, and then docked with the Space Station. The APM is equipped with docking ports at both ends, one of which will be used for docking to the Space Station; the other will remain available for Station growth or contingency docking.

The APM, and the other three pressurised Space-Station modules — the two US modules and the Japanese Experiment Module (JEM) — will be mounted along the Station's flight axis, close to its centre of gravity, in order to achieve the best possible microgravity environment.

The internal architecture of the Module, which will provide a shirt-sleeve environment for the crew, reflects the familiar 1 g working environment on Earth, with lateral racks, a floor/subfloor area, and an overhead area. The subsystems required to sustain the Module's functions and to provide the necessary payload services and life-support for the crew are accommodated under the floor and in standard, side-mounted single or double equipment racks. All subfloor subsystem equipment and the standard racks can be exchanged in orbit.

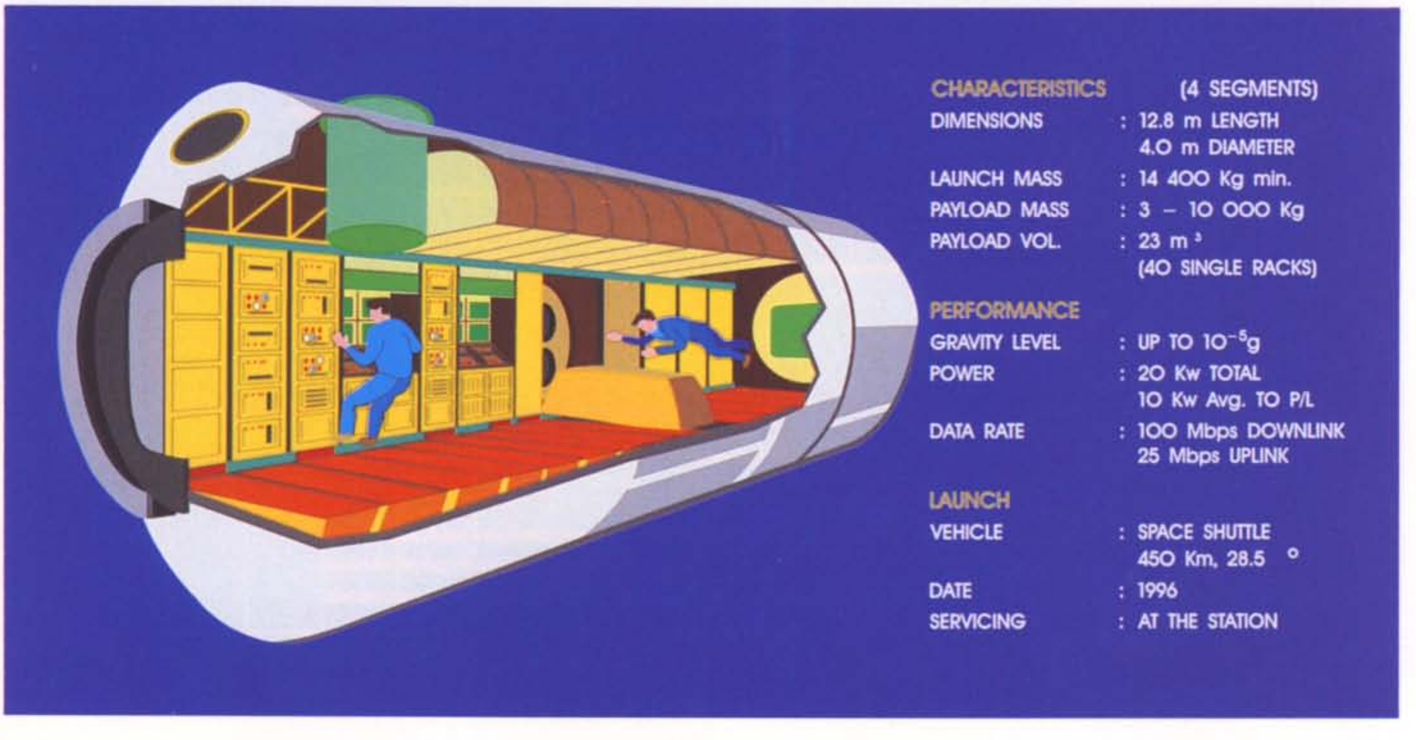


Figure 2 — The Attached Pressurised Module (APM)

Figure 3 — The Man-Tended Free-Flyer (MTFF)

The APM has two viewing ports for external observation, and a scientific airlock for small experiments that require exposure to the vacuum of space.

The equivalent of about 40 single racks (approximately 23 m^3) is dedicated to the accommodation of European and internationally provided payloads. The reduced performance of the Space-Shuttle system after the Challenger accident allows only a partial installation of the APM payload with the initial launch. The rest — the maximum APM payload mass under operational conditions is 10 000 kg — will be gradually installed using subsequent Shuttle logistics flights.

The APM will rely on the Space Station's manned base for all primary technical resources, including power and communications links, heat rejection, environmental and life support, and crew accommodation. It will be serviced via the standard Space-Shuttle logistics support flights to the Space Station. Internally mounted items will be serviced by the crew, including European astronauts. External items will be serviced using the Space-Station's Remote Manipulator System, and via crew Extra-Vehicular Activity (EVA).

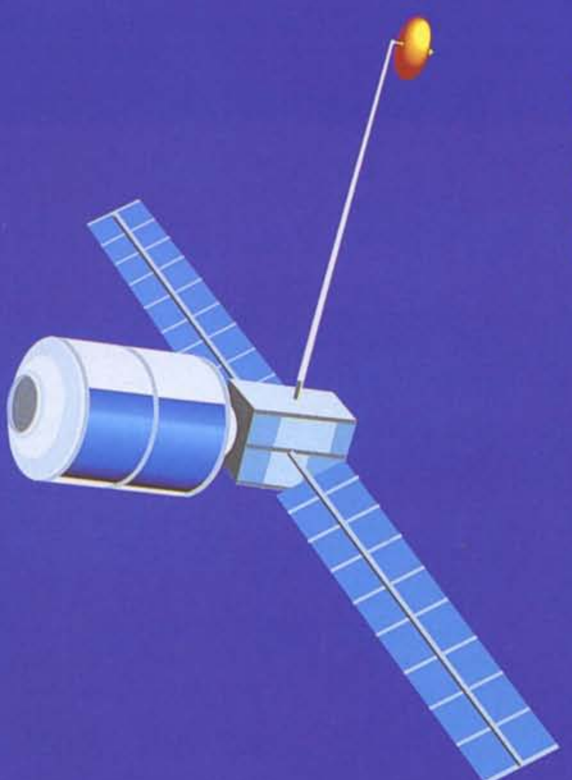
The MTFF

The MTFF will be operated in a microgravity-optimised orbit of 28.5° inclination, centred on the International Space Station's manned base. It will accommodate automatic and remotely controlled payloads, primarily from the materials sciences, fluid-sciences and compatible life-sciences and technology disciplines.

The MTFF will be launched, together with its initial payload, by an Ariane-5 vehicle from Kourou, French Guiana.

The MTFF consists of a two-segment 'Pressurised Module' for the accommodation of payloads, and an unpressurised 'Resource Module' that provides the main utilities and services required by the MTFF and its payloads.

The Pressurised Module has the same structural concept and architectural layout as the APM, with a Space-Station-compatible docking port in one end cone and the Resource Module attached to the other. The subsystems are accommodated under the floor and in side-mounted, standard single or double equipment racks. All under-floor subsystem equipment and the standard single and double equipment racks can be exchanged in orbit.



CHARACTERISTICS	(2 SEGMENTS)
DIMENSIONS	: 12.08 m LENGTH 4.37 m DIAMETER
LAUNCH MASS	: 18 200 Kg
PAYLOAD MASS	: 2 – 5 000 Kg
PAYLOAD VOL.	: 10.5 m^3 23 SINGLE RACK EQUIVALENT (INCLUDING STORAGE)
PERFORMANCE	
GRAVITY LEVEL	: UP TO 10^{-6}g
POWER	: 10 Kw TOTAL 5 Kw Avg. TO P/L
DATA RATE	: 100 Mbps DOWNLINK 20 Mbps UPLINK
LAUNCH	
VEHICLE	: ARIANE 5 460 Km CIRC., 28.5°
DATE	: 1998
SERVICING	: 180 DAYS BY HERMES OR AT SPACE STATION

Figure 4 — The Polar Platform, Option A

The maximum payload volume is equivalent to approximately 23 single racks, including storage. Up to 2000 kg of payload will be installed in the Module during launch. The Module's maximum payload under operational conditions is 5000 kg.

The Resource Module is linked to the Pressurised Module by an interface adaptor, and consists of a main body and a 'Super Orbital Replaceable Unit'. Two solar arrays, a large antenna mast for the Ka/Ku-band antenna, and the L- and S-band antenna booms are mounted externally on the main body.

The reference concept for the Super ORU contains bipropellant tanks, cold-gas and Environmental-Control Life-Support (ECLS) tanks, batteries, a freon pump package and four standard ORUs for drive electronics. The other subsystems are mounted in small standard ORUs under protective covers.

The MTFF will be routinely serviced in-orbit by Hermes at approximately six monthly intervals. Initially this servicing will be performed at the Space Station, which the MTFF will also visit every three to four years for major external maintenance events, such as the exchanging of the Super ORU.

The PPF

The unmanned Polar Platform will be stationed in a highly inclined, Sun-synchronous polar orbit (morning descending node) and will be used primarily for Earth-observation missions. It is planned to operate the PPF in conjunction with one or more additional platforms provided by NASA and/or other international partners, and it will be sized to accommodate both European and other internationally provided, automated payloads.

Two expendable-platform concepts are presently being studied in parallel:

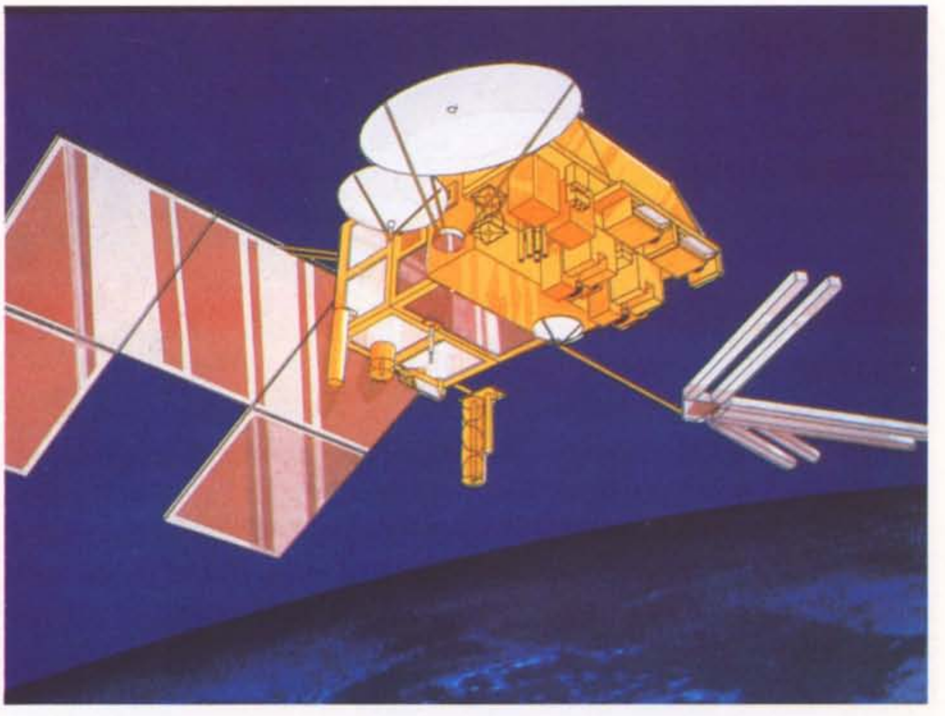
Option A: a platform with a nominal lifetime of four years (propellants for six years), consisting of a utility module with all platform systems, and a payload carrier which provides payload instrument mounting and platform-services distribution networks.

The platform has a payload capacity of 2300 kg (net), plus 500 kg of payload support hardware, and provides 2.6 kW of power (average) to the payload. The concept is based on maximum commonality with the APM and MTFF, and uses proven technology from, for example, Eureca to reduce development cost and risk.

Launched by Ariane-5 from Kourou into a high-inclination intermediate orbit, this platform deploys automatically after separation from the L5 stage, is activated from the ground for initial verification of on-board systems and payloads, and then transfers itself up to its operational orbit under its own propulsion to commence its mission. The propulsion system is sized for a controlled platform re-entry at the end of its orbital lifetime.

CHARACTERISTICS	
DIMENSIONS	: 10 m LENGTH PAYLOAD CARRIER: 7 x 2.9 x 1.4
LAUNCH MASS	: 10.837 Kg
PAYLOAD MASS	: 2.300 Kg (NET INSTRUMENTS) + 500 Kg (INTERFACING H/W)
PERFORMANCE	
POWER	: 5.8 Kw TOTAL 3.2 Kw TO P/L
DATA TRANSMISSION	: (1) VIA EDRS → 3 CHANNELS MAX 150 Mbps EACH (2) VIA X-BAND DIRECT TO GROUND → 3 CHANNELS MAX 150 Mbps EACH
DATA STORAGE	: TOTAL CAPACITY 30 Gb RECORDING 10 Mbps PLAYBACK 50 Mbps
LAUNCH	
VEHICLE	: ARIANE 5 824 Km, 98,8° incl.
DATE	: 1997
LIFETIME	: 4 YEARS (PROPELLANT FOR 6 YEARS)

Figure 5 — The Polar Platform, Option B



Option B: a platform with a nominal lifetime of four years (propellants for five years), consisting of a bus derived from the Spot-4 spacecraft, which provides the main resources for system and payloads, and a payload module that houses a payload-data broadcast assembly.

This platform option has a payload capacity of up to 1700 kg (net) and provides up to 1.7 kW of power (average). The concept benefits from the Spot bus development and its recurring manufacturing process, while the payload module and its electronics compartment would be a new development.

Launched by an Ariane 44P or 42L vehicle from Kourou, the platform deploys after separation and is activated from the ground for system and payload verification before commencing its nominal four-year mission.

The concept to be developed eventually in the context of Columbus Programme will be selected based on the results of the current industrial studies of both Polar-Platform options. This selection will take place in early 1989, and user requirements, technical and programmatic definition and overall system costs will be critical parameters in this choice.

Approach to space-segment development

The overall industrial structure for the Columbus space-segment development programme is headed by a Prime Contractor, contracting directly with ESA on behalf of the Columbus industrial consortium, which includes 'element' contractors, system-level contractors (e.g. for the development of the Data-Management System), and several subcontractors.

Early industrial Phase-C/D work (Phase C-0) was initiated in April 1988, immediately after completion of the industrial activities related to the Columbus Preparatory Programme, and will continue until mid-1989.

The industrial proposals in response to the Request for Quotation (RFQ) issued to industry in July 1988 will be available in May 1989 and will be based on the design and definition work performed during Phase C-0. The main development (Phase-C/D) contract will come into effect in July 1989.

The space-segment development programme will be phased in a way that allows maximum benefit to be derived from subsystem and equipment commonality between the elements and, where feasible, in conjunction with other programmes. The phasing of the APM and the MTFF development programmes will also be arranged to exploit the cost benefits of follow-on production.

Buildup of the ground infrastructure

The ground infrastructure for the Columbus Programme will consist of a range of facilities in the ESA Member States, and in the USA, to meet the European and international requirements for:

- mission control and payload-operations coordination
- test and verification of the space segments and payloads
- training of crew and support personnel
- engineering support and payload integration
- logistics.

The planned European In-Orbit Infrastructure (IOI) for Columbus brings a new dimension to the scale of the problems to be solved, in terms of the complexity of the interrelationships between the various elements, the need to interface with several international partners, the demands on human resources, and the size of the investments required on the ground. The last two aspects in particular have led to a decentralised IOI being considered, drawing on both current and planned facilities and capabilities in the ESA Member States, but still under the overall control of a central planning and monitoring authority (Fig. 6).

Figure 6 — Columbus In-Orbit Infrastructure (IOI) ground-segment configuration

The Central Mission Control Centre (CMCC) at ESOC, in Darmstadt, will coordinate and control the preparation of mission activities, as well as monitor their execution, and control the overall communications network.

The decentralised facilities for element control include:

- A Manned Space Laboratories Control Centre (MSCC) at the German Space Operations Centre (GSOC) in Oberpfaffenhofen, including a Regional Payload Operations Centre (ROC) responsible for the coordination of European payload operations on-board the APM and elsewhere on the Space Station, and the MTFF Control Centre (MTFFCC), responsible for systems-operations control and payload-operations coordination.
- The PPF Control Centre (PPFCC) (which could be provided by upgrading an existing facility), responsible for system and payload control.
- Centres for payload integration, engineering support and logistics services for the APM and the MTFF, located in Italy and Germany, respectively.

The APM will be operated by an ESA team at the Space-Station Control Centre (SSCC) in the USA. ESA will also establish facilities in the USA for real-time operational support.

In addition to the facilities mentioned above, there will also be a range of User Support Operations Centres (USOCs), as well as User Familiarisation Centres (UFCs). One USOC and one UFC for the user community will be provided by the Columbus Programme as part of the 'Utilisation Preparation Activities'. The remainder, the number of which will be determined by users' needs, will be provided by national agencies in the ESA Member States.

A range of facilities will also be made available for astronaut training using both existing facilities and new developments, such as APM and MTFF simulators. The central crew-training facility will be at ESA's Astronaut Headquarters, to be established at Porz-Wahn, in Germany.

The detailed overall architecture and the functions of the various centres and facilities have already been specified by ESA's Central Design Authority and the detailed design phase, which will last until the end of 1990, is about to begin.

Preparations for initial operations

The purpose of these activities is to ensure that the ground segment is ready approximately 18 months before the launch of each space element. This means provision of verified procedures for operating the complex space segment from the ground, with its payloads and astronauts on board, reflecting the high demands in terms of crew safety and the need for high-quality scientific output from the payloads to the principal investigators. A fully tested and validated ground segment, including hardware, software, support services, training, etc., is a prerequisite in this context.

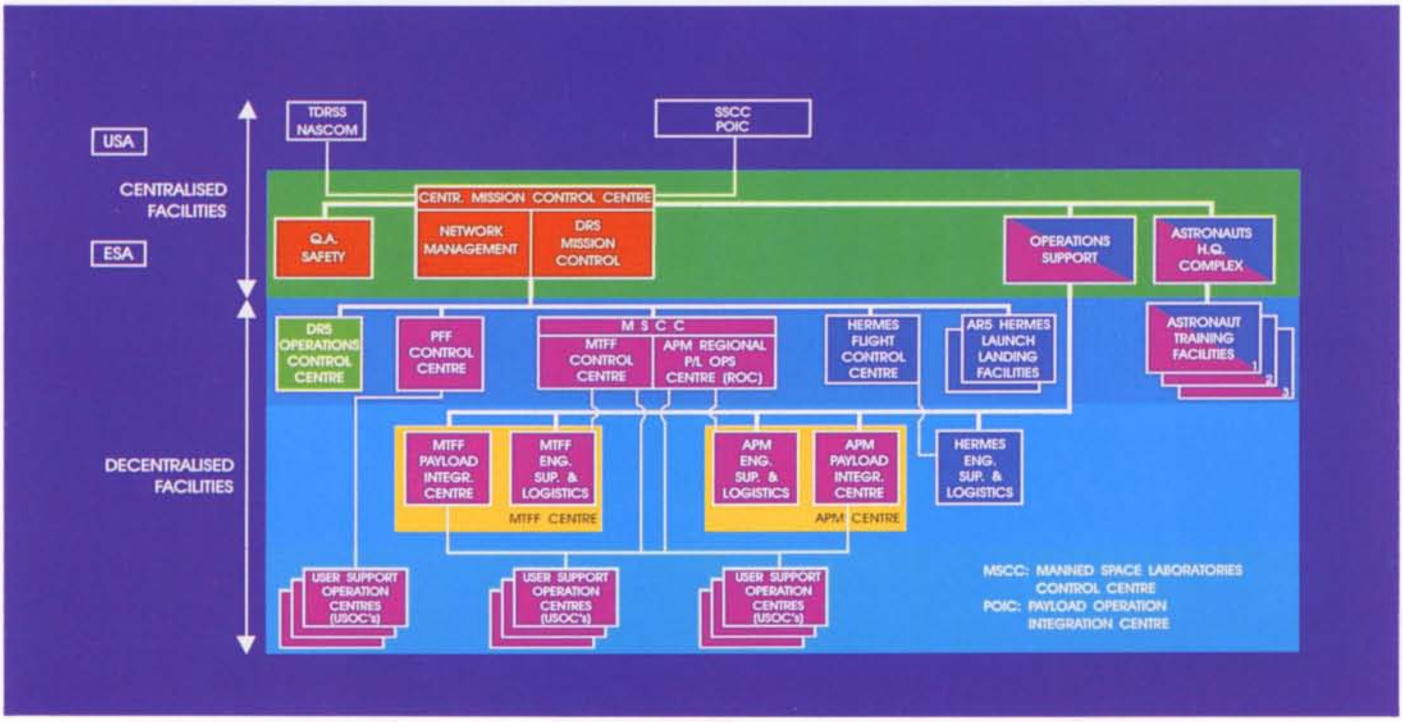


Figure 7 — Artist's impression of the Columbus Programme elements: APM, MTFF and Polar Platform

Until the end of 1990, activities will concentrate on the preparation of mission-control and operations support for the Central Mission-Control Centre (CMCC) and for the APM. The remaining activities will be completed between 1991 and a date 18 months before the launch of a given Columbus space element.

In the remaining 18 months prior to launch, the integrated mission-preparation activities will form part of the Columbus Exploitation Programme, covering the transition from development to operations by gradually staffing the mission-control and support posts and providing the necessary training.

Preparations for initial utilisation

These activities are intended to ensure the efficient exploitation of the Columbus system throughout its lifetime, by:

- defining the rules of utilisation: strategic planning of facilities, tactical planning of experiments, management plan, charging policy, etc.
- building-up a Columbus user community, familiarising them with and helping them to access the Columbus system
- complementing the Columbus system by defining and building common user equipment, interface hardware, and interactive operational tools in order to improve the efficiency and flexibility of the system and user autonomy
- training the teams, i.e. investigators, astronauts, project and ground teams, for routine Columbus operations.

The utilisation activities will have three main themes: definition and planning, hardware development, and flight testing.

Efficient exploitation of Columbus also calls for the efficient provision of information to users. Documentation and databases have to be set up that are compatible with the other partners' information systems. An electronic Columbus Utilisation Information System, currently in a prototype definition phase, will be tested by the users during 1989.

A significant amount of training, validation and qualification can be done on the ground to familiarise the user with the Columbus system by exploiting test beds and simulators. A full-scale mock-up of the APM has been set up which will be used to verify man/machine interfaces and to test the proposed system/payload interfaces. Test beds for the interactive operational concepts, i.e. 'telescience', Data Management System, and Crew Work Station, will be available to users from 1989 onwards.

The flight-testing element is the logical extension of the ground activities, before the commencement of routine operations. It embraces:

- hardware tests: capabilities and use of new hardware related to payloads, robotics and common equipment
- operations tests, such as payload maintenance, changing and checking out of racks, interactive operations (telescience), etc.
- training of teams prior to routine operations.

Figure 8 — Full-scale mockup of the APM

The four criteria used in defining the flight-testing programme will be:

1. What cannot be done by ground simulation?
2. When do we need this flight experience according to the Columbus Development Plan?
3. What are the most appropriate available flight opportunities (parabolic flights, sounding rockets, or Spacelab)?
4. How will it improve the scientific return?

It is planned to share some Spacelab flights with the other Space-Station partners as a simulation test bed for Space-Station utilisation.

These so-called 'Initial Utilisation Preparation Activities' will last until 1995, with the Columbus Exploitation Programme taking over utilisation activities from 1993 onwards (Fig. 1).

Conclusion

The decision to conduct the Columbus Development Programme represents an important milestone in the development of Europe's expertise in autonomous space infrastructures. The Programme provides for the setting up of both a space and a ground infrastructure in the framework of the International Space Station Programme, as well as preparations for its operation and utilisation.

As a complement and follow-on to these initial operations and utilisation activities, a Columbus Exploitation Programme will be prepared, with a proposed starting date in 1993. This Programme will cover the systems operations for the Columbus space and ground segments, and utilisation support, such as payload launch and recovery and payload coordination.

A Future Studies and Development Programme, starting in 1991, will phase over during the 1990s into the development of a fully autonomous European Space Station for the beginning of the next century.

A New Generation of Spacecraft Control System — 'SCOS'

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Several factors have prompted ESOC to develop a new generation of spacecraft control system architecture. The advent of satellite on-board processors handling more and more complex data structures, the consequent increase in requirements for operational functions, and the availability of commercial software products suitable for this type of application have all played a role.

ESOC decided, based on its experience with its original Multi-Satellite Support System (MSSS), which is still in operation, to develop a new software package called 'SCOS', which is essentially telemetry- and packet-oriented, and which will be used by all future ESA missions supported by the Dedicated Mission-Support System (DMSS).

The Hipparcos, Eureca and ERS-1 spacecraft will be the first Agency missions to rely on the new generation of control system.

Background

The spacecraft control systems currently in use at ESOC are: the Multi-Satellite Support System (MSSS), on which the main Operations Control Centre in Darmstadt is based; and systems that are essentially copies of the MSSS, with the addition of some dedicated software. The system installed at the Agency's Redu ground station in Belgium to support the ECS family of communications satellites, and the system installed by Telespazio at the Fucino station near Rome to support the Olympus satellite, both fall into this latter category.

The design for the MSSS, first used in 1977, was based on the concept that the same software should support different types and models of satellites, which were to be described through appropriate tables derived from the so-called 'Satellite Characteristics Files'.

This concept proved to be extremely flexible and provided for re-usability of the system at two levels:

- The same system could support several spacecraft simultaneously, provided enough capacity was available in terms of memory and processing power; hence the name 'Multi-Satellite Support System'.
- The system could be 'cloned', i.e. reproduced and installed at other control centres, with a minimum of modification and very little effort.

The MSSS has exploited two generations of hardware during its lifetime. The initial version installed in 1977 was converted in the early 1980s to a more modern family of computers. It still represented the state-of-the-art for spacecraft control systems in the mid-1980s and several licences to re-utilise the system or its design have been granted by ESOC to industry and to other organisations developing spacecraft operations control centres.

New factors

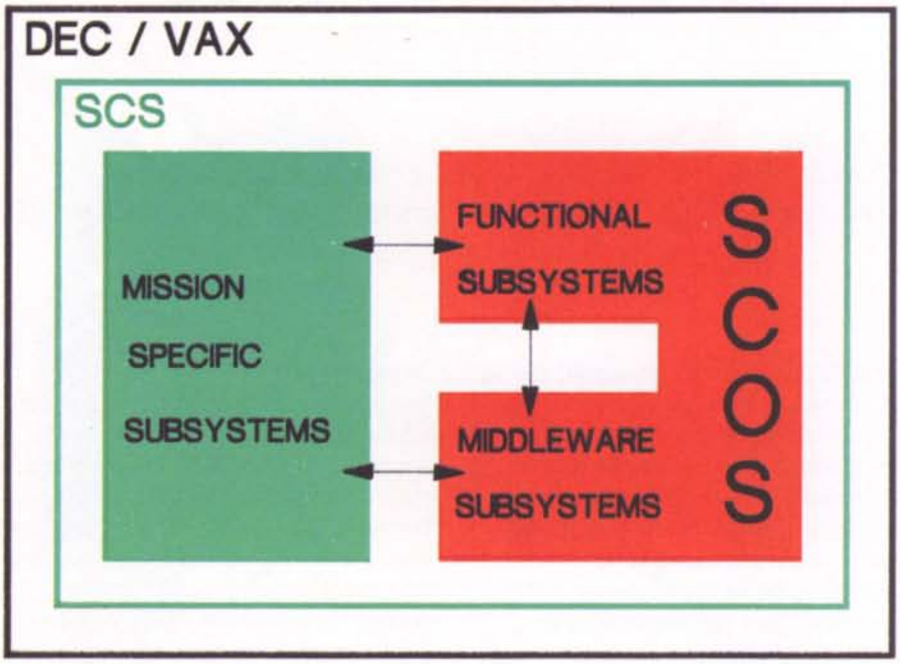
Evolution of spacecraft data structures

The design of spacecraft has evolved considerably since the MSSS was first conceived. The presence of intelligent processors on-board the satellite has fundamentally changed the nature of the information needed to control it, and hence the nature of the data to be handled by spacecraft control systems.

The traditional fixed-format telemetry delivered at synchronised time intervals, i.e. the so-called 'Time-Division Multiplexed' (TDM) telemetry, began to be modified to enable the introduction of floating areas in the format, thereby very much complicating the software needed for interpreting the telemetry. Similar or even greater levels of complication were introduced in the telecommand structure. Moreover, with the ever-growing presence of microprocessors on-board spacecraft, data generation no longer needs to be synchronised.

Recognising this evolution, the Consultative Committee for Space Data Systems (CCSDS) has recommended a new standard for telemetry called the 'Telemetry Packet Standard', which

Figure 1 — The Spacecraft Control and Operation System (SCOS) concept



supports variable-length, asynchronous-type data. ESA has adopted this standard for its future spacecraft. Unfortunately, a system like the MSSS that supports the classical type of telemetry and telecommands cannot support packet telemetry and telecommands.

Evolution of hardware
When the MSSS was first installed in 1977, hardware costs were high compared with software costs, and it was therefore advantageous to share the same hardware configuration between several missions. However, this approach subsequently posed problems, particularly when a mission with very special characteristics, such as Giotto, had to be supported.

In the meantime, hardware costs have fallen dramatically and the level of sophistication of the satellites, and hence of the missions supported, has increased greatly. Both of these factors serve as a driver for:

(a) having dedicated hardware configurations

(b) re-utilising software to the maximum extent possible.

The new concept
The combination of the above elements led ESOC to conceive a new generation of spacecraft control systems based on:

(a) Dedicated hardware configurations. This concept has been adopted to support the Hipparcos, Eureca and ERS-1 missions via the so-called 'Distributed Mission Support System' (DMSS) based on DEC/VAX computers (see ESA Bulletin No. 53).

(b) Re-utilisation of common software, since many data-handling functions are common to many spacecraft.

(c) Support initially for packet telemetry and later for packet telecommands.

(d) Use of commercial database management systems, which are particularly useful where there is a need for describing configurable aspects of a system. The new generation of spacecraft control systems at ESOC uses a relational database management system.

The SCOS requirements
The concept for the new standard Spacecraft Control & Operation System (SCOS) stemmed directly from the above considerations (Fig. 1). The initial objectives for this software package, which provides the backbone for any mission-dedicated spacecraft control system, were to:

— cover the classical telemetry-related functions: telemetry real-time validation and processing, real-time filing, real-time display, retrieval display, printouts

— support packetised telemetry as well as fixed TDM telemetry. However, telemetry packets can contain potentially unlimited data formats. For the time being, therefore, the SCOS supports a generalised version of the packet structures adopted for Eureca

— provide all low-level functions not visible to the user (so-called 'middleware' functions) needed to build a complete Spacecraft Control System (SCS). The SCOS incorporates these middleware functions as well as the mission-specific software

— provide standard interface points for mission-specific applications to be easily integrated with the SCOS

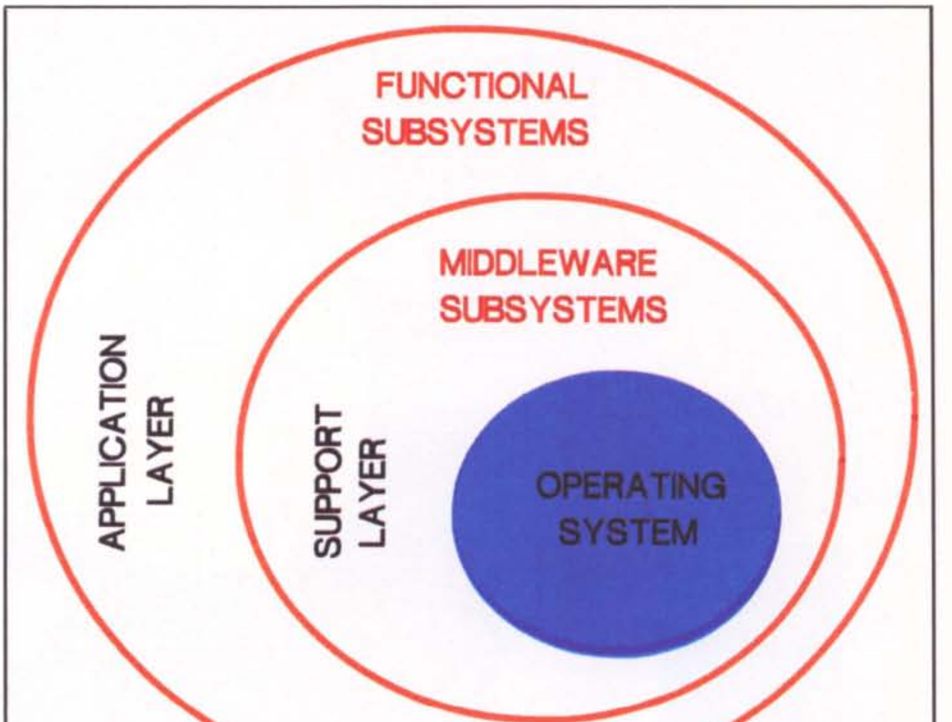
— be able to run on any of the DEC/VAX computer series (the sizing of the computer will depend on the mission load profile)

— interface with the existing INTEL work stations in operation at ESOC and used by the MSSS

— be able, if needed, to support several missions (e.g. of the same spacecraft family) on the same computer (rather than having multiple copies of SCOS)

— as with the MSSS, to have the system consist of loosely coupled subsystems in order to permit functional

Figure 2 — The SCOS layered model



expandability while maintaining robustness

- be able to support multiple asynchronous telemetry data streams, particularly for low-orbit missions
- be easily and safely configurable using the 'Oracle' relational database management system.
- be ready to be used initially for Hipparcos, Eureca and ERS-1.

The SCOS architecture

The SCOS system embraces a set of well-defined subsystems providing standard interfaces and which can configured in a variety of ways. Hence there is no fixed system architecture in the strict sense, but rather there are principles and rules governing the combination of these subsystems.

The principal architecture of a generic Spacecraft Control System is based on two layers of operation (Fig. 2):

- The *application layer*, which is composed of those functional subsystems that handle all operational features that are directly perceptible to the user. Each functional subsystem is itself composed of applications tasks.
- A subordinate *support layer*, composed of an infrastructure of middleware subsystems performing low-level functions not supplied by the operating system.

The application layer contains the SCOS functional subsystems as well as the mission-specific subsystems. The SCOS functional subsystems provide standard connection points, enabling the integration of the complete SCS. The services of the middleware subsystems are shared between the higher level subsystems, and ensure a coherent architecture.

The most important subsystems are:

Functional subsystems

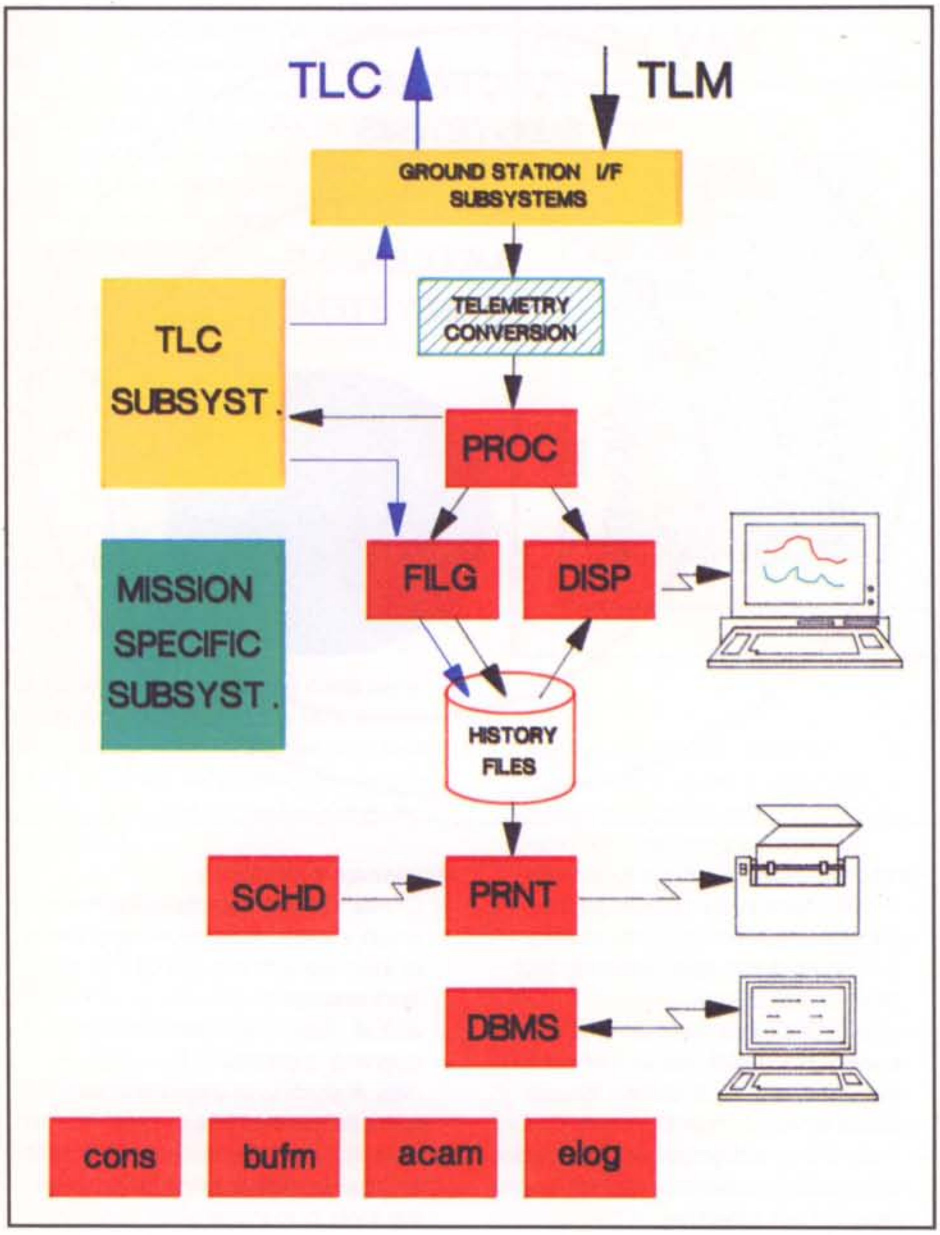
- PROC: Telemetry processing subsystem performing parameter derivation, and overall checking (out-of-limits, consistency, etc.)
- DISP: Display of the telemetry parameters in real-time or retrieved from history files, in various formats (alphanumeric, graphic)
- FILG: Filing subsystem which provides any application with the possibility of filing data in real time
- PRNT: Printout subsystem used to select and execute various types of telemetry prints
- SCHD: Scheduler subsystem enabling the scheduling of any task or action within the system at an absolute time or relative to defined events (e.g. satellite pass)
- DBMS: Database management subsystem enabling consistent editing of spacecraft characteristics or user-defined data (e.g. display proforma) and derivation of the necessary run-time files.

Middleware subsystems

- CONS: Console-handler subsystem, which enables interactive applications to interface with the operational INTEL work stations
- BUFM: Buffer-manager subsystem enabling applications to exchange data according to distribution lists without core movement
- ACAM: Circular access method used to file data. This subsystem provides the tools to manage such files and the routines to access them concurrently in real time from several applications
- ELOG: Event-logger subsystem which allows applications to log important messages in a file and send them to users, e.g. alarms.

A typical SCS assembly is shown in Figure 3. The ground-interface subsystems and the (major) telecommand subsystem are not yet part of the SCOS. For those missions not conforming to the telemetry format standards, telemetry

Figure 3 — SCOS-based spacecraft control system architecture
Red : current implementation
Yellow : future implementation
Green : mission-specific software



conversion subsystems of varying complexity are needed.

Technical characteristics of the SCOS
The SCOS has been developed in structured Fortran to run on DEC/VAX computers. The system is portable to other computer types, provided the middleware subsystems are suitably adapted.

The SCOS is highly configurable. Some of the software configuration tables are static and correspond to a 'system generation'. Others are modified dynamically by the system itself and saved whenever modified. In the event of a system breakdown, the whole system can be booted up in its previous configuration.

The SCOS is driven by the satellite characteristics described in 'Oracle' database tables. Telemetry and telecommand contents and interpretation rules are entered via editors in the relational database, which check the consistency of all predefined relations. Other types of information, such as user-display or print definitions, are also entered in the same way.

Like the MSSS, the SCOS can be configured as a multisatellite system, which means that any of its functional subsystems is able to support several spacecraft concurrently, provided that the necessary computing power is available.

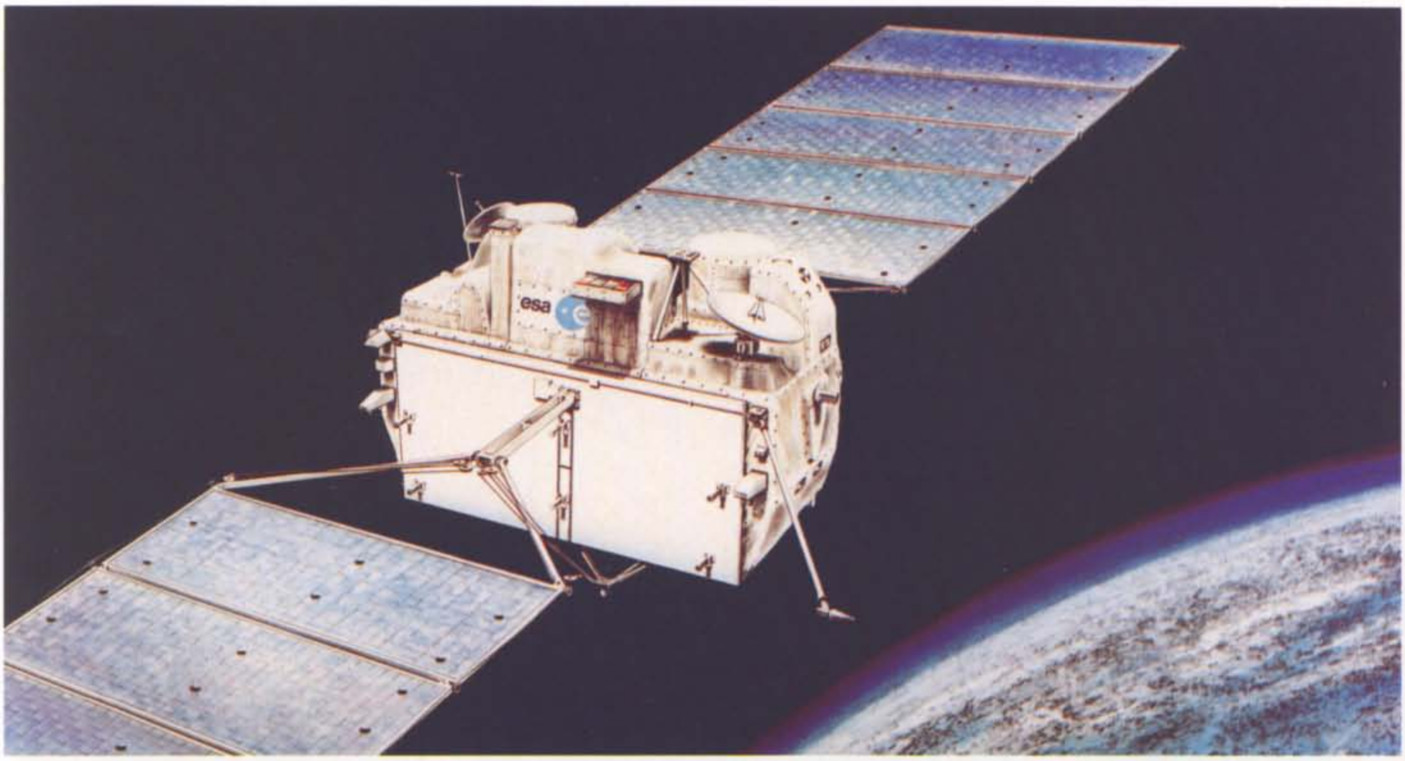
Present status
The SCOS will be used initially by the dedicated control systems for the Agency's Hipparcos, Eureca and ERS-1 spacecraft. The package went through several releases in 1988, which were used to build up the Hipparcos spacecraft control system. It was used to run the so-called Hipparcos 'listen-in tests' in April 1988 with the real spacecraft, which successfully demonstrated the functional status of the SCOS. The SCOS will be fully operational by the end of 1988.

The SCOS has also been integrated into the Eureca dedicated spacecraft control system. This project is now in a fairly advanced implementation phase and will be the first real user of packet telemetry. This low-orbit mission will also rely on recorded telemetry which will be downloaded in parallel with the real-time telemetry. The SCOS system is able to handle both streams simultaneously and to reconstruct the original telemetry data set as generated onboard the spacecraft, irrespective of the passes when the telemetry (either real-time or played-back) is acquired at the ground station (Fig. 4).

The SCOS will also be used by ERS-1's dedicated spacecraft control system. This project is also in the so-called detailed implementation phase.

The operational standardisation of these dedicated spacecraft control systems from a telemetry-monitoring point of view is regarded as a major achievement

Figure 4 — Eureca



made possible by the availability of the SCOS.

Future developments

The selection of the SCOS for three future ESA missions already with such different characteristics has resulted in very useful and practical standardisation experience that has led to the rapid identification of points for further improvement. These upgrades will be implemented as part of the SCOS follow-on activities.

The major activities planned for the future to make the SCOS both a complete and state-of-the-art product are:

New work stations

The present operational work stations are supported by an ESOC-engineered configuration based on an INTEL microprocessor. These so-called 'semi-intelligent' work stations were introduced at a time when no work station on the market was able to satisfy the operational requirements. It has recently been decided to implement a new generation of work stations based on SUN equipment. The latter provides a very user friendly man/machine interface supported by standard software and also provides considerable computing power. In order not to invalidate already developed interfaces (SCOS and mission-specific software), however, it has been decided to proceed with an 'emulation mode' implementation so that the interfaces of the new work stations to the application layer will remain identical to that of the old work stations.

The new work stations should become operational in emulation mode during the first quarter of 1990.

Decentralised SCOS

The 'emulation mode' is a transitory phase in which the SUN work station's power is not fully exploited. In fact, most of the interactive applications now running on the host computer can be 'distributed' to the new work stations. This has the advantage of giving the user a more informative data presentation (in terms of graphics, synoptic diagrams, etc.) combined with a faster response time, without competing for the host computer's resources.

This distributed version of the SCOS should be ready by mid-1991.

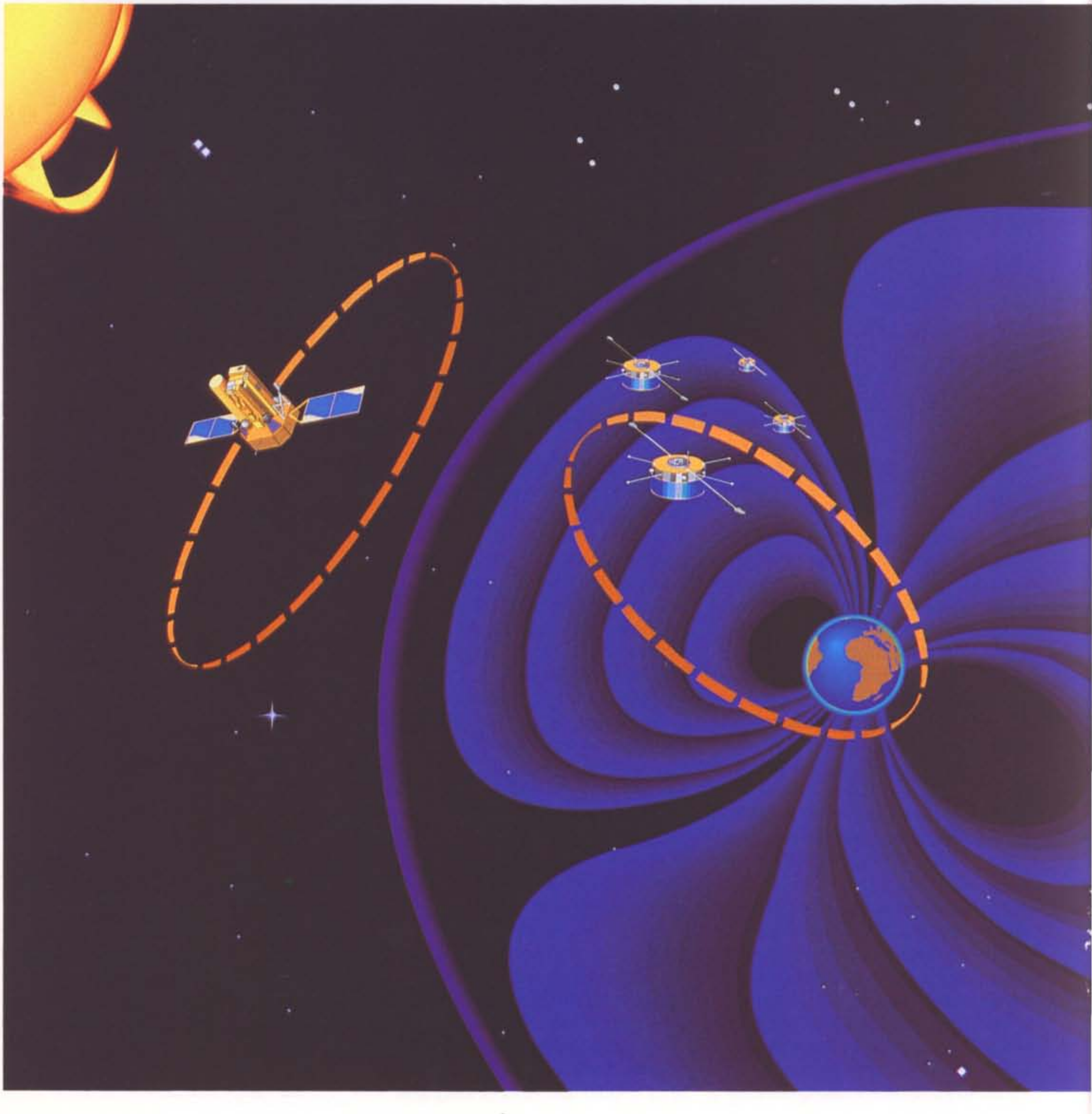
Telecommand chain

To make the SCOS a fundamental but complete standard spacecraft control system, all the common telecommand functions have to be implemented. This activity will start once the ESA Telecommand Packet Standard (derived from CCSDS) has been selected. This, again decentralised, implementation should also be completed by mid-1991.

Ground-station interface

It is also necessary to make the SCOS compatible with the ESA ground-station baseband equipment. The subsystem (supporting Mark II and III baseband standards for telemetry and telecommand) needed for this is also due to be ready by mid-1991.

Figure 1 — Schematic of the Soho and Cluster missions. The Soho spacecraft is located near the L_1 Lagrangian point in the interplanetary medium. The four Cluster spacecraft are shown in a 3 × 20 Earth radii (R_o) near-polar orbit



Soho and Cluster — The Scientific Instruments

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In March 1988, ESA and NASA jointly announced the scientific payloads to be carried by the single Soho and four Cluster spacecraft, which will be launched in 1995. These two missions will form the first scientific 'Cornerstone' in the framework of ESA's Long-Term Programme 'Space Science: Horizon 2000' and will represent the Agency's major contribution to the international Solar-Terrestrial Science Programme (described in detail in ESA Bulletin No. 50).

The need to understand the complex processes that control the structure and dynamics of our daylight star and define the Earth's environment in space, has long been widely realised (Fig. 1). Its continuing importance is reflected by the fact that twenty-three Principal Investigators and several hundred Co-Investigators from more than eighteen countries are now actively involved in the preparations for and execution of the Soho and Cluster missions.

The Soho mission

Scientific aims

The primary scientific aims of the Soho mission are to investigate:

- The physical processes that form and heat the Sun's corona, maintain it and give rise to the expanding solar wind; this is to by done by imaging and obtaining spectroscopic plasma diagnostics of the solar chromosphere, transition region and corona, as well as by in-situ solar-wind measurements.
- The interior structure of the Sun by helioseismological means and by the observation of variations in solar irradiance.

The solar corona and its expansion into the solar wind

Understanding the physical processes that form the Sun's corona requires coordinated investigation of the physical parameters involved with appropriate spatial and temporal resolution (Fig. 2). Such parameters include composition, density, velocities, temperatures, magnetic field, mass flows, temperature and density gradients, evolution of magnetic structures, shocks and waves. All of these need to be measured at different heights in the Sun's coronal holes, in loops and other atmospheric structures, in order both to test our current magneto-hydrodynamical models of coronal structures and to develop them further.

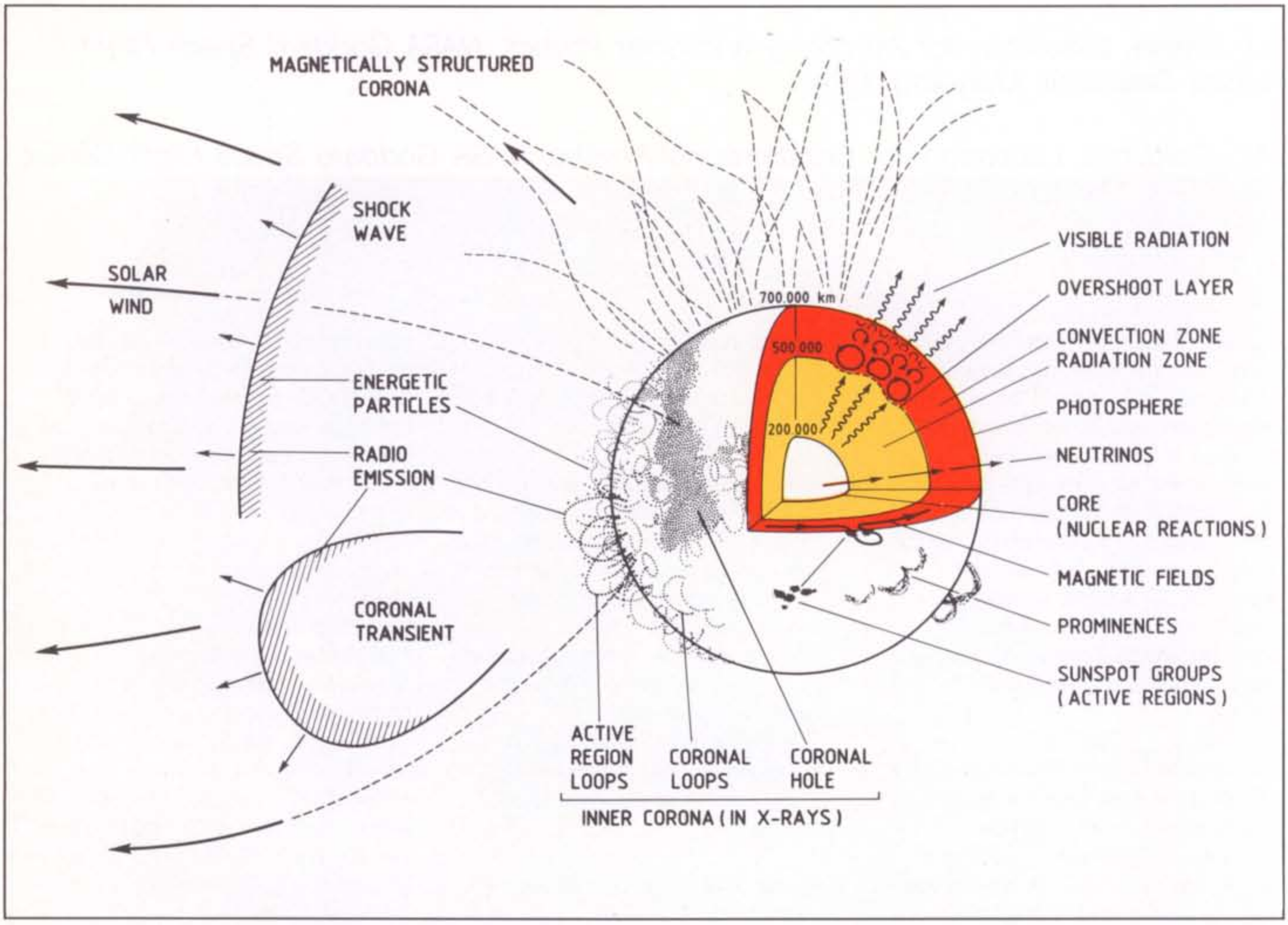
Current theories are either unable to explain completely the acceleration of the solar wind, or lack verification by measurement of important plasma parameters that are essential to test our understanding of the basic physical processes involved. To understand the corona and the solar wind as one physical system, the wind's main characteristics need to be measured at its source, in its acceleration regions, and in interplanetary space.

The Sun's interior

Past studies of the Sun's surface have revealed the presence of a large number of individual modes of oscillation of the surface. Their periods range from a few minutes to several hours, and their wavelengths from distances comparable with the Sun's circumference to a few thousand kilometres. The modes are coherent over at least a day, and in many cases much longer. Their frequencies can thus be determined with very high accuracy, making them sensitive probes of the Sun's interior structure.

Earlier helio-seismological investigations have already produced significant results, including determination of the Sun's equatorial rotation rate over a large part of its interior and the speed of sound in the outer 60% of its structure. Several coordinated efforts have been started to study solar oscillations from ground observatories, but they are hampered by noise effects introduced by the Earth's diurnal rotation and the transparency and 'seeing' fluctuations of its atmosphere. Soho will address in particular those parts of the solar-oscillation spectrum that cannot be properly observed from Earth.

Figure 2 — Sketch showing some of the major solar and heliospheric phenomena to be addressed by the Soho mission



The instruments and their measurements

The investigations that have been selected by the Joint Evaluation Committee for Soho (Table 1) provide a coherent set of Instruments that should achieve both of the primary goals outlined above.

The physical properties of the solar atmosphere and of the structures and regions discussed above can be determined by the analysis of emission-line spectra in the extreme ultraviolet (EUV). Electron density and temperature can be obtained from intensity ratios of spectral line pairs. Such line pairs reflect the excitation conditions and thus the physical state of the relevant part of the solar atmosphere. Spectral line shifts and line broadening can be used to derive line-of-sight velocity fields, temperatures and small-scale turbulence.

Soho's measurements will be made with a combination of normal- and grazing-incidence spectrometers (SUMER and CDS, respectively) to achieve the necessary spatial and spectral resolution and sensitivity. The SUMER and CDS spectrometers together cover a wavelength range that contains a large number of convenient ion emission lines for performing the desired plasma diagnostics in the chromosphere, transition region and low corona. The EIT instrument will provide the necessary synoptic information about the overall structure of the chromosphere and corona, as well as an evolutionary study of many structures.

To address the problem of the origin of the solar wind, and to investigate the outer corona, Soho will also carry an EUV coronal spectrometer (UVCS) that will extend the plasma diagnostics described above to a few solar radii, and a white-light coronograph (LASCO) to extend further the coronal observations out to 30 solar radii. The SWAN instrument will provide observations of the solar-wind streams at high latitudes by continuous mapping of the photon fluxes that result from the resonant scattering of solar Lyman-α photons by interstellar hydrogen atoms in the heliosphere.

Table 1 — Investigations to be performed by Soho

Instrument	Principal Investigator	Measurement(s)	Technique
Solar Ultraviolet Measurement of Emitted Radiation (SUMER)	K. Wilhelm, Max Planck Inst. für Aeronomie (MPAe), Lindau (D)	Plasma flow characteristics (temperature, density, velocity): chromosphere through corona	Normal-incidence spectrometer, 50—160 nm; spectral res. 2—40000; angular res. 1.2—1.5 arcsec
Coronal Diagnostic Spectrometer (CDS)	B.E. Patchett, Rutherford Appleton Lab. (RAL), Chilton (UK)	Temperatures and density: transition region & corona	Grazing-incidence spectrometer, 17—50 nm; spectral res. 5000; angular res. 2 arcsec
Extreme-Ultraviolet Imaging Telescope (EIT)	J.P. Delaboudinière, Lab. de Physique Stellaire et Planétaire (CNRS/LPSP), Verrières-le-Buisson (F)	Evolution of chromospheric and coronal structures	Images (1024×1024 pixels in 42×42 arcmin^2) at lines of He I, Fe IX, Fe XII & Fe XV
Ultraviolet Coronagraph Spectrometer (UVCS)	J.L. Kohl, Smithsonian Astrophys. Obs., Cambridge, MA (USA)	Electron & ion temperatures densities, velocities in corona (1.3—10 $R_\odot$)	Profiles and/or intensity of several spectral EUV lines between 1.3 & 10 $R_\odot$
White Light & Spectrometric Coronagraph (LASCO)	D.J. Michels, Naval Research Lab., Washington DC (USA)	Structures evolution, mass, momentum and energy transport in corona (1.1—30 $R_\odot$)	One internally and two externally occulted coronagraphs. Spectrometer for 1.1—3 $R_\odot$
Solar-Wind Anisotropies (SWAN)	J.L. Bertaux, Service d'Aéronomie, Verrières-le-Buisson (F)	Solar-wind mass-flux anisotropies. Temporal variations	Scanning telescopes with hydrogen absorption cell for H Lyman alpha light
Charge, Element and Isotope Analysis (CELIAS)	D. Hovestadt, Max Planck Inst. für Extraterrestrische Physik, Garching (D)	Ion (0.1—1000 keV/e) composition $M/\Delta M > 100$; charge res. 0.3—1	Electrostatic deflection, time-of-flight measurements & solid-state detectors
Suprathermal- and Energetic- Particle Analyser (COSTEP)	H. Kunow, Univ. Kiel (D)	Energy spectrum & composition protons 0.06—107 MeV, ions 1.2—330 MeV/n, electrons 0.06—25 MeV	Solid-state, and plastic and crystal-scintillator detector telescopes
Energetic-Particle Analyser (ERNE)	J. Torsti, Univ. Turku (SF)		
Global Oscillations at Low Frequencies (GOLF)	A. Gabriel, CNRS/LPSP, Verrières-le-Buisson (F)	Global Sun velocity and magnetic-field oscillations. Harmonic degree ℓ=0—4	Na-vapour resonant scattering cell, Doppler shift & circular polarisation
Variability of Solar Irradiance (VIRGO)	C. Fröhlich, World Radiation Centre (PMOD/WRC), Davos (CH)	Low-degree (ℓ=0—7) irradiance oscillations and solar constant	Global Sun & low-resolution (12 pixels) photometers, & active-cavity radiometers
Michelson Doppler Imager (MDI)	P.H. Scherrer, Stanford Univ., CA (USA)	Velocity oscillations, high-degree modes (up to ℓ=4500)	Doppler shift with Fourier tachometer, 4 & 1.5 arcsec resolution

Figure 3 — Artist's impression of the Soho spacecraft (study configuration only)

The solar wind carries important information from its source regions out to the Earth's orbit. The wind's ion composition contains information about the ion-separation processes in the chromosphere (elemental composition), the temperature structure and the flow conditions in the lower corona (isotopic mass and charge state). Insight into the ion-acceleration and heating conditions in the corona and solar wind can be obtained from the composition of both the suprathermal and energetic particles.

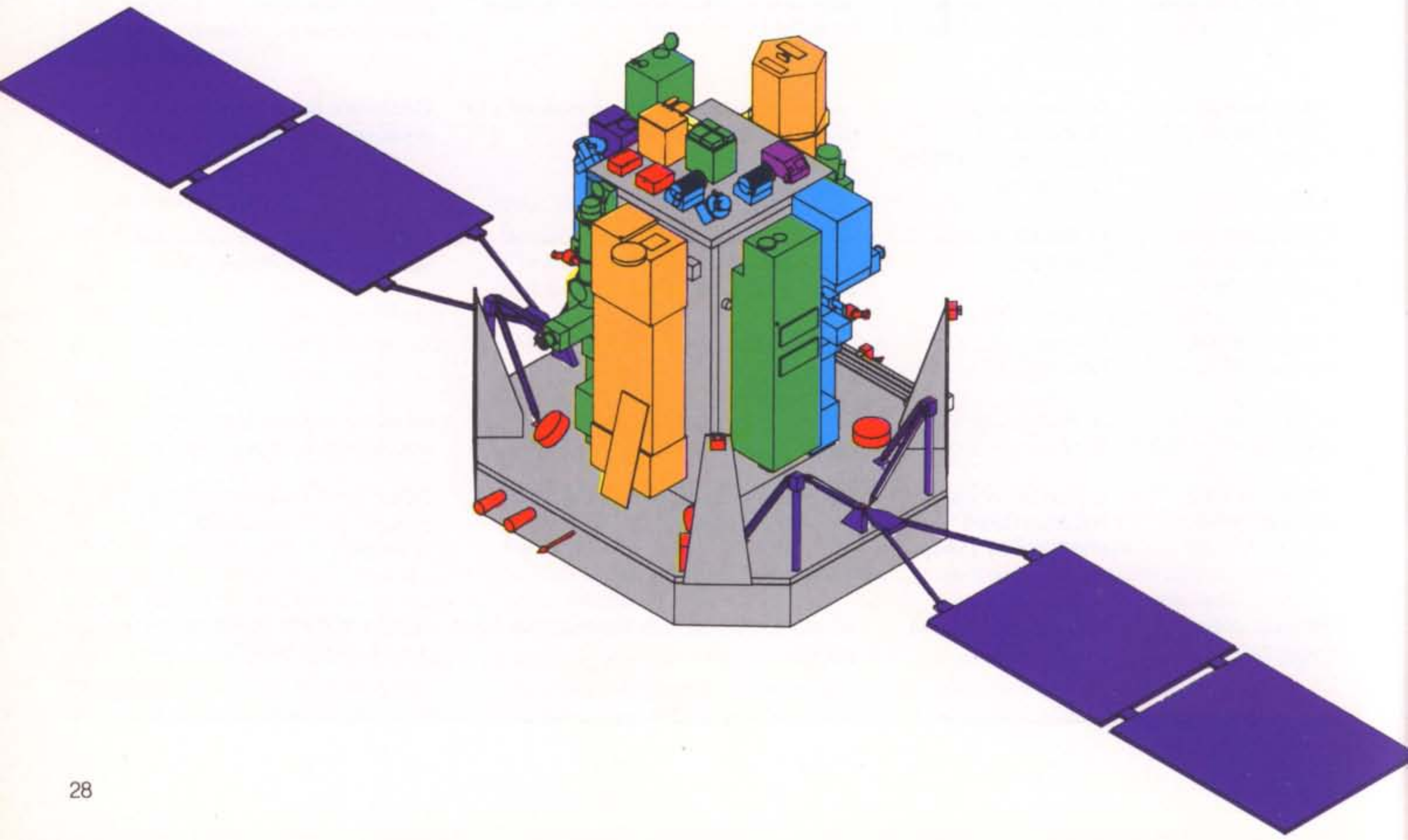
'In-situ' measurements of ion composition in terms of elemental abundance, isotopic mass and charge state will be made by the CELIAS instrument, and measurements of the energy and composition of suprathermal and energetic particles by COSTEP and ERNE. Soho's three-axis stabilisation (Fig. 3) gives its particle instruments a very high collecting power and makes them sensitive enough to detect rare elements.

Two helioseismology investigations will perform a long, uninterrupted series of oscillation measurements over the full solar disc in terms of velocity and magnetic field (GOLF), complemented with low-resolution irradiance imaging (VIRGO). They will provide information about the long wavelength modes of oscillation caused by waves that penetrate the solar core.

The MDI instrument will measure velocity oscillations at the surface of the Sun with high angular resolution (4 and 1.5 arcsec), thereby allowing determination of frequency spectra of many waves, including those of very short spatial wavelength, which carry very precise information about the thin outer layer of the convection zone. This investigation will produce a very large volume of data (about 1000×1000 pixels/min), allowing many details of the structure and dynamics of the convection zone to be studied. It will also provide data for the study of large-scale convection, as well as the intermediate-scale structure of the active regions in relation to the underlying magnetic field.

VIRGO will also investigate variations in the solar 'constant' (the total amount of energy radiated by the Sun in the direction of Earth) via measurements with active-cavity radiometers.

Spacecraft design and ground segment
The Soho spacecraft will be three-axis stabilised and will point towards the Sun with an accuracy of ± 10 arcsec and a pointing stability of 1 arcsec per 15 min. It consists of a Payload Module to accommodate the instruments and a Service Module carrying the spacecraft subsystems and the solar arrays. It will weigh a total of 1350 kg, and 750 W power will be provided by its solar panels. Soho's payload will weigh approximately 650 kg and consume 350 W in orbit.



Soho is planned to be launched in March 1995 and will be injected into a halo orbit around the L1 Sun-Earth Lagrangian point, about 1.5 million kilometres sunward from the Earth. It has a design lifetime of two years, but will be equipped with sufficient onboard consumables for an extra four years of operations.

Soho's telemetry will be received daily by ground stations belonging to NASA's Deep-Space Network (DSN) during three short (1.3 h) and one long (8 h) time window. Scientific data acquired outside these periods will be stored on magnetic tape onboard the spacecraft and transmitted to ground during the three short daily sessions. The payload will produce a continuous stream of 40 kbit/s, but this will be increased by 160 kbit/s whenever the solar oscillation imaging instrument is operated in high-bit-rate mode, either during the scheduled daily 8 h periods or during dedicated campaigns. The latter will be organised to provide approximately two-month long uninterrupted observations by the solar-oscillation imaging instrument.

An Experiment Operations Facility (EOF), located at NASA's Goddard Space Flight Center, in Greenbelt (USA) will be used to coordinate and plan the scientific operation of the payload. Its main task will be to organise real-time operation of the payload and control the solar imaging and spectrometric instruments during the daily 8 h ground-linked interval. During this time the coronal imaging instruments will be able to be pointed and used to make observations and measurements in a similar way to a telescope in a classical observatory. ESA intends to issue an Announcement of Opportunity to invite proposals for a second Experiment Operations Facility to be located in Europe.

Cooperative endeavours

The Soho payload has been conceived as an integrated package that requires coordinated operation and data analysis for the onboard investigations to achieve its scientific aims. It will benefit from cooperation with other contemporary spacecraft, like Cluster and NASA's Wind, which will be in orbit in the same time frame and will provide a full set of solar-wind parameters (Fig. 4). Cooperation with the ground-based solar observatories making simultaneous measurements in the visible or radio bands will also be important. The EOF in Greenbelt will be the focal point for coordinating these activities.

The Cluster mission

Scientific aims

Cluster has been conceived to investigate, in three dimensions, space-plasma phenomena that are believed to be ubiquitous in space, but are most easily accessible in the Earth's environment. Such phenomena — for instance the interaction of different plasmas, magneto-hydro-dynamic turbulence, etc. — involve small-scale plasma structures with spatial extents of several hundred to several tens of thousands of kilometres (a few to a few tens of Larmor radii).

Single-satellite measurements suffer from an intrinsic inability to distinguish unambiguously between spatial and temporal variations. With two satellites, this ambiguity is removed only for simple motions of essentially one-dimensional structures. An unambiguous determination of the shape and dynamics of three-dimensional structures requires a minimum of four spacecraft flying in a tetrahedral configuration and equipped with instrumentation capable of measuring fields and flows in three dimensions.

The Cluster mission therefore calls for a novel space segment based upon four spacecraft in non-coplanar orbits with adjustable separation distances. Their orbits have to pass through the key regions of geospace and they also have to extend into the solar wind.

Scientific enhancement of the Cluster mission is expected as a result of contributions by the Institute of Space Research (IKI) of the Soviet Academy of Sciences. Discussions with IKI have resulted in plans to launch at least two spacecraft, tentatively called 'IKI-1' and 'IKI-2', in orbit in the same time period. These spacecraft will be capable of performing collaborative investigations with Cluster and will also provide an important contribution in terms of spacecraft redundancy. The final orbits for the IKI-1/2 are still under discussion, but ESA and IKI are fostering close cooperation between the respective Science Working Teams to ensure that both missions will allow highly accurate correlative studies.

The instruments and their measurements

The payload of each of the four Cluster spacecraft is composed of an advanced set of instruments designed to measure electric and magnetic fields, plasmas and energetic particles. Table 2 contains the key parameters of the instruments and explains the acronyms. With the exception of the WBD instrument, the instrumentation is identical on all four spacecraft.

Accurate measurement of the low-energy plasma population demands that the spacecraft's electrostatic potential be maintained at a very low level with respect to the ambient plasma. Cluster will therefore be the first mission to be equipped with an ion emitter to routinely stabilise the fluctuating spacecraft potential by emitting indium ions. A hardwired link to the electron sensor of PEACE and the electric field double-probe (EFW) instruments will provide the measured surface potential against which the ion emission will be controlled. The ASPOC experiment will also investigate surface-charging behaviour under varying plasma conditions and the interaction of its weak ion beam with the ambient plasma.

Table 2 — Investigations to be performed by Cluster

Instrument	Principal Investigator	Measurement(s)	Technique
Fluxgate Magnetometer (FGM)	A. Balogh, Imperial College, London (UK)	B, waveform DC to ~20 Hz; resolution ≥6 pT	Two three-axis fluxgate sensors on 5 m boom
Spatio-Temporal Analysis of Field Fluctuations (STAFF)	N. Cornilleau-Wehrlin, Centre de Recherche en Physique de l'Environnement Terrestre et Planétaire, Paris (F)	B, waveform up to 10 Hz, compressed data up to 4 kHz. Cross-correlator for <E,B>	Three-axis search-coil sensor on 5 m boom
Electric Fields and Waves (EFW)*	G. Gustafsson, Swedish Institute of Space Physics, Uppsala (S)	E, waveform up to 10 Hz, compressed data up to 100 kHz, sensitivity <50 nV/m $(Hz)^{1/2}$	Double probes, two pairs of wire booms, each 100 m tip-to-tip
Waves of High Frequency and Sounder for Probing of Density by Relaxation (WHISPER)	P.M.E. Décréau, Lab. de Physique et Chimie de l'Environnement, Orléans (F)	Active: Total electron density.	Sounding, using parts of EFW wire booms.
		Passive: Natural plasma waves up to 400 kHz	Filter banks.
Wide-Band Data (WBD)*,[1]	D.A. Gurnett, Univ. of Iowa (USA)	Transmission of E-field waveform up to ~100 kHz, variable centre frequency	Using sensors of EFW
Digital Wave Processor (DWP)*	L.J.C. Woolliscroft, Univ. of Sheffield (UK)	Data compaction & compression, event selection, particle/wave correlation, control of WHISPER	CMOS multiprocessor unit
Electron Drift Instrument (EDI)	G. Paschmann, MPI für extraterrestrische Physik, Garching (D)	E, (0.1—10 mV/m, <100 Hz), ∇B, |B| (5—1000 nT), emission and tracking of two electron beams	Two emitter/detector assemblies, each with 2π Field of View (FOV).
Cluster Ion Spectrometry (CIS)	H. Rème, Centre d'Etude Spatial des Rayonnements, Toulouse (F)	CODIF: Composition and Distribution Functions analyser, ~0—40 keV/q	Symmetric hemispherical analyser with Retarding Potential Analyser (RPA) and Time of Flight (TOF), 2π×8° FOV, split geometric factor
		HIA: Hot Ion Analyser for high time resolution (e.g. solar wind), ~3 eV/q—40 keV/q	Symmetric quadrispherical analyser, 2π×8° FOV with high resolution (2.8°)
Plasma Electron and Current Analyser (PEACE)	A.D. Johnstone, Mullard Space Science Laboratory, Holmbury St. Mary (UK)	LEEA: Low-Energy Electron Analyser, 0—100 eV	Spherical electrost. analyser, π×3.8° radial FOV
		HEEA: High-Energy Electron Analyser, 0.1—30 keV	Toroidal electrost. analyser, 2π×4.6° FOV
Research with Adaptive Particle Imaging Detectors (RAPID)	B. Wilken, MPI für Aeronomie, Lindau/Harz (D)	IIMS: Imaging Ion Mass Spectrometer, ion distribution and species, energy 2—1500 KeV/nuc	Position-sensitive solid-state detectors with TOF section.
		IES: Imaging Electron Spectrometer, distribution of energetic electrons, energy 20—400 keV	Position-sensitive solid-state detector
Active Spacecraft Potential Control (ASPOC)	W. Riedler, Institut für Weltraumforschung, Graz (A)	Spacecraft potential control, emission current ~20 μA, indium ions	Field ionisation liquid-metal ion emitter

B = magnetic field E = electric field * Members of the Wave Consortium [1] Only on two spacecraft

Figure 4 — Schematic of some of the satellite missions that may be in orbit at the time of the Cluster launch, including IKI-1 and -2. The 'ESP' mission shown in the inset may be performed with the engineering model of the IKI spacecraft

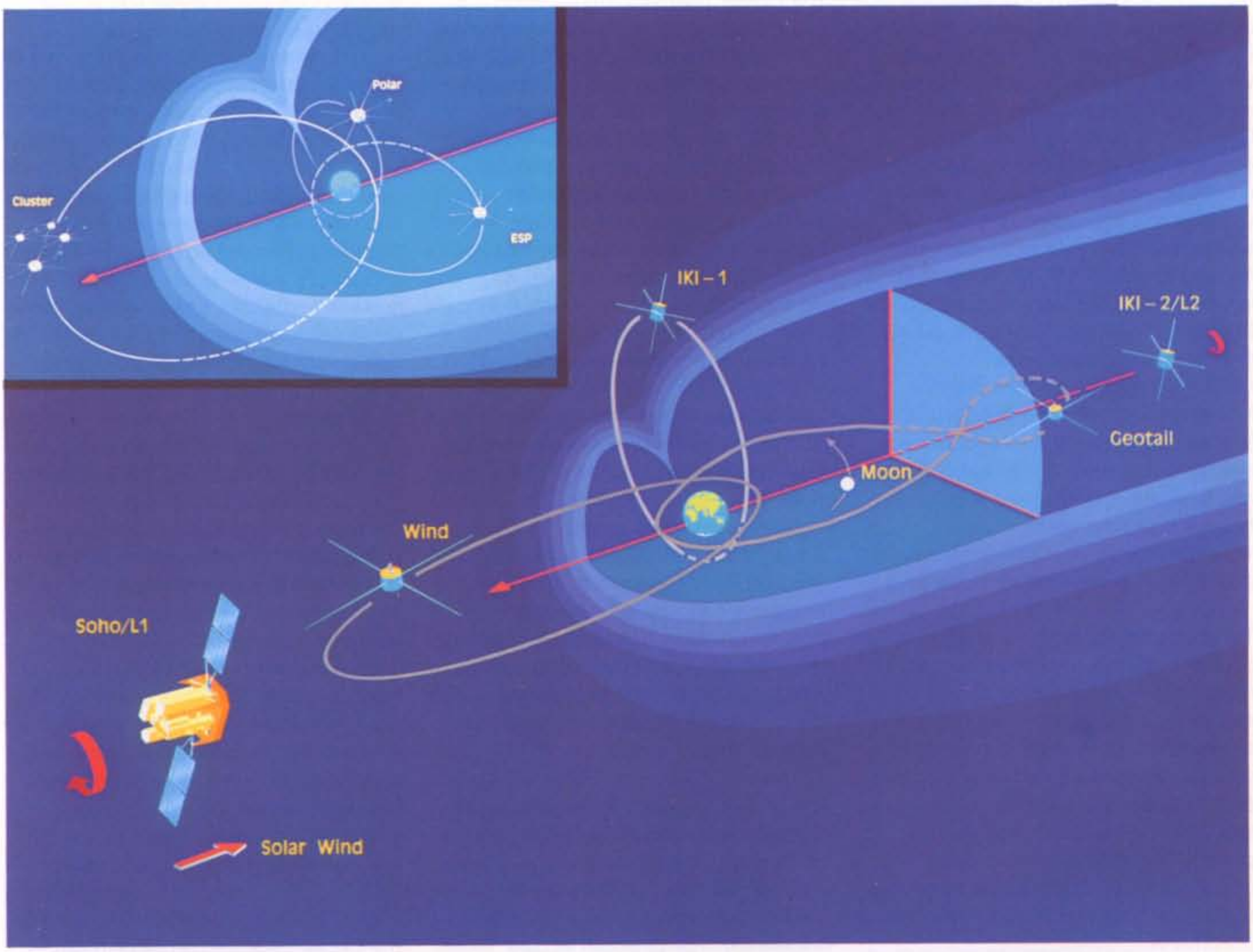
A suite of five instruments — EFW, STAFF, WHISPER, WBD and DWP — represents the so-called 'Wave Experiment Consortium' (WEC).

The EFW instrument is specifically designed for the investigation of fast time- and space-varying vectorial electric fields, but will also cover the static to low-frequency range. The dynamic range of EFW spans a wide range of amplitude. The double-probe technique used will also permit measurement of ambient-plasma density fluctuations and of the spacecraft potential.

STAFF, the search coil magnetometer, will measure the magnetic components of electromagnetic fluctuations in the frequency range up to 4 kHz. A built-in spectrum analyser will perform auto- and cross-correlation between electric and magnetic components. Such measurements will allow the shape, current density and motion of small-scale current structures to be characterised and the source of plasma waves and turbulence to be identified.

The relaxation sounder WHISPER is an instrument that will be operated in both active (transmitting) and passive (listening) modes. The transmitter will emit a short pulse to stimulate plasma resonances. After each transmission, the receiving unit will be activated to detect echoes in a narrow frequency range. By switching rapidly between the two modes, the receiver can scan the frequency range 4–80 kHz. Echoes at characteristic frequencies will allow the investigators to determine the plasma density under widely varying plasma conditions.

The Cluster wide-band receiver system (WBD) is designed to provide high-resolution electric-field waveforms and frequency/time spectrograms of terrestrial plasma waves and radio emissions. These measurements are very important



for analysing the highly structured and complex waves that occur in the Earth's magnetosphere. The receiver accepts signals in the frequency range up to 600 kHz, but a narrow band of ~100 kHz is windowed out and transmitted to ground. This instrument is currently only foreseen for two of the four Cluster spacecraft.

The scientific aims of the digital wave processing (DWP) system are concerned with wave/particle correlation. These (auto- and cross-) correlation functions are an important tool when investigating nonlinear wave/particle interactions, which are believed to be the source of many plasma-transport processes.

In the context of the Wave Experiment Consortium, several of the instruments will work together to provide a further enhancement of the scientific return. The DWP forms the 'heart' of the WEC's onboard data processing, by performing event selection, mode control, data compaction/compression and the resonance-frequency identification and tracking for WHISPER. Moreover, the interconnection between, for instance, the EFW and STAFF instruments will permit time- and phase-coordinated measurements that will help both to localise and characterise electrostatic (e.g. double layers) and electromagnetic structures (e.g. field-aligned currents), and to assess the role played by low-frequency plasma waves in the 'anomalous' behaviour (diffusion, parallel acceleration, thermalisation) of plasmas.

The fluxgate magnetometer (FGM) will perform important investigations that make unique use of Cluster's simultaneous four-point measurements in space. The ability to infer current-density vectors, wave-propagation characteristics and discontinuities from measurements in space will be 'firsts' in space-plasma-physics. The FGM will also provide onboard measurements of the static and quasi-static magnetic fields for all other instruments.

Cluster carries another instrument to measure electric fields. The electron drift instrument (EDI) is based on the emission and subsequent detection of tracer electrons to derive the ambient electric fields. In the case of stronger ambient magnetic fields, the displacement of the gyrating electron over one gyration can be measured by a triangulation method. At smaller magnetic field values, the instrument works in a mode whereby two beams are emitted in opposite directions and their times of flight are measured. By additionally varying the electron energy, the instrument can also determine gradients in the local magnetic field.

The Cluster plasma instrumentation (CIS and PEACE) is intended to provide three-dimensional measurement of the distribution functions of both electrons and major ion species. The scientific objectives will include study of heating and plasma flows near reconnection lines, the mid-latitude energisation mechanism for electrons and ions, the mechanism of plasma thermalisation and the structure of plasma populations during substorm growth, onset and decay. Special attention will be paid to the low-energy plasma component.

The CIS plasma ion spectrometer employs two sensors to measure the full three-dimensional distribution of the major ion species, with high time resolution and mass-per-charge plasma composition. CODIF takes care of the typical plasma populations encountered inside the magnetosphere. It also includes a retarding potential analyser for the low-energy ions. The second sensor, HIA, is specifically designed for the highly directional, beam-like ion flows in the solar wind.

The plasma electron measurements will be performed by the PEACE instrument, which has two separate sensors covering very cold electrons (LEEA) and the medium and higher energies (HEEA), respectively. The detection of cold electrons calls for a very carefully designed instrument to eliminate spurious effects introduced by the presence of photo-electrons, which are known to be dominant in the vicinity of a spacecraft. PEACE will provide the three-dimensional electron distribution with high time resolution.

Energetic particles are sensitive remote-sensing probes for nearly all the plasma-filled regions of geospace. These particles help identify distant acceleration regions and they can also be used to trace plasma flows. The RAPID instrument consists of two spectrometers, each containing position-sensitive solid-state detectors; a mass-discriminating energetic ion spectrometer (IIMS), and another sensor to determine the distribution in velocity space of suprathermal electrons (IES). Both spectrometers will provide high angular and time resolution.

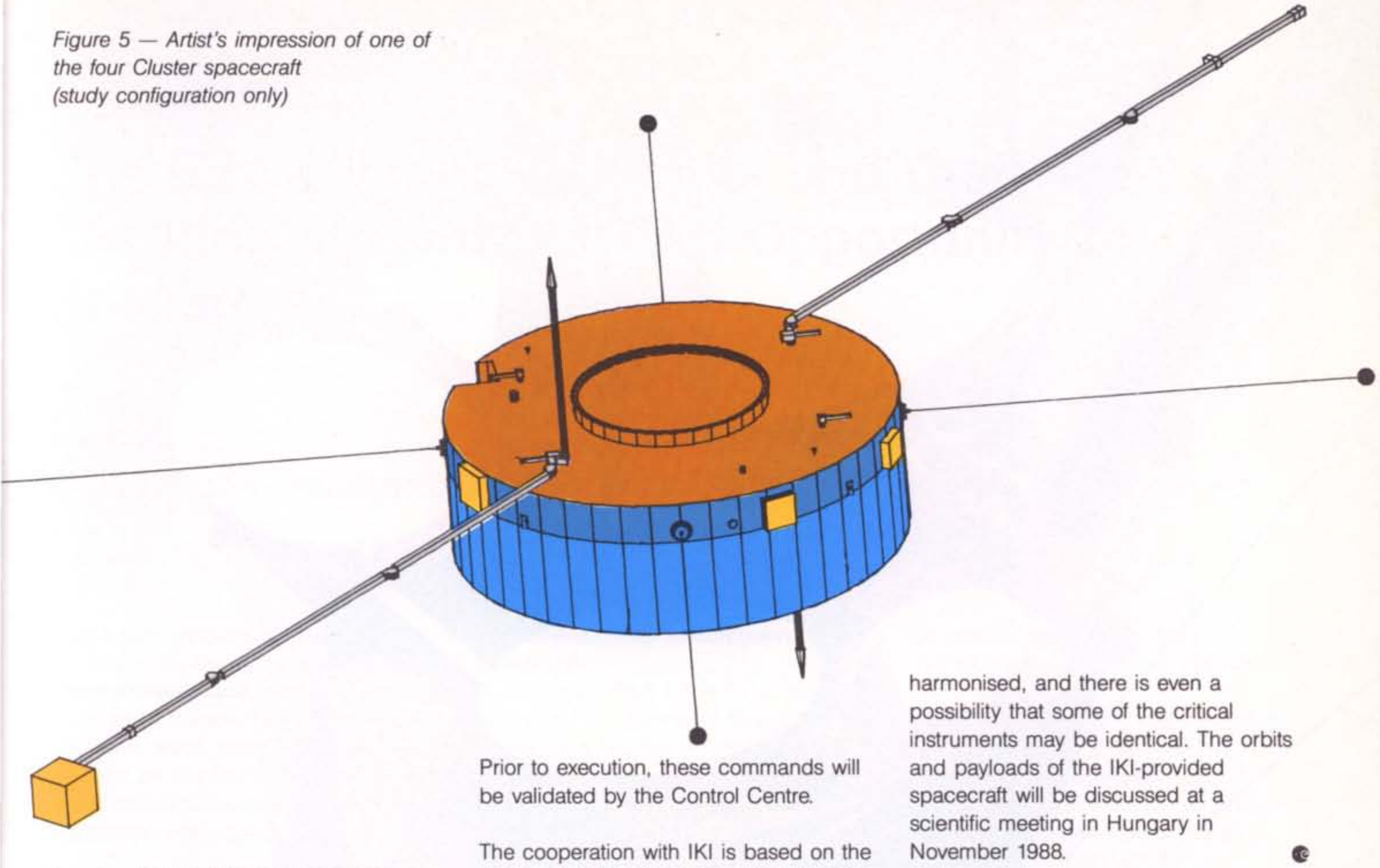
Spacecraft design and ground segment

Each of the four Cluster spacecraft will be spin-stabilised at 15 rpm. Their design is driven by the large amount of fuel needed to inject the spacecraft from the equatorial transfer orbit into the final near-polar orbit. Additional fuel will be required for the in-orbit separation manoeuvres.

The spacecraft are cylindrical in shape, approximately 2.9 m in diameter and 0.9 m high. Figure 5 shows one of the spacecraft in orbital configuration. The platform will accommodate the instruments on one side and the subsystems on the other. Two 5 m long rigid booms will carry the magnetometers. Two pairs of wire booms, each with a tip-to-tip length of 100 m, measure the electric field using the wire-boom technique. The dry mass of each spacecraft will be 354 kg, with an additional fuel load of 570 kg at launch. The current launch date is December 1995.

The Cluster payloads can be commanded

Figure 5 — Artist's impression of one of the four Cluster spacecraft (study configuration only)



to generate two different bit streams, totalling 16.8 (normal mode) and 100 kbit/s (high speed), respectively. Routine real-time operation of the payload is not foreseen and data will therefore be stored on one of two redundant tape recorders (each with a capacity of 1 Gbit). As for the high-speed mode, the tape may either be filled in one contiguous sequence, or in several shorter blocks. The tape's contents will be dumped at the next ground-station pass.

The scientific need for highly accurate measurements imposes stringent requirements on spacecraft design in terms of attitude reconstitution, electromagnetic cleanliness, timing (± 2 ms) of the data takes and separation strategy. The planned mission lifetime is two years.

Cluster operations will be performed by ESA, and supported by NASA's Deep-Space Network. Present planning foresees that each Principal Investigator will be provided with the entire decommutated data set from all four payloads on optical disc. The most recent raw data will be accessible via a computer link, which would also provide the possibility of indirectly commanding the instruments from home institutes. Prior to execution, these commands will be validated by the Control Centre.

The cooperation with IKI is based on the assumption that complete data sets will be exchanged between the respective Operations Centres. It will be up to the respective Science Working Teams to devise the appropriate procedures. ESA and IKI intend to establish voice and computer links to ensure proper coordination of the missions. The computer link may also serve for the shipment of the bulk data.

Cooperative endeavours

Several cooperative scenarios involving other space missions are presently under consideration. The Global Geospace Science (GGS) Programme implemented by NASA and encompassing the Wind and Polar spacecraft and the joint NASA/ISAS Geotail satellite will be in their extended mission phases in the mid 1990's. A Working Group has therefore been set up in the framework of the Inter-Agency Consultative Group for Space Science (IACG) to identify means of maximising the scientific return from these and other missions that will be in orbit at that time.

The closest cooperation will nevertheless be with IKI, as their Cluster-type satellite will be launched at about the same time as Cluster itself. The payloads of the Cluster and the Soviet spacecraft will be harmonised, and there is even a possibility that some of the critical instruments may be identical. The orbits and payloads of the IKI-provided spacecraft will be discussed at a scientific meeting in Hungary in November 1988.


OLYMPUS

The ESA Olympus Satellite and Distance-Learning in Europe – An Opportunity for Educators

J. Chaplin, ESA Directorate of Telecommunications, ESTEC, Noordwijk, The Netherlands

This article outlines ESA's plans for the use of its Olympus satellite for the development of distance-learning services in Europe. Much progress has been made since May 1987 when a report on the Olympus Utilisation Programme last appeared in the ESA Bulletin (see No. 50).

Figure 1 – ESA's Olympus satellite will be carrying demonstrations of distance-learning and other services, starting next year. The large circular antenna extending from the underside of the satellite will transmit the European DBS channel

Distance-learning in European education

In 1984–1985 ESA funded studies in the broad field of 'information dissemination' (see Bulletin No. 47) with regard to the expansion of the use of satellites in the 1990s, and with the emphasis on commercially viable applications. The applications that emerged as having the most potential were 'corporate training' and 'educational services' for the general public or specialist 'user groups'.

The USA and Japan spend proportionally more than three times as much as Europe on in-company training. Compared to its Europe counterpart, American industry is training more than twice the proportion of its young work force. IBM, for example, spends nearly a billion dollars a year on training, with its employees spending five percent of their company time (more than two weeks a year) learning.

The European Commission has said that most of us need complete re-training four times during our lives*. Given the difficulties of combining training with a busy work schedule, 'open-learning' – studying when and where convenient – can provide the answer.

The number of European organisations involved in open-learning and distance-learning is growing. Increased use of advanced information storage and distribution technologies is encouraging this growth, and here satellite communications can play a vital role.

*CEC Proposal for a Council Regulation on Community Action in the Field of Learning Technology – DELTA (July 1987).

The number of video courses available is potentially very large, but their cost is only likely to be recovered if course material can be distributed over a large enough area. Where 500 or more students are involved, satellite transmission can provide the solution. The development of satellite entertainment TV and pay services provides the technical means to deliver such courses.

The ESA Olympus Programme

Olympus is a satellite programme supported by eight ESA Member States, including the UK (39%), Italy (30%) and Canada (10%). The main contract was signed in 1983 and the launch is expected on Ariane flight 32 in the spring of 1989. The Olympus spacecraft will have an in-orbit lifetime of about seven years, lasting well into the second half of the 1990s.

The objectives of the Olympus Programme are to develop and prove, in-orbit, key satellite technologies that will be relevant to commercial satellite programmes in the 1990s, and to demonstrate new applications of satellites for communications and broadcasting.

The Olympus payloads

Olympus carries three communications payloads and a beacon package that continuously transmits signals for propagation-research purposes. Two of these payloads will operate in the 14/12 GHz and 30/20 GHz frequency

Figure 2 – The Olympus European DBS channel beam will be steerable. Here a typical coverage is shown which will complement that of the Italian beam. Fair-quality reception of TV transmitted in the MAC-packet standard will be obtained with 45 cm-diameter antennas on the inner contour, and with 90 cm antennas on the outer contour

bands and were described in ESA Bulletin No. 50 (pages 32–41).

Most relevant to distance-learning, however, is the two-channel Direct Broadcasting Service (DBS) payload, one channel of which is designed to serve Italy and the second to cover most of the rest of Europe (Fig. 2). These channels will have such high powers that antennas of 45 cm diameter or less will be sufficient to receive the signal. These small receivers will soon be widely available as a result of the other DBS programmes, including TV-Sat (Germany), TDF-1 (France) and BSB (UK). The estimated launch dates for these DBS satellites are given in Table 1.

Olympus Demonstration Programme
It is obvious that the range of potential applications of satellites for communication and broadcasting is vast. There are perhaps four main general classes of activity: technical tests; system or service demonstrations; pilot services and pre-operational services. To encourage development towards commercial maturity, the intention is to a limit the time spent in any one stage to one or two years.

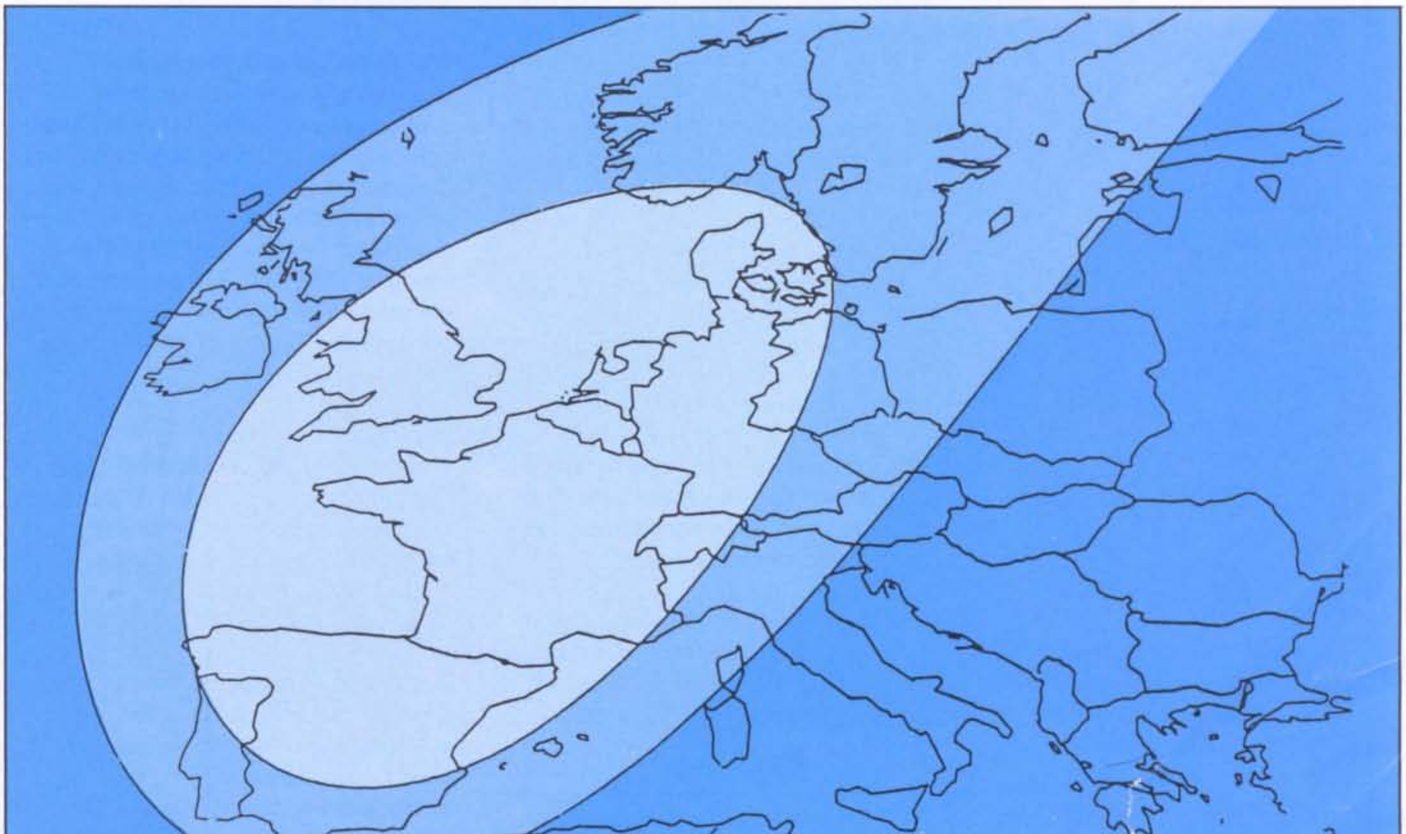
The purpose of demonstrations
Olympus will be able to demonstrate the value of DBS as a delivery system for operational services. This will help to convince Eutelsat, PTTs, established broadcasters and private companies that there is a market for DBS satellite capacity provision.

Demonstration can show schools and colleges, industry and private individuals that such distance-learning courses are becoming available and these users can then develop their own plans.

Some distance-learning concepts will rely on facilities for the provision of electronically-distributed courseware or the provision of high-resolution graphics. Succesful demonstrations will encourage

Table 1 – Projected launch dates for European DBS satellites

TDF-1	France	Ariane-V26	October 1988
Astra 1	Luxembourg	Ariane-V27	November 1988
Olympus	ESA/Italy	Ariane-V32	June 1989
TV-Sat	Germany	Ariane-V33	July 1989
BSB	UK	Delta	October 1989
TDF-2	France	Ariane-V37	December 1989



equipment manufacturers to invest in the development, manufacture and/or distribution of appropriate products.

Status of demonstration planning
The distance-learning group is already scheduled to be a major user of the DBS European channel on Olympus (about 80% of all applications). About 40% of all channel time has been allocated to this group. Many of these proposals resulted from a small number of 'User Liaison' contracts placed by ESA to identify potential users and provide assistance in preparing proposals for submission to the Agency.

The distance-learning proposals were evaluated by an ad-hoc group of advisers which made its recommendations to ESA in early February 1988. ESA has accepted these recommendations and letters offering Olympus time and the associated terms and conditions were sent to most applicants by the end of February. The majority have been offered two years' free access for service demonstrations. Table 2 lists these lead institutions and the transmission time offered. Table 3 illustrates the international spread of over 300 participating organisations in 20 countries.

The planning for these 'pioneers' on Olympus was greatly helped by a most successful seminar and workshop held at Avignon in April 1988*. Over 150 people attended and much was achieved by working in groups on practical issues concerning the use of the satellite. At Avignon, the 'pioneers' elected an interim committee of 11 people from seven countries who will study the issues, liaise with ESA and report back to the users.

Future planning
The DBS transmission schedule for the

*The Workshop Proceedings (ESA WPP-002), including the full paper from which this article has been extracted, are available from the author.

Table 2 – Organisations offered Olympus transmission time by ESA

Organisations	City	Hours/year	Programmes
Training Commission	Sheffield	162	Adult Education
Open University	Milton Keynes	12	Tertiary Educat.
Birkbeck College	London	104	Medicine
Heriot-Watt University	Edinburgh	50	Tertiary Educat.
Educational TV Assoc.	York	50	Group
SCET	Glasgow	20	Mixed
University College	Dublin	120	Group
Fern Universiteit	Hagen	78	Adult Education
Universities Film/Video	London	150	Group
British Medical TV	Woking	150	Medicine
Univ. of Glasgow	Glasgow	50	Language Learning
Satecosse	Edinburgh	26	Language Learning
Brighton Polytechnic	Brighton	30	Language Learning
Centre for Int. Studies	Exmouth	16	Group
TVE1 Centre	Clwyd	36	Mixed
Univ. of East Anglia	Norwich	35	Tertiary/Adult Educat.
Univ. of London	London	144	Group
Gwynedd Country Council	Llangefni	30	Mixed
Oxford University	Oxford	150	Language Learning
Integrated Info. Syst.	Athens	150	Mixed
Coventry Lanch. Poly.	Coventry	50	Mixed
Royal Coll. Psychiatry	London	24	Medicine
European Parliament	Luxembourg	36	Adult Education
Univ. Thessaloniki	Thessaloniki	50	Mixed
European Commission	Brussels	243	DELTA*
IASPA	Brussels	12	The Arts
Univ. Leiden	Leiden	100	Medicine
ALCATEL	Antwerp	50	Corporate Training
Post-Grad. Medic. School	Exeter	50	Medicine
Vrije Univ. Brussel	Brussels	40	Tertiary Educat.
Aston University	Birmingham	30	Adult Education
Elec. Univ. Norway	Stavanger	200	Adult Education
Acton High School	London	12	Secondary Educat.
Univ. Nancy VIDEOSCOP	Nancy	12	Medicine
TV-Inter	Stockholm	50	Religion
Generalitat de Catalunya	Barcelona	35	Culture
Europa Press TV	Madrid	52	Mixed
Internat. Space Univ.	Boston	20	Adult Education
Escuola Univ. de EGB	Tenerife	5	Culture
Min. Affaires Etrangères	Paris	92	Culture
Min. Affaires Etrangères	Paris	241	Adult Education
Min. Affaires Etrangères	Paris	117	Language Learning
Cosejeria de Ed. (Anda.)	Sevilla	12	Culture
Univ. of Barcelona	Barcelona	12	Mixed
Cent. Cult. Tajamar	Madrid	26	Adult Education
Min. Education & Science	Madrid	24	Language Learning
Circulo de Bellas Artes	Madrid	74	The Arts
Total transmission time		3232 hours per year	

*'Developing European Learning through Technology Advance', an EEC Programme.

first year of Olympus operations is already agreed and time offered to a number of users for the second year as well. The blocks of time for allocated for distance-learning purposes are:

0000 – 0400	Downloading to video recorders
0900 – 1400	Live transmissions every
1600 – 1700	day*.

*Every fourth Sunday will be reserved for ESA to carry out routine and other necessary satellite tests.

Three months before the Olympus launch, i.e. early in 1989, the users will have to confirm their willingness to proceed and the availability of funding for their own activities. Time slots that become available at this point will be offered either to organisations who received less time than originally requested, or to late applicants.

It must therefore be emphasised that the door is not closed for new proposals for distance-learning, or indeed other, activities aboard Olympus. There are still opportunities for 'new' organisations to join the programme.

Table 3 – Geographical distribution of Olympus distance-learning participants

	Project leaders	Other participants	Total
Austria	–	2	2
Belgium	4	10	14
Denmark	–	2	2
Spain	11	8	19
Finland	–	1	1
France	24	29	53
Germany	1	21	22
Great Britain			
England	16	88	104
Scotland	5	24	29
Wales	2	6	8
Greece	3	2	5
Italy	–	12	12
Ireland	1	20	21
Luxembourg	–	1	1
Netherlands	3	11	14
Norway	1	3	4
Poland	–	1	1
Portugal	–	2	2
Sweden	1	9	10
Switzerland	–	7	7
Turkey	–	1	1
USA	1	–	1
Total	73	260	333

Organisation of distance-learning on Olympus

Olympus will provide a framework for early service development. In line with its terms of reference, the Agency intends the Olympus users to manage their own activities.

In 1984, a significant problem was identified; namely that there are a large number of establishments that could provide distance-learning services, but that individually lack the resources to exploit the available or imminent satellite technology. The solution appears to lie in the formation of a User Association. A feasibility study in 1986/87 confirmed the need for such an association. The study concluded that a 'Development Unit' should be set up to assist in the formation of the Association.

Creation of a User Association

The Agency is encouraging the distance-learning group to organise themselves and to progress their plans and preparations as far as possible without ESA financial support. The Agency continues to explore the possibility of inviting proposals for forming an 'Association Development Unit'.

This Development Unit would undertake all the work necessary for the formal creation of the Association, perhaps by the end of 1990. It would also be responsible in the shorter term for identifying and assisting Olympus users, and planning and managing distance-learning as a complete integrated activity.

ESA will provide access to Olympus, with an infrastructure to be fully defined in discussion with the users, and will provide some support for the creation and running of the Association.

Where do you go from here?

If you are interested applying for time on the ESA Olympus satellite, the 'Olympus Users' Guide' provides more detailed information on the framework of the programme and the technical capabilities of the satellite. It also explains the formal steps that must be taken in applying to ESA for satellite time.

The future

Olympus is only a stepping stone towards the future. Present projections indicate that there will be soon be ample capacity on European satellites to support education and training services.

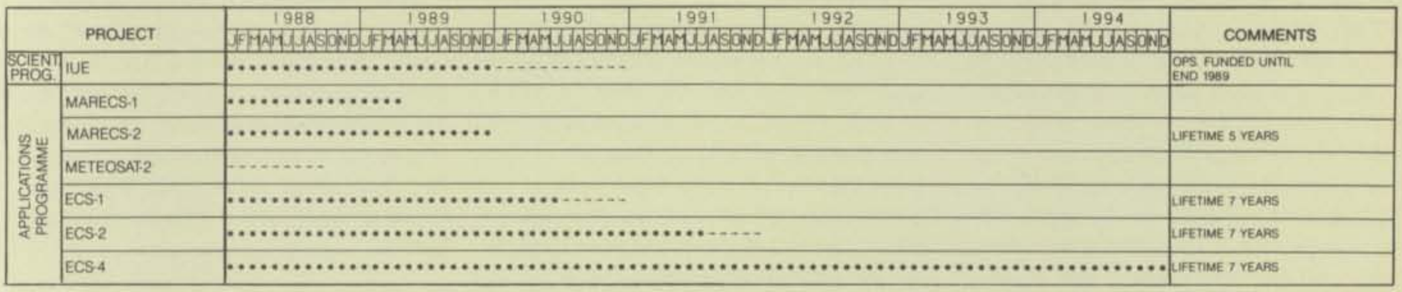
The best vehicle for corporate training by Europe in the short- and medium-term is probably Eutelsat. Eutelsat already operates a system of several telecommunications satellites and will be launching higher-powered satellites from 1990 onwards.

For general education, the future is more speculative. Of the current plans by Germany, France, Italy, Scandinavia and the United Kingdom to establish national DBS services, only Italy appears to have given serious thought to the provision of educational services. An Italian DBS system planned for the 1990s could have a whole channel reserved for education.

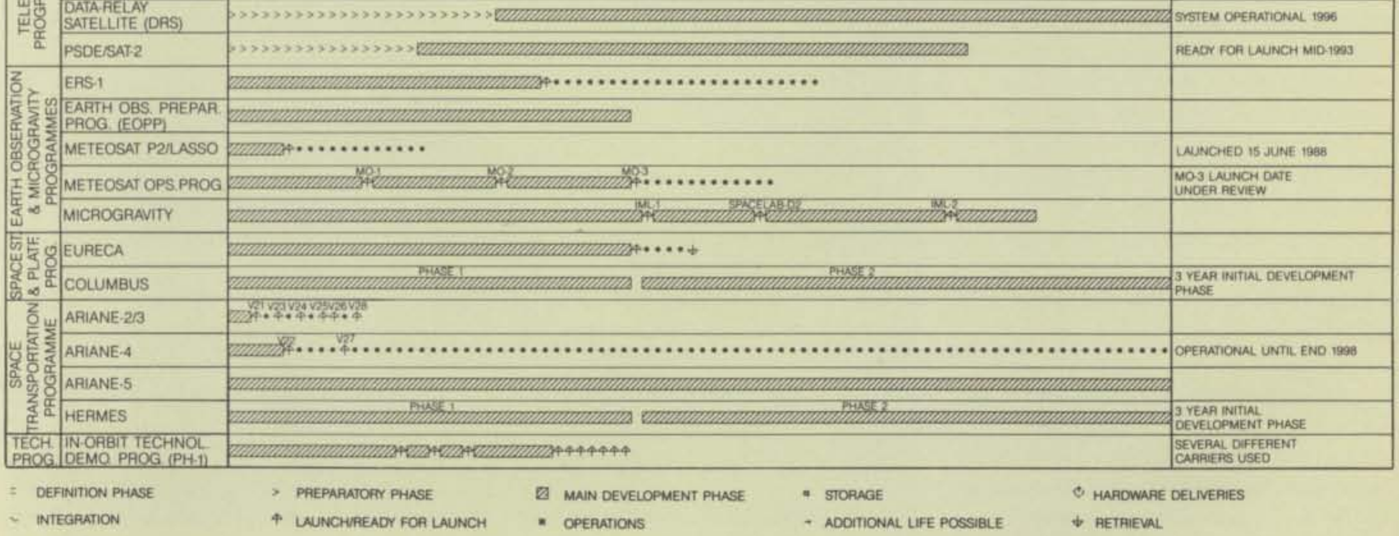
These systems could provide DBS channels at a cost affordable for education and training, and reaching a large enough service area to permit economic viability of all the services. ESA's Olympus satellite, available next year, will provide a rare opportunity for European educators.

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

In Orbit / En orbite



Under Development / En cours de réalisation



Extension de la mission Giotto

Le 20 juin 1988, le Comité du programme scientifique de l'ESA a approuvé le projet d'une campagne spéciale de réactivation et de vérification de Giotto qui doit avoir lieu au début de 1990.

La sonde Giotto a pleinement atteint ses objectifs scientifiques pendant sa rencontre avec la comète de Halley, les 13 et 14 mars 1986. Elle a survolé le noyau de la comète du côté exposé au Soleil à la distance de 596 km seulement. Comme on pouvait s'y attendre, le véhicule spatial et plusieurs détecteurs ont été endommagés pendant le survol par des particules de poussières qui les ont percutés à la vitesse relative de 68,4 km/s. En dépit des dommages causés, il serait peut-être possible d'envoyer Giotto à la rencontre d'une autre comète. La sonde se trouve actuellement sur une orbite héliosynchrone d'une période de 10 mois. Sur cette orbite, elle s'approchera de nouveau de la Terre le 2 juillet 1990, cinq ans précisément après son lancement. Depuis le 2 avril 1986, sa poursuite n'est plus assurée mais elle pourrait être réactivée à tout moment dans la limite des contraintes imposées par le secteur spatial et le secteur sol.

A l'issue de la campagne de vérification du début de 1990, le SPC décidera de prolonger ou non la mission de Giotto après avoir confronté au coût de la mission les possibilités de fonctionnement des expériences et du véhicule spatial. Si le SPC approuve le projet, Giotto profitera de l'effet de fronde de la Terre, le 2 juillet 1990, pour atteindre une nouvelle orbite qui lui permettra d'aller à la rencontre d'une autre comète. Actuellement, la comète à courte période Grigg-Skjellerup paraît être la meilleure cible possible (date de la rencontre: 10 juillet 1992) mais d'autres comètes sont également à l'examen. Il ne sera pas nécessaire de procéder au choix définitif avant mai 1990.

Pour ces opérations de réactivation et de vérification, il faudra faire appel au réseau pour l'espace lointain (DSN) de la NASA. Des négociations sont en cours avec la NASA pour en fixer la date exacte, compte tenu des demandes d'utilisation du DSN provenant d'autres missions, ayant un rang de priorité plus élevé (Galileo par exemple).

Météosat

Programmes préopérationnels

Le satellite Météosat P2, lancé avec succès le 15 juin par le premier lanceur Ariane 4, se trouve maintenant en orbite géostationnaire au-dessus du Golfe de Guinée où il remplit sa mission opérationnelle depuis le 11 août.

Météosat P2 est contrôlé et exploité pour le compte d'Eumetsat par le Centre européen d'opérations spatiales (ESOC) de Darmstadt en Allemagne.

Les deux satellites Météosat précédents, F1 et F2, ont été lancés en 1977 et 1981 respectivement. Météosat F2, mis à poste à 10° de longitude W, servira désormais de satellite de réserve. Météosat P2, à l'origine modèle de qualification des satellites de première génération, est le dernier représentant de la série préopérationnelle. Il fera la soudure entre Météosat F2 et MOP-1, premier satellite du programme Météosat opérationnel d'Eumetsat.

Programme opérationnel

A l'issue de son intégration finale, le satellite MOP-1 a été soumis à des essais de fonctionnement qui touchent à leur terme. Son lancement est actuellement prévu pour janvier 1989.

La fabrication du matériel de vol et l'intégration des deux prochains modèles, MOP-2 et MOP-3, progressent de façon satisfaisante.

ECS

Le cinquième et dernier modèle de vol de la série ECS a été lancé avec succès par Ariane V24 le 21 juillet. Toutes les opérations prévues après le lancement ont donné lieu à un parcours sans faute et la mise en service de la charge utile du satellite a commencé le 12 août. Eutelsat a pris livraison du satellite le 28 août. ECS-5 entrera donc très prochainement en service opérationnel.

Avec quatre satellites opérationnels en orbite (ECS-1 a été lancé en juin 1983, ECS-2 en août 1984, ECS-4 en septembre 1987 et ECS-5 dernièrement), le système européen de télécommunications Eutelsat de première génération est maintenant complet. Ce système, dont le taux de disponibilité enregistré à ce jour est de 99,995%, sera en mesure de fournir à l'Europe jusqu'à 39 canaux de télécommunications pour le téléphone, le télex, le courrier électronique, la télévision par câbles, Eurovision et un certain nombre de services spécialisés.

Télescope spatial

Les modifications à apporter au modèle de vol des panneaux du réseau solaire pour en augmenter la puissance et les protéger de l'oxygène atomique sont en cours. Les nappes de photopiles du générateur solaire du premier panneau ont été livrées et sont actuellement mises en place. Les deux panneaux doivent être livrés début 1989 au Centre spatial Kennedy où ils seront fixés au Télescope spatial.

La chambre à objets faibles (FOC) a été retirée du Télescope spatial fin juin et des remaniements mineurs ont été apportés aux modes opératoires spectrographiques et coronographiques. La FOC a été ensuite réinstallée dans le Télescope spatial. La lancement reste fixé au 1er juin 1988.

STSP

La Programme d'études des relations Soleil/Terre (Cluster et Soho) a franchi d'importantes étapes en 1988.

Après avoir procédé à une évaluation scientifique et technique poussée, le Comité du programme scientifique de l'ESA et l'administrateur adjoint de la NASA pour la science spatiale et ses applications ont, en mars dernier, sélectionné en commun la charge utile scientifique du STSP. Certains choix en suspens à l'issue de la réunion de mars ont été définitivement réglés par le SPC lors de sa réunion de juin.

Immédiatement après la sélection, les chercheurs ont engagé des études détaillées de chacun des instruments afin

Giotto Extended Mission

On 20 June 1988, ESA's Science Programme Committee (SPC) approved a special Giotto reactivation and checkout campaign in early 1990.

The Giotto spacecraft successfully completed its scientific objectives during the Halley flyby on 13/14 March 1986. It passed the comet nucleus on the sunward side at a distance of only 596 km.

As could be expected, the spacecraft and several experiment sensors suffered damage during the flyby from cometary dust particles impacting on the spacecraft at the relative flyby velocity of 68.4 km/s. Despite this damage, it may be possible to redirect Giotto to encounter another comet. The spacecraft is presently orbiting the Sun with a period of 10 months. In this orbit it will approach the Earth again on 2 July 1990, precisely five years after launch. Since 2 April 1986, it is no longer being tracked, but could be reactivated at any time that space and ground-segment constraints allow.

After the checkout campaign in early 1990, the SPC will decide on the Giotto mission extension, weighing spacecraft and experiment performance against mission cost. If the approval is given, Giotto will perform an Earth swingby manoeuvre on 2 July 1990, putting it into a new orbit that will allows it to encounter another comet.

So far, the short-period comet Grigg-Skjellerup (encounter date: 10 July 1992) has been identified as the best possible target, but other comets are also under consideration. The final selection will not have to be made before May 1990.

For the reactivation of the Giotto spacecraft and the checking out of its experiments, access to NASA's Deep-Space Network (DSN) is needed. Discussions with NASA are currently underway to determine the exact date for Giotto's reactivation, taking into account the constraints imposed on the DSN by other, higher priority missions (e.g. Galileo).

Meteosat

Pre-operational programme
After its successful launch aboard the first Ariane-4 flight on 15 June, the Meteosat-P2 satellite is now on station in geostationary orbit over the Gulf of Guinea, from which position it has been operating since 11 August.

The Meteosat-P2 spacecraft is controlled and operated from ESOC in Darmstadt (Germany) on behalf of Eumetsat.

The two previous Meteosat satellites, F1 and F2, were launched in 1977 and 1981, respectively. Meteosat-F2 will now be kept on stand-by, at 10°W longitude. The Meteosat-P2 spacecraft, which was originally used as the qualification model for the earlier satellites, represents the last of the pre-operational Meteosat series. It will bridge the gap between the Meteosat-F2 satellite and the launch of the first satellite for Eumetsat's Meteosat Operational Programme (MOP-1).

Operational programme
After final integration, the MOP-1 satellite is nearing the completion of performance testing. It is scheduled for launch in January 1989.

Manufacture of flight hardware and integration of both subsequent models, MOP-2 and MOP-3, are progressing satisfactorily.

ECS

The fifth and last flight model of the ECS series was launched successfully by Ariane flight V24 on 21 July. All post-launch operations were completed flawlessly and commissioning of the satellite payload started on 12 August. On 28 August, ECS-5 was formally accepted by Eutelsat for operational use.

With four operational ECS satellites currently in orbit — ECS-1 launched in June 1983, ECS-2 in August 1984, ECS-4 in September 1987, and ECS-5 on 21 July — Eutelsat's first-generation European telecommunications system is now complete. This system, which has a 99.995% availability record so far, will be able to offer to Europe up to 39 telecommunications channels for telephone, telex, electronic mail, cable television, Eurovision, and a number of other specialised services.

Rencontre de Giotto avec la comète de Halley (vue conceptuelle)

Artist's impression of the Giotto encounter with Comet Halley *de fournir à l'ESA un liste définitive des impératifs, établie d'un commun accord. C'est sur cette base que l'industrie sera invitée à soumettre des offres d'approvisionnement pour les véhicules spatiaux Cluster et Soho.*

La première réunion de l'équipe de travail scientifique (SWT), qui s'est tenue à Noordwijk du 27 au 30 juin, a constitué une étape importante dans cette première phase de la définition de la charge utile scientifique. Cette réunion a donné aux chercheurs participants une première occasion de se rencontrer dans le cadre du STSP et a servi de forum à des entretiens avec des représentants de l'ESA et de la NASA sur la définition et la situation financière du programme dans son ensemble. La deuxième réunion de la SWT doit avoir lieu en février 1989.

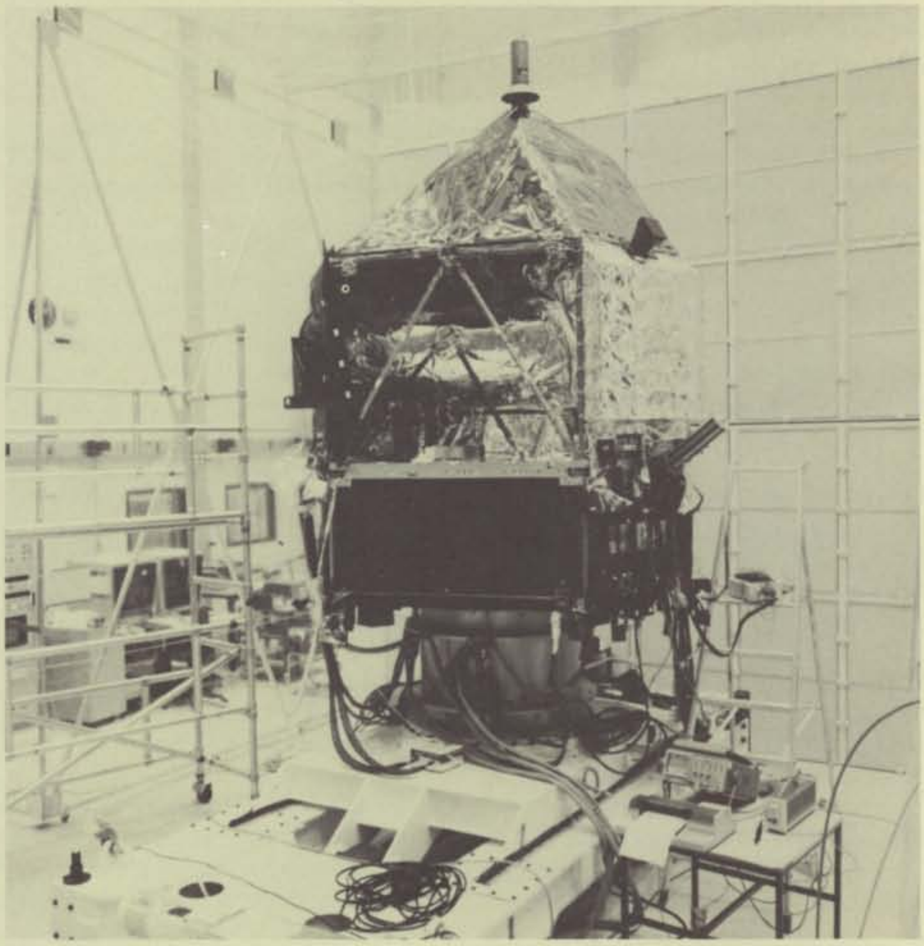
La charge utile scientifique étant sélectionnée, la deuxième grande étape consistait à entreprendre l'approvisionnement industriel des véhicules spatiaux. Le STSP est un programme ambitieux sur les plans scientifique, administratif et financier, ce que reflète la stratégie industrielle approuvée par la Comité de la politique industrielle (IPC) de l'ESA à sa réunion des 22 et 23 juin 1988. Le 1er juillet, l'ESA a communiqué à l'industrie européenne, après approbation de l'IPC, un avis préliminaire d'appel d'offres destiné à fournir aux sociétés des éléments d'information sur les questions scientifiques et techniques et les problèmes d'organisation générale du projet. Cet avis devrait permettre à l'industrie d'exécuter certains travaux préliminaires en prévision de l'appel d'offres lui-même qui doit être lancé en octobre 1988 et qui invitera l'industrie européenne à soumissionner pour les véhicules spatiaux Cluster et Soho. L'ESA devrait recevoir ces offres en février 1989.

Hipparcos

Pendant la durée du stockage du prototype de vol (PFM) du satellite, l'ESA et l'industrie se sont attachées à résoudre les problèmes rencontrés lors de la revue d'aptitude au vol du PFM ainsi qu'à préparer le lancement et l'exploitation du satellite en orbite. Les travaux dont les équipes de projet ont été chargés afin d'éliminer les écarts constatés lors de la revue d'aptitude au vol progressent et, dans plusieurs cas, sont terminés. Un supplément d'analyse a souvent suffi pour trouver des solutions mais, dans certains cas, une modification du matériel est en cours. En particulier, tous les relais qui avaient donné lieu à une 'alerte générale' (problème signalé antérieurement) sont en cours de remplacement. Une réunion spéciale se tiendra en septembre pour constater que toutes ces activités ont été menées correctement à terme.

La préparation des opérations de lancement et des activités en orbite se poursuit à un rythme soutenu. Les manuels des opérations de lancement, de la conduite des activités en vol et des utilisateurs du satellite font l'objet d'une révision finale ou d'une dernière mise à jour avant publication sous leur forme définitive.

Le calendrier des lancements d'Ariane affecte actuellement à Hipparcos et à TV Sat-2 le vol V-30, fixé en mai 1989. L'ordre chronologique des lancements reste cependant sujet à modifications en raison de facteurs indépendants de la volonté des responsables d'Hipparcos. Le calendrier actuel de réactivation du satellite après stockage se fonde sur l'hypothèse d'un lancement en mai 1989.



Hipparcos under test at ESTEC

Hipparcos aux essais à l'ESTEC

Olympus

La phase d'essais sous vide thermique d'Olympus-1 a eu lieu pendant les mois de juillet et août. Le véhicule spatial a été fixé dans le montage infrarouge et l'ensemble installé à la mi-juin dans la chambre à vide thermique des laboratoires David Florida (DFL) d'Ottawa. Les moyens et appareils de mesure qui comportaient un grand nombre de liaisons en guides d'ondes avec le véhicule spatial, ont été validés et étalonnés. Un essai du système intégré (IST-2) a été mené sur le véhicule spatial et ses résultats comparés à ceux de l'essai IST-1 réalisé avant le démarrage des essais d'environnement. Les essais sous vide thermique ont comporté un cyclage thermique, l'exposition à des températures extrêmes (hautes et basses) et des phases de

Space Telescope

Modifications to the flight solar-array wings to increase power output and to provide protection against atomic oxygen are under way. The solar-array blankets for the first wing have been delivered and are being fitted. It is planned to deliver both wings to Kennedy Space Center (KSC) in early 1989, where they will be fitted to the Space Telescope.

The Faint-Object Camera (FOC) was removed from the Space Telescope at the end of June and minor reworking of the spectrographic and coronographic operating modes was carried out successfully. The FOC has since been reinstalled in the Space Telescope. The launch date remains 1 June 1989.

STSP

The Solar-Terrestrial Science Programme (Cluster and Soho) has achieved major milestones during 1988.

Following very intensive ESA/NASA scientific and technical evaluation activities, the scientific payload was jointly selected by the ESA Science Programme Committee and the NASA Associate Administrator for Space Science and Applications, in March of this year. Some options that remained open after the March meeting were finally resolved by the Agency's Science Programme Committee (SPC) at its June meeting.

Immediately after the selection was announced, the scientists began a detailed study phase for each instrument with the purpose of providing ESA with definitive, agreed requirements documentation. This will form the basis on which Industry will be invited to tender for procurement of the Cluster and Soho spacecraft.

A major step in this early scientific payload definition effort was the first Science Working Team (SWT) meeting, held in Noordwijk on 27–30 June. This SWT provided the first opportunity for participating scientists to meet in the context of STSP, and constituted a forum for collective discussions with both ESA and NASA representatives concerning the definition and funding status of the Programme as a whole. The second SWT is scheduled for February 1989.

Once the scientific payload had been selected, the next major task was the initiation of the industrial procurement cycle for the spacecraft. STSP is an ambitious programme in scientific, managerial and financial terms, and this is reflected in the industrial strategy that was approved by the Agency's Industrial Policy Committee (IPC) at their meeting of 22—23 June. Following this IPC approval, an Advance Notification of Tender was released to European industry by ESA on 1 July, with a view to providing companies with preliminary information concerning scientific, technical and policy matters. This Advance Release should permit industry to undertake some preliminary preparation in anticipation of the release of the official Invitation to Tender (ITT) in October 1988, when European firms will be invited to propose for the Cluster and Soho spacecraft procurements. These proposals are scheduled to be received by ESA in February 1989.

Hipparcos

During the Proto-Flight Model (PFM) satellite storage period, activities in ESA and industry have concentrated on the resolution of issues raised at the PFM satellite Flight Acceptance Review (FAR), and on preparations for launch and in-orbit satellite operations. The actions placed upon the project teams to resolve FAR discrepancies are progressing, and in several cases have already been completed. Solutions have largely been found through further analysis, but in some cases hardware changes are being implemented. In particular, replacement of all the relays that were the subject of a 'general alert' (reported earlier) is continuing. The closure status of all of these actions will be examined at a special meeting to be held in September.

Launch and in-orbit-operation preparations are continuing at full speed. Launch-operations, flight-operations and satellite-user manuals are undergoing final review or update in readiness for their publication in final form.

A revised Ariane launch manifest allocates Ariane flight V-30 to Hipparcos (together with TV Sat-2), this flight being nominally scheduled for May 1989. All current planning for satellite reactivation after storage is currently based upon this May 1989 launch date.

Olympus

The thermal-vacuum environmental testing of Olympus-1 was conducted during the months of July and August. The spacecraft was mounted on an infrared rig and the complete assembly installed in the thermal-vacuum chamber at the David Florida Laboratories (DFL) in Ottawa in mid-June. The test equipment, which included a large number of waveguide runs to the spacecraft, was then validated and calibrated.

An integrated system test (IST-2) was performed on the spacecraft and the results compared with the IST-1 test performed prior to starting the environmental test phase. The test in thermal vacuum included thermal cycling, cold and hot extremes and thermal transitions. Full integrated system tests (IST-3 and IST-4) were performed during the temperature extremes and selective electrical tests were continued during the thermal transitions.

After the satellite's return to ambient pressure, an integrated system test (IST-5) and a communications baseline test (CBT-2) were conducted and the results compared with previous tests to verify performance.

Off-line testing of the solar-array wings is currently in progress.

The latest Arianespace launch manifest allocates Olympus-1 to flight V-32 in April 1989.

Integration of the TMS-4 and TMS-5 earth stations into the Redu (Belgium) ground station's in-orbit testing system is well advanced. TMS-4 has already been used successfully for the in-orbit testing of ECS-5. The TMS-6 earth station will be transported from INISEL, Spain, to Redu in October and is expected to be ready for use early next year.

Integration of the two TDS-4 earth stations is nearly complete. The integration of the TDS-5 earth station is complete and delivery to Redu is expected in October/November. Delivery of the three TDS-6 earth stations to Redu is scheduled for September.

The contract for the TDS-7 earth station has been awarded to Selenia Spazio (Italy).

transition. Les essais du système intégré (IST-3 et IST-4) menés ensuite pendant l'exposition aux températures extrêmes ont été des essais complets tandis que des essais électriques sélectifs se sont poursuivis pendant les phases de transition.

Après rétablissement de la pression ambiante, un essai du système intégré (IST-5) et un essai de base de télécommunications (CBT-2) ont été réalisés et leurs résultats comparés avec ceux des essais précédents afin de vérifier les caractéristiques de fonctionnement et de contrôler les tendances.

On procède actuellement à un essai distinct des ailes des panneaux.

Selon le dernier manifeste des lancements d'Arianespace, Olympus-1 sera lancé par Ariane V32 en avril 1989.

L'intégration des stations terriennes TMS-4 et TMS-5 au système d'essais en orbite de Redu a beaucoup progressé. TMS-4 a déjà été utilisée avec succès pour l'essai en orbite d'ECS-5. La station terrienne TMS-6 qui se trouve chez INISEL, en Espagne, sera apportée à Redu au mois d'octobre et devrait être prête à l'utilisation au début de l'année prochaine.

L'intégration des deux stations terriennes TDS-4 est presque achevée. L'intégration de la station terrienne TDS-5 est terminée et sa livraison à Redu doit avoir lieu en octobre ou novembre. L'arrivée des trois stations terriennes TDS-6 à Redu est prévue pour septembre. Le contrat portant sur la station terrienne TDS-7 a été attribué à Selenia Spazio.

Etablir le calendrier détaillé des expériences à mener avec les différentes charges utiles d'Olympus est une tâche dont la complexité ne cesse de croître. Un atelier ESA sur le télé-enseignement s'est tenu à Avignon en avril dernier; il a réuni quelque 140 représentants des universités, de l'industrie, des médias et autres organismes. Un Centre de coordination et de gestion des activités d'utilisation d'Olympus a donc été mis en place. Ce Centre, dénommé OPUS (secrétariat pour l'utilisation de la charge utile d'Olympus), est implanté à la Division des systèmes de télécommunications de l'ESTEC. Un Centre d'exploitation de la charge utile du satellite Olympus (SPOC) est actuellement mis sur pied à Redu dans les installations de l'ESA. Le SPOC sera directement en liaison avec les expérimentateurs, gérera l'exploitation des charges utiles minute par minute en coopération avec le Centre de contrôle du satellite Olympus basé à Fucino et fournira des moyens de suivi des charges utiles.

DRPP

Après évaluation et négociation de la proposition de Selenia, l'étude système de phase A2 du satellite de relais de données (DRS) a démarré au début du mois de juillet. Cette étude, à laquelle participent 18 sociétés européennes, se poursuivra jusqu'en avril 1989 et consistera principalement à:
- *revoir le scénario de 'mission utilisateurs' élaboré par l'Agence qui prend en compte l'évolution des besoins des utilisateurs depuis le début de la phase A1;*
- *élaborer et analyser les caractéristiques de fonctionnement d'une série de configurations de charges utiles DRS, avec certains écarts admissibles par rapport au scénario de la mission;*
- *évaluer les possibilités d'aménagement des diverses charges utiles envisageables sur les différentes plates-formes de satellites disponibles en Europe;*
- *poursuivre les études des terminaux utilisateurs à Terre et en orbite terrestre basse (LEO) afin d'être en mesure de définir les caractéristiques et concepts nécessaires pour qu'ils répondent aux besoins des utilisateurs;*
- *étudier et mettre au point le concept du secteur sol de commande et de contrôle opérationnels du DRS;*
- *fournir des plans de réalisation schématiques et des coûts indicatifs des éléments du DRS complet, y compris les diverses configurations possibles du véhicule spatial.*

A l'appui de l'étude système principale, l'Agence a également lancé des études dans les domaines qui représentent un défi technologique et qui demandent à être évalués et analysés en profondeur. Il sera procédé de même chaque fois que les résultats de l'étude système feront apparaître de nouveaux domaines de préoccupation.

En mai s'est tenu un atelier au cours duquel des représentants de l'industrie spatiale européenne et des experts financiers ont été invités à exprimer leur avis sur la question de la commercialisation du DRS. Le large éventail des idées présentées et des questions abordées reflète la complexité du sujet. Des recherches et des investigations beaucoup plus poussées seront nécessaires avant que des recommandations positives puissent être faites sur la question de la commercialisation du DRS et, le cas échéant, sur la mise en oeuvre de ce projet.

PSDE

Sat-2

Trois études de phase B1 sont en cours pour la définition des configurations du véhicule spatial. Ces contrats, qui doivent s'achever à la fin du mois de novembre, ont pour objet d'étudier comment installer les différentes charges utiles de Sat-2 sur des plates-formes existantes. Les charges utiles elles-mêmes font l'objet de contrats parallèles distincts.

Si l'on prend en compte les activités de la phase A et de la phase B1, une très large gamme de charges utiles et de combinaisons de charges utiles a été étudiée. Les problèmes que pose l'installation de chaque charge utile et des combinaisons de charges utiles sur les trois plates-formes (Eurostar, Italsat et Spacebus) sont maintenant bien compris et les configurations à retenir ainsi que les capacités limites de fonctionnement de chaque plate-forme ont été définies. Beaucoup d'attention a également été portée à l'architecture du système de télécommunications et à l'interconnexion des charges utiles et de la liaison de connexion.

La définition de la mission prend forme: les principales charges utiles sont destinées à assurer à titre préopérationnel des services de relais de données et des services mobiles terrestres mais un grand nombre d'options sont encore à l'examen. On étudie également plusieurs petites charges utiles comme la charge utile de

The detailed scheduling of experiments using the various payloads of Olympus is becoming an increasingly complex activity. An ESA workshop on distance-learning held in Avignon last April was attended by approximately 140 people, representing universities, industry, the media and other organisations. A coordination and management centre for all Olympus utilisation activities has therefore been established. This centre, called the Olympus Payload Utilisation Secretariat (OPUS), is within the Communications Systems Division at ESTEC.

An Olympus Satellite Payload Operations Centre (SPOC) is being established at Redu (Belgium). This SPOC will interface directly with individual experimenters and manage minute-by-minute operations of the payloads in cooperation with the Olympus Satellite Control Centre in Fucino (Italy), and will provide payload monitoring facilities.

DRPP

Following evaluation and negotiation of the Selenia proposal, the Data-Relay Satellite (DRS) Phase-A2 System Study commenced at the beginning of July. This study, involving 18 European companies, will last until April 1989. Its main tasks are to:

- review the user mission scenario generated by the Agency, which takes into account the evolution of the users' requirements since the commencement of Phase-A1;
- generate and analyse the performances of a range of DRS payload configurations consistent with various tolerances in the mission scenario;
- assess the accommodation of the various payload alternatives on the range of spacecraft platforms available in Europe;
- continue studies on the user low-Earth orbit (LEO) and earth terminals in order to define the terminal characteristics and designs needed to meet the users' requirements;
- review and finalise the design of the DRS operational ground-control segment;
- provide outline development plans and cost indications for the DRS elements, including the various alternative spacecraft configurations.

In support of the main System Study, the Agency has also initiated studies in areas considered to be technologically challenging or requiring in-depth evaluation and analysis. This process will continue as the results of the System Study highlight new areas of concern.

A workshop was held in May at which representatives of European space industry and financiers were invited to express their views on the question of DRS commercialisation. The wide spectrum of ideas and issues raised reflects the complexity of the subject and much more research and investigation will be needed before positive recommendations can be made on whether DRS should be commercialised and, if so, how such a scheme could be implemented.

PSDE

Sat-2

Three Phase-B1 studies for the definition of spacecraft configurations are in progress. These contracts, due for completion by the end of November, cover analysis of the accommodation of the various Sat-2 payloads on existing platforms. The payloads themselves are the subject of separate, parallel contracts.

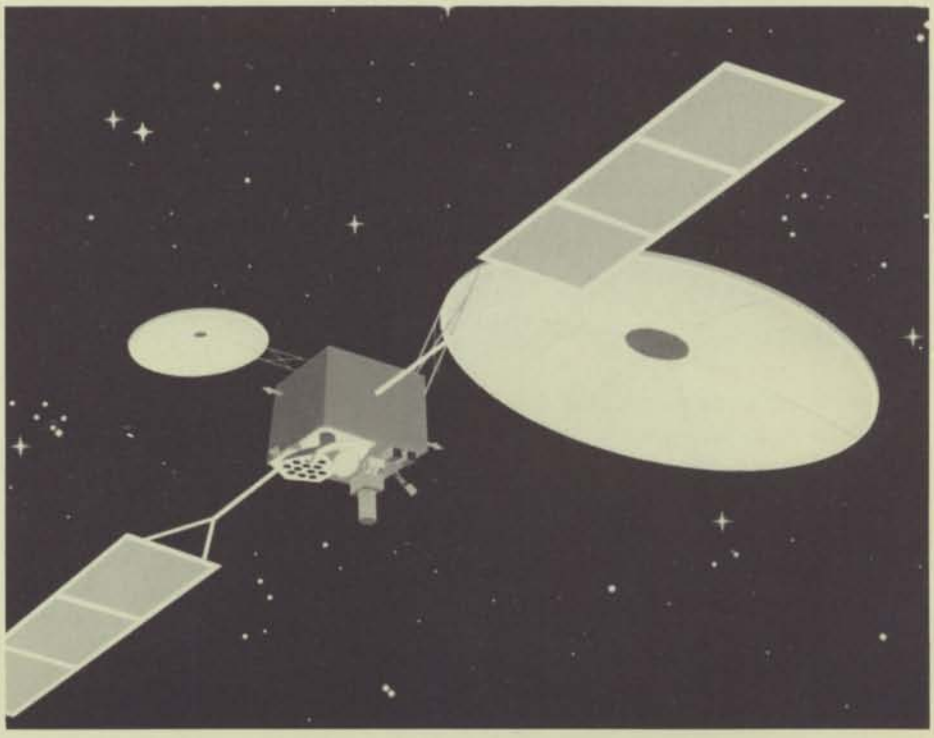
Taking the activities of both Phase-A and Phase-B1 into account, a very wide range of payloads and payload combinations has been studied. The problem of accommodating individual payloads and payload combinations on the Eurostar, Italsat, and Spacebus platforms is now well understood, and the preferred configurations and limiting performance capabilities of each of the three platforms have been established. The communications-system architecture, and the interconnection of payloads and feeder link, have also been given considerable attention.

Mission definition is taking shape, with the main payloads aimed at providing pre-operational data-relay and land-mobile services, but there are a number of options still under discussion. There are also several smaller payloads, such as the On-Board Processing and Millimetre-Wave Communication packages.

The formation of industrial groups is under way, and the final payload options are becoming clearer. The second potential participants' meeting will be held in early September.

Vue conceptuelle d'un satellite du programme PSDE

Artist's impression of a PSDE satellite



traitement à bord et celle de télécommunications en ondes millimétriques. La constitution des groupes industriels est en cours et les options de charges utiles définitives deviennent plus claires. La deuxième réunion des participants potentiels aura lieu au début du mois de septembre.

ERS

Les travaux portant sur les modèles d'identification des instruments ont considérablement avancé et de nombreuses non-conformités, constatées lors des premiers essais des instruments, ont été corrigées ou sont en passe de l'être. Le programme d'essai du satellite et de la charge utile du modèle d'identification qui fera suite doit se poursuivre jusqu'à la mi-1989.

La fabrication du matériel du modèle de vol est achevée dans plusieurs domaines (par exemple pour la structure porteuse de la charge utile) et se poursuit dans tous les autres. La revue d'aptitude au vol est prévue pour février 1990 dans la perspective d'un lancement en mai de la même année.

Les travaux portant sur le secteur sol avancent conformément au plan et les essais de recette des premiers éléments ont été menés à bien.

Les activités de planification concernant la préparation au lancement, la mise en service en orbite, l'étalonnage et la validation ainsi que la mission progressent de façon nominale.

Les discussions se poursuivent au niveau du Conseil directeur du programme et du Conseil de l'Agence afin d'assurer une plus grande continuité des observations des instruments d'ERS-1.

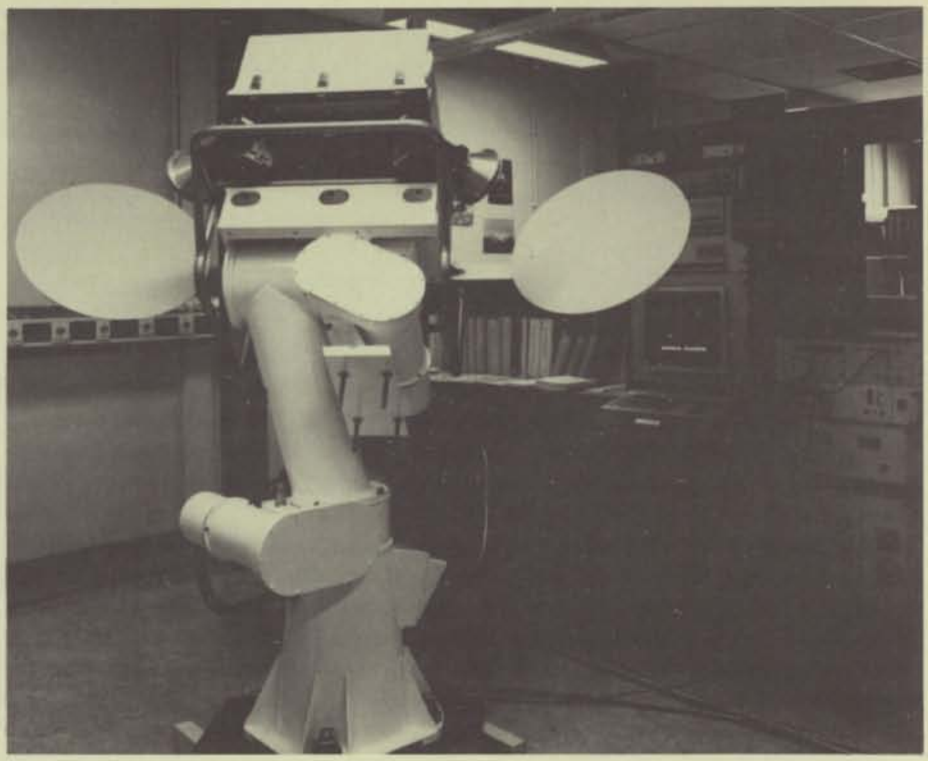
Earthnet

Earthnet a traité de façon nominale les données de toutes les missions dont il a la charge (Landsat, MOS-1, Tiros et Spot). Les stations de Kiruna, Fucino, Maspalomas et Tromsø continuent à travailler de façon satisfaisante sur ces données, conformément au plan d'acquisition et d'élaboration des produits établi par l'Agence. La réalisation du sous-système d'archivage des données de Tiros ainsi que du sous-système d'élaboration des produits utilisateurs normalisés de MOS-1 a progressé de façon satisfaisante.

En ce qui concerne le secteur sol d'ERS-1 dans son ensemble, des progrès ont été faits dans différents domaines avec notamment:
- *la remise du projet de rapport relatif à l'étude de la mise à hauteur de la station de Gatineau;*
- *le choix de la configuration de référence des chaînes de traitement des données pour les stations ERS-1 de Maspalomas, Fucino et Gatineau;*
- *l'achèvement des études portant sur les structures des données d'ERS-1, les produits utilisateurs et les algorithmes de traitement de même que la définition du système mondial de références pour le repérage géographique des produits d'ERS;*
- *le bon avancement de la spécification des interfaces entre les différentes installations du secteur sol.*

L'accord ESA/INTA sur l'utilisation de Maspalomas pour les campagnes CEE au-dessus de l'Afrique de l'Ouest a été prolongé jusqu'à juillet 1989 et couvre l'acquisition des données de Tiros, de Spot et de Landsat.

Des négociations ont été engagées avec la NASDA, agence spatiale japonaise, sur la tarification des données de MOS-1 ainsi que sur l'accès par les stations Earthnet aux données de MOS-1B et de J-ERS-1 et par les stations japonaises aux données d'ERS-1.



ERS scatterometer ground calibration unit

L'installation d'étalonnage au sol du diffusiomètre d'ERS-1

Le programme de formation à l'observation de la Terre, organisé dans des pays en développement (par exemple à Nairobi et à Bangkok) en coopération avec les Centres régionaux des Nations Unies et des banques régionales de développement, a été conduit à bonne fin.

EOPP

Pendant la période considérée, les activités du programme préparatoire d'observation de la Terre (EOPP) se sont poursuivies en ce qui concerne ses trois éléments principaux.

Programme solide terrestre 'Aristoteles'
La seconde et dernière partie de l'étude de phase A d'Aristoteles a été conduite par une équipe d'industriels européens ayant pour chef de file la société allemande Dornier System. La configuration de satellite choisie lors de la présentation à mi-parcours de mars 1988 comporte un gradiomètre plat fixe composé de quatre accéléromètres à deux axes sensibles chacun. Parmi les concepts étudiés, c'est celui qui

ERS

Work on the engineering models of the instruments has progressed considerably and many non-conformances identified in early instrument testing have been or are being corrected. The ensuing engineering-model payload and satellite test programme will run until mid-1989.

Flight-model hardware manufacture has been completed in several areas (e.g. for the Payload Support Structure) and continues in all others. The Flight Acceptance Review is foreseen for February 1990, assuming a launch in May 1990.

Work on the ground segment is proceeding according to plan, and acceptance testing of the first elements has been completed.

Launch preparation, in-orbit commissioning, calibration and validation, and mission-planning activities are proceeding nominally.

Discussions at Programme Board and Council level with a view to extending the continuity of ERS-1 instrument observations are continuing.

Earthnet

All satellite missions handled by Earthnet (Landsat, MOS-1, Tiros and Spot) have been performing nominally. The Kiruna, Fucino, Maspalomas and Tromsø stations continue to handle the data from these missions successfully, in accordance with the Agency's acquisition and product-generation plans. Development of the Tiros archiving subsystem, as well as that for the production of standard MOS-1 user products, is progressing satisfactorily.

Progress has also been achieved in various areas of the ERS-1 overall ground segment. In particular:
- the draft study report concerning the upgrading of the Gatineau station has been delivered;
- the baseline configuration for the data-processing chains for the Maspalomas, Fucino and Gatineau stations has been selected;
- studies related to ERS-1 data formats, user products and processing algorithms, as well as the definition of the worldwide reference system for the geographical location of ERS products, have been completed;
- specification of the interfaces between the various ground-segment facilities is well advanced.

The ESA–INTA (Spain) agreement on the use of Maspalomas for the European Commission campaigns over West Africa has been extended until July 1989, and covers the acquisition of Tiros, Spot and Landsat satellite data.

Negotiations with the Japanese Space Agency NASDA have started regarding pricing policy for MOS-1 data, and access by Earthnet stations to MOS-1B and J-ERS-1, and by Japanese stations to ERS-1.

The earth-observation training programme in developing countries (e.g. Nairobi and Bangkok) organised in cooperation with the United Nations regional centres and regional development banks has been successfully completed.

EOPP

Earth-Observation Preparatory Programme (EOPP) activities during the reporting period have concentrated on the three main elements of the Programme.

Solid-Earth Programme, 'Aristoteles'
The second and final part of the Aristoteles Phase-A study has been carried out by a European industrial team led by Dornier System, Germany. A satellite configuration with a fixed flat gradiometer consisting of four accelerometers, each with two sensitive axes, was chosen at the mid-term presentation in March 1988. This was the most cost-effective of the concepts investigated, fulfilling the overall mission objective of a gravity field of 5 mgal for block sizes of 100 km^2. The study was completed in early July with final presentations to Earth-Observation Scientific and Technical Advisory Group (EOSTAG) Members and the European scientific community.

Additional study activities lasting about nine months have been approved by ESA's Earth-Observation Programme Board and by the Agency's Industrial Policy Committee (IPC) in June. These studies will investigate specific technical problems in more detail and prepare with industry for Phase-B.

Meteosat Second Generation
The Executive presented the results of the pre-Phase-A satellite configuration studies and of the instrument studies corresponding to the requirements of the previous workshops and consultancy reports.

Thereafter, work proceeded for a short time on the preparation of Phase-A, but later meetings within Eumetsat delegate bodies revealed further concerns regarding the cost of a future Meteosat Second Generation programme. Accordingly, the Invitation to Tender for Phase-A has been delayed and current efforts are concentrated on analysing means of further reducing programme costs without losing all of the industrial momentum that has been generated to date.

Polar Platform
The framework for the Phase-A study of a first polar-orbiting mission, prepared within the EOPP Programme, has been approved by the Earth-Observation Programme Board. The corresponding procurement proposal has been agreed by the Agency's Industrial Policy Committee (IPC).

Following the EOSTAG recommendation, a mission definition and a payload complement (including three different options) for the baseline Polar-Platform concept have been submitted to and approved by the Earth-Observation Programme Board.

An alternative mission and payload complement will be submitted to the September EOSTAG and October Programme Board for the Spot-4-derived Polar-Platform concept.

Microgravity

In June, Germany announced its participation in the Microgravity Programme Extension Phase with a 25% contribution, bringing the total subscription base to 77.65%. This Extension Phase will now be combined with Phase-2 of the Microgravity Programme into a single programme referred to as 'Extended Phase-2'.

The scheduled launch of NASA's

présente le meilleur rapport coût/efficacité tout en satisfaisant aux objectifs généraux de la mission: champ gravifique de 5 mgal pour des blocs de 100 km². L'étude s'est achevée au début du mois de juillet par la présentation finale et une présentation faite par l'Exécutif aux membres du Groupe consultatif scientifique et technique pour l'observation de la Terre (EOSTAG) et à la Communauté scientifique européenne.

Le Conseil directeur du Programme d'observation de la Terre et le Comité de la politique industrielle (IPC) de l'ESA ont approuvé en juin un supplément d'études d'une durée approximative de neuf mois, qui permettra d'examiner de façon plus détaillée des problèmes techniques spécifiques et de préparer la phase B avec l'industrie.

Météosat de deuxième génération
L'Exécutif a présenté les résultats des études de préphase A sur la configuration du satellite et des études sur les instruments qui répondaient aux impératifs définis lors des précédents ateliers et par des rapports d'experts.

Des travaux de préparation de la phase A se sont déroulés pendant un court laps de temps mais des réunions ultérieures des organes délibérants d'Eumetsat ont mis en lumière d'autres préoccupations concernant le coût d'un futur programme Météosat de deuxième génération. L'appel d'offres de la phase A a donc été reporté et les travaux actuels sont axés sur l'analyse de moyens qui permettraient de réduire encore les coûts du programme sans perdre la vitesse acquise jusqu'ici au plan industriel.

Plate-forme polaire
Les principes de l'étude de phase A d'une première mission en orbite polaire, préparée sous l'égide du programme EOPP, ont été approuvés par le Conseil directeur du programme et la proposition d'approvisionnement correspondante par l'IPC.

A la suite de la recommandation de l'EOSTAG, la définition de la mission et la composition de la charge utile (trois options différentes) pour le concept de référence de la plate-forme polaire ont été soumises au Conseil directeur du programme qui les a approuvées.

Pour le concept de plate-forme polaire dérivé de Spot-4, une autre formule de mission et de charge utile sera soumise en septembre à l'EOSTAG et en octobre au Conseil directeur.

Microgravité

En juin, l'Allemagne a annoncé qu'elle participerait à la phase d'Extension du Programme de recherche en microgravité et que sa contribution y serait de 25%, ce qui porte le total des souscriptions à 77,65% pour cette phase. La phase d'Extention et la phase 2 du programme seront fondues en un seul programme, dit de 'Phase 2 élargie'.

Le lancement du laboratoire international de recherche en microgravité (IML-1) de la NASA a été reporté à février 1991 et celui de la mission allemande D2 à fin 1991. Ces deux dates dépendent du manifeste de la Navette.

Phase 2
Les impératifs plus sévères imposés par la NASA en matière de résistance structurelle et de sécurité à la suite de l'accident de la Navette ont été négociés avec les contractants industriels pour les charges utiles de l'ESA devant être embarquées lors de la mission allemande D2 du Spacelab (à savoir l'Anthrorack, le module de physique des fluides de haute technologie, l'installation d'étude des phénomènes de point critique). Ces exigences se traduiront par des augmentations de coûts subtantielles et par des retards de livraison des modèles d'identification et de vol.

Le Biorack passe actuellement par un cycle de mise à niveau afin de rendre son matériel conforme aux nouvelles normes de sécurité de la NASA et de remettre à neuf les roulements et commandes des centrifugeuses.

Maintenant que l'Allemagne contribue au financement de la phase d'Extension, l'ESA est en mesure de participer au lancement des fusées-sondes Texus 19 et 20 prévu pour cet automne et dont les préparatifs sont actuellement en cours.

La charge utile de l'ESA à embarquer sur la fusée-sonde suédoise Maser-3 a été choisie et la participation de l'ESA fixée à environ 90%. Le lancement est prévu pour le printemps 1989.

Charge utile constituant le noyau d'Eureca
Les travaux d'intégration et d'essai des modèles de vol des cinq charges utiles du noyau d'Eureca progressent. Dans certains cas, les essais déjà conduits ont montré la nécessité de corrections techniques limitées et de nouveaux essais. La livraison de la première charge utile doit avoir lieu en octobre/novembre et les livraisons suivantes au cours du premier semestre 1989.

Eureca

L'essai du modèle thermique grandeur réelle d'Eureca dans le grand simulateur solaire de l'ESTEC s'est terminé de façon satisfaisante. L'évaluation des données de l'essai et leur comparaison avec les prévisions du modèle analytique sont en cours.

En dépit des progrès réalisés par SNIA/BPD (Italie) dans l'intégration des systèmes de propulsion à la structure de vol d'Eureca, les délais de livraison des réservoirs haute pression de PSI (Etats-Unis) sont maintenant cause de retards. Ces retards auront une incidence sur l'assemblage du modèle de vol chez MBB/ERNO. Afin d'en réduire les conséquences, des essais supplémentaires des instruments du modèle de vol seront conduits dans les installations d'essai de la charge utile afin de détecter, à l'avance, les problèmes d'interface.

La dernière revue de sécurité d'Eureca menée conjointement avec la NASA a montré qu'il fallait apporter certaines modifications à la conception de la connexion ombilicale et de la boule d'accrochage.

Le lancement d'Eureca est actuellement prévu pour janvier 1991 et sa récupération en juin de la même année.

Station Spatiale/ Columbus

Les principales activités de la phase C-zéro de Columbus, qui est en cours, ont

International Microgravity Laboratory IML-1 has been shifted to February 1991 and the date for the German Spacelab-D2 mission has been moved to the end of 1991. Both of these launch dates are dependent on the Shuttle launch manifest.

Phase-2
The more stringent NASA requirements concerning structural verification and safety aspects imposed as a result of the Challenger accident have been negotiated with the industrial contractors for the ESA payloads to be flown on the German Spacelab-D2 mission (i.e. Anthrorack, Advanced Fluid-Physics Module, Critical-Point Facility). The impact of these requirements will be substantial additional costs, and delays in the delivery of the engineering and flight models.

Biorack is presently undergoing a refurbishment cycle to make the hardware compatible with these more stringent NASA safety requirements. The centrifuge bearings and controls are also being refurbished.

Now that Germany is contributing to the Extension Programme, ESA is in a position to participate in the Texus-19 and -20 sounding-rocket launches, which are scheduled for this Autumn. Preparations are already under way for these flights.

The ESA payload for the Swedish sounding rocket Maser-3 has been selected (ESA participation approximately 90%). Launch is scheduled for the spring of 1989.

Eureca core payload
The work on integration and testing of the flight models of the five Eureca core payloads is progressing. In some cases limited technical corrections and retesting are necessary as a result of the tests already carried out. The first payload delivery is expected in October/November, with subsequent staggered deliveries during the first half of 1989.

Eureca

The Eureca full-scale thermal-model test in the Large Solar Simulator (LSS) at ESTEC has been completed satisfactorily. Evaluation of the test data and its correlation with analytical model predictions are in progress.

In spite of the good progress made in the integration of the propulsion systems into the Eureca flight structure at SNIA/BPD (Italy), delays are now being caused by late delivery of the high-pressure tanks from PSI (USA). These delays will affect assembly of the flight spacecraft at MBB/ERNO (Germany). To minimise the effects of this, additional testing of flight-unit instruments will continue on the payload test facility to allow early identification of interface problems.

As a result of the last Eureca safety review with NASA, some changes have to be made to the umbilical connection and grapple fixture designs.

Launch of Eureca is currently planned for January 1991, with retrieval in June 1991.

Space Station/ Columbus

The main activities within the ongoing Columbus Phase-C/zero have been firstly the updating of the system requirements, and secondly the replanning of this phase itself and of the main development phase itself and of the submission of the main development phase (Phase-C/D) proposal to match the changing situation. It is now foreseen to hold the Preliminary Requirements Review (PRR) in two parts. Part 1 in December 1988 will cover all specifications except those for the pressurised modules (PM2) and Attached Pressurised Module (APM); Part 2 in February 1989 will cover the latter two elements. Also agreed were milestones for Phase C/D-proposal submittal in May 1989, and termination of Phase-C/zero at the end of June 1989.

The ESA Request for Quotation (RFQ) for Columbus Phase-C/D was issued to industry, as planned, on 1 July, immediately after the June Council meeting. Open-ended System Requirements were closed-out by the end of August, except for those related to NASA Space Station and Hermes. Two parallel studies for two different concepts of the Polar Platform have been added to the scope of Phase-C/zero and will be completed early in 1989.

The NASA Level-2 Preliminary Requirements Review, which resulted in 6000 items needing further attention or change, ended in June. NASA will concentrate on these items, including ESA priority-1 issues, during the rest of 1988.

A Columbus Payload Rack Concept Study was recently completed. This study analysed and determined, from a users' viewpoint, the functional and resource capabilities of all identified payload rack interfaces. This study is expected to influence both the Columbus Phase-C/D proposal preparation and the ongoing Multilateral Utilisation Study.

Progress in Crew Work Station activities has included further definition and initial buildup of the General-Purpose Workbench and the development of several software 'building blocks' for crew support, such as expert systems, failure identification, contingency management, and activity scheduling.

Hermes

Coherence management
The Ariane-5, Hermes and Columbus development phases have been initiated at the same time. Their simultaneous management represents an important coherence task for ESA, for CNES (in the case of Ariane and Hermes), and for European space industry.

This challenge occurs firstly at the technical level, because of the complex composite operation of Hermes and Ariane during launch, and of Hermes and Columbus during their servicing mission. It also impacts on numerous joint programme activities, from the coordination of resources and reviews, to the joint development of infrastructure, particularly in the testing, software, operations and crew-support areas.

Coherence will be addressed at three levels. At the overall policy level, and reporting to the Director General and the Programme Boards, the Directors of Space Station and Platforms and of Space Transportation Systems will co-chair a 'Coherence Board'. This Board will direct all common Columbus and Hermes activities, approve the programme requirements, and define the agreements with third parties. In the case of Hermes and Ariane, coordination

Preparation of Eureca solar panels for thermal vacuum acceptance testing

Préparation des panneaux solaires d'Eureca aux essais de recette de vide-température

consisté premièrement à s'entendre sur les impératifs au niveau système et à les actualiser, et deuxièmement à revoir le planning de cette même phase et de la proposition de phase C/D en fonction de l'évolution de la situation. Il est maintenant prévu de procéder à la revue préliminaire des impératifs (PRE) en deux parties: une première partie en décembre 1988 qui couvrira toutes les spécifications sauf celles des modules pressurisés PM2 et APM (modèle pressurisé raccordé) et une deuxième en février 1989 qui portera sur ces deux derniers éléments. Il a également été convenu de deux étapes-clés: la soumission de la proposition de phase C/D en mai 1989 et l'achèvement de la phase C-zéro à la fin du mois de juin 1989.

Comme prévu, l'ESA a envoyé à l'industrie la demande de prix (RFQ) relative à la phase C/D de Columbus le 1er juillet, immédiatement après la session du Conseil de juin. Les impératifs système qui restaient à définir ont été figés pour la fin août, à l'exception de ceux qui ont trait à Hermès et à la Station spatiale de la NASA. Deux études parallèles portant sur deux concepts différents de plate-forme polaire ont été lancées en plus de celle de la phase C-zéro; elles prendront fin au début de 1989.

La revue préliminaire des impératifs au niveau 2 de la NASA s'est terminée en juin. Elle a montré que 6000 points devaient faire l'objet d'un supplément d'étude ou d'une modification. Pendant le reste de l'année, la NASA concentrera son attention sur ces points ainsi que sur les questions qui constituent la priorité no. 1 pour l'ESA.

On vient de mettre la dernière main à une étude qui avait pour objet d'analyser et de définir, du point de vue des utilisateurs, les besoins en ressources et les capacités fonctionnelles à toutes les interfaces recensées des bâtis charge utile de Columbus. Ses conclusions devraient peser à la fois sur la préparation de la proposition de phase C/D de Columbus et sur l'étude de l'utilisation multilatérale qui est en cours.

Les activités portant sur le poste de travail de l'équipage ont consisté à affiner la définition de l'établi à usage général et à en réaliser un modèle initial, ainsi qu'à élaborer plusieurs 'modules' de logiciel servant au soutien de l'équipage: systèmes-experts, diagnostic de défaillances, gestion des risques et planification des activités.

Hermès

Gestion de la cohérence

Les trois plus grands programmes de l'ESA, Ariane, Hermès et Columbus, sont entrés au même moment dans leur phase de réalisation. Leur gestion simultanée demande donc un important travail d'harmonisation à l'ESA, au CNES (pour Ariane et Hermès) et à l'industrie spatiale européenne. Il s'agit en premier lieu de relever un défi technique en raison de la complexité de la conduite des opérations avec les 'composites' Ariane et Hermès au lancement et Hermès/Columbus pendant les missions de service, mais aussi d'assurer la cohérence des nombreuses activités communes aux différents programmes qui vont de la coordination des ressources et des revues d'avancement à la réalisation d'éléments communs de l'infrastructure, notamment dans le domaine des essais, du logiciel, de la conduite des opérations et du soutien des équipages.

Cette cohérence sera gérée à trois niveaux. A celui de la politique générale, le Directeur du Départment 'Station spatiale et plates-formes' et celui du Département 'Systèmes de transport spatial' co-présideront une Commission de la cohérence et feront rapport au Directeur général et aux Conseils directeurs des programmes. Cette Commission dirigera l'ensemble des activités communes à Columbus et Hermès, approuvera les impératifs des programmes et définira les accords avec des tiers. Pour le couple Hermès-Ariane, ce sont des réunions de coordination entre les directeurs compétents de l'ESA et du CNES qui assumeront les mêmes responsabilités.

Au niveau de la gestion technique, les deux responsables de projet président le Groupe 'Interface Hermès/Columbus' (CHIG) responsable de l'ensemble des interfaces techniques et opérationnelles et de l'approbation des impératifs communs. Un groupe CNES 'Interface Ariane/Hermès', au sein duquel l'ESA est représentée par ses deux responsables de projets, assure la cohérence au même niveau.

De toute évidence, l'industrie jouera un rôle important dans la mise en oeuvre de la cohérence, notamment pour le contrôle des interfaces. Le CHIG sera conseillé, dans l'évaluation de la validité de son programme de vérification des meetings will take place between the relevant ESA and CNES Directors.

At the technical-management level, the two project managers will chair a Columbus–Hermes Interface Group (CHIG), which will be responsible for all technical and operational interfaces, and the approval of joint requirements. A CNES Ariane–Hermes Interface Group, in which ESA will be represented by its two project managers, will ensure coherence at the same level.

Obviously, industry will play a major role in this coherence effort, particularly as regards interface control. To assess the validity of its performance verification programme, the CHIG will be advised by a Coherence Support Contractor (CSC), who will perform system and trade-off studies relating to Hermes–Columbus composite performance.

As Aerospatiale is the prime contractor for both Hermes and Ariane, a similar arrangement is unnecessary in this case.

Finally, coherence between Ariane and Columbus, as well as between the three programmes and other ESA projects — DRS in particular — will be pursued via the usual ESA management procedures.

Astronaut training

On 17–18 March, the ESA Council approved proposals regarding the locations for various training facilities for Hermes astronauts. Porz-Wahn in Germany will be the astronauts' home base and various mockups for basic training and for MTFF servicing training will also be located there. The Pilot Training Facility will be in Belgium and the Hermes Training Centre for system and subsystem training will be in Toulouse. Two further training facilities associated with external servicing will be the Extravehicular Activity (EVA) facility in Marseilles, and the Hermes Robotic Arm (HERA) training facility at ESTEC.

This overall training concept is now being elaborated further. A detailed workload per facility is being evaluated and the resulting astronaut work plan is being derived.

In parallel with this system-level study, various facility-related studies are being carried out to establish preliminary definitions for the five centres.

TDP

Common support subsystems

Payload Control Unit

Phase-2 of the contract (hardware design) is in progress, with the Critical Design Review planned in January 1989. The prototype of the unit will be delivered in July 1989.

Experiments

Gallium-Arsenide (GaAs) Solar Array: The result of the Phase-1 contract will be the in-orbit testing of a complete panel and two patches of ultra-thin cells. The engineering model of the panel to be flown next year will be completed in September and the flight model will be delivered in November. The Invitation-to-Tender for Phase-2, aiming to support applications such as Columbus, will be issued by the end of 1988.

Solid-State Microaccelerometer: Breadboards of critical subsystems have been manufactured and tested. The Critical Design Review is planned for November and flight-unit manufacture will start in December.

Two proposals are currently under negotiation for the *Collapsible-Tube Mast and Heat-Pipe Radiator*, and the Invitation-to-Tender for the *Inflatable Space-Rigidised Antenna* has been completed.

Transputer and Single-Event Upset: The contract kick-off meeting took place in July. Work is progressing on manufacture of the transputer board. The development of on-board software has also been initiated.

The *In-Space Aluminium Coating* proposal has been received and is under evaluation.

Liquid-Gauging Technology: The contractor has delivered the system design and requirements document as part of the definition study already completed. The proposal for experiment adaptation/integration is pending.

ESA/NASA cooperative experiments

International cooperation with NASA's Office for Aeronautics and Space Technology is progressing with the start of the NASA Phase-B study for the In-Flight Contamination experiment in August. An important technical meeting concerning the Solar-Array Module Plasma Interaction experiment interfaces was held in September. Both experiments should be carried as passengers on the top of the Collapsible-Tube Mast, on subsequent flights. The same mast will be reflown after refurbishment. Discussions on further joint experiments are continuing.

Flight opportunities

The Get-Array Special (GAS) end plate for the Solid-State Microaccelerometer (G-21) was received from NASA, and will be used for experiment integration. The second half of 1989 is still considered feasible for the flight of G-21, pending Shuttle-flight resumption.

Work on the preliminary accommodation and safety data package for the Liquid Gauging Technology experiment (G-22) and the In-Space Aluminium Coating experiment (G-485) is progressing according to schedule.
Regarding the experiments using the Hitchhiker-G Carrier, notification has been received that the Attitude Sensor Package will be flown on the first Hitchhiker-G after Shuttle flight resumption, possibly in 1990. For the Collapsible-Tube Mast and Heat-Pipe Radiator, manifesting is awaiting the ammonium-perclorate assessment. A draft of the launch-service agreement for the above is under discussion between ESA and NASA.

Final discussions are being held on an agreement to fly the Inflatable Space-Rigidised Antenna on the USSR's MIR Space Station.

The Transputer and Single-Event Upset experiment, as well as the Gallium Arsenide Solar panel and two solar-cell patches will now be carried by the University of Surrey's UoSAT-E spacecraft, due for a piggy-back launch with the Spot-2 satellite on an Ariane-4 vehicle in June 1989.

In the context of looking, together with the Ariane Department, for further flight opportunities, the development of a first demonstration platform called 'Pathfinder' has started. This platform has completed its definition phase, and it will carry an experiment to measure the radiation environment in geostationary transfer orbit for future missions. A piggy-back launch is planned in the second half of 1989.

caractéristiques techniques, par un contractant responsable du soutien de la cohérence (CSC) qui procédera à des études au niveau système et à des arbitrages en ce qui concerne les caractéristiques du composite Hermès-Columbus. L'Aérospatiale ayant la maîtrise d'oeuvre d'Hermès comme d'Ariane, un arrangement similaire n'est pas nécessaire dans ce cas.

Enfin, la cohérence entre Ariane et Columbus ainsi qu'entre les trois grands programmes et d'autres projets de l'ESA — le DRS en particulier — sera assurée selon les procédures de gestion ordinaires de l'ESA.

Entraînement des astronautes
Lors de sa session des 17 et 18 mars, le Conseil de l'ESA a approuvé les propositions relatives à l'implantation des diverses installations d'entraînement des astronautes d'Hermès. Porz-Wahn sera le port d'attache des astronautes où seront installées diverses maquettes pour la formation de base et l'entraînement à la desserte du MTFF. L'installation d'entraînement des pilotes se trouvera en Belgique et le centre Hermès pour l'entraînement au niveau système et sous-systèmes à Toulouse. Deux autres installations d'entraînement aux sorties dans l'espace seront implantées l'une à Marseille pour les activités extravéhiculaires et l'autre à l'ESTEC pour la formation sur le bras-robot d'Hermès (HERA). On travaille actuellement à affiner le concept global de l'entraînement. Le détail de la charge de travail de chaque installation est en cours d'évaluation et le plan de travail des astronautes en sera dérivé.

Parallèlement à cette étude au niveau système, diverses études liées aux installations sont en cours en vue d'établir une définition préliminaire des cinq centres.

TDP

Sous-systèmes de soutien communs
Unité de commande de la charge utile: *La phase 2 du contrat (conception du matériel) est en cours et la revue de conception critique est prévue pour janvier 1989. Le prototype de l'unité de commande sera livré en juillet 1989.*

Expériences
Générateur solaire à l'arséniure de gallium (GaAs): *Le contrat de phase 1 va prendre fin avec l'essai en orbite d'un panneau complet et de deux lots de photopiles ultrafines. Le modèle d'identification du panneau devant être embarqué l'an prochain sera achevé en septembre et le modèle de vol livré en novembre. L'appel d'offres relatif à la phase 2, destinée au soutien d'applications pour Columbus entre autres, sera lancé fin 1988.*

Micro-accéléromètre à l'état solide: *Des montages sur table des sous-systèmes critiques ont été fabriqués et essayés. La revue critique de la conception est prévue pour novembre et la fabrication de l'unité de vol commencera en décembre.*

*Deux propositions font actuellement l'objet de négociations (*mât à tube enroulable *et* radiateur à caloducs*) et l'appel d'offres pour* l'antenne gonflable et rigidifiable dans l'espace *est achevé.*

Transordinateur et perturbations sous l'effet de particules élémentaires: *La réunion de mise en route du contrat a eu lieu en juillet. Les travaux de fabrication de la carte du transordinateur progressent. La réalisation du logiciel de bord a également commencé.*

Aluminiage dans l'espace: *la proposition reçue est en cours d'évaluation.*

Technologie de jaugeage des liquides: *Le contractant a livré la documentation sur le concept et les impératifs du système qui fait partie intégrante de l'étude de définition déjà achevée. La proposition d'adaptation/intégration de l'expérience est en attente.*

Expériences en coopération ESA/NASA
La coopération internationale avec le Bureau de technologie aéronautique et spatiale de la NASA progresse: l'étude de phase B de la NASA portant sur l'expérience de contamination en vol a commencé en août. Une importante réunion technique concernant les interfaces de l'expérience d'interactions entre le module de générateur solaire et le plasma a eu lieu en septembre. Ces deux expériences devraient être emportées comme passagers au-dessus du mât à tube enroulable lors de vols ultérieurs. Ce même mât volera de nouveau après remise à neuf. Les négociations sur d'autres expériences communes se poursuivent.

Occasions de vol
La NASA a fait parvenir le plateau terminal du conteneur de petites charges utiles (GAS) destiné au micro-accéléromètre à l'état solide (G-21). Il servira à intégrer l'expérience. On considère qu'il reste matériellement possible de faire voler G-21 au second semestre 1989 sous réserve de la reprise des vols de la Navette.

Les travaux sur l'implantation et l'ensemble des données de sécurité de l'expérience de technologie du jaugeage des liquides (G-22) et de l'expérience d'aluminiage dans l'espace (G-485) progressent conformément au calendrier.

En ce qui concerne les expériences faisant appel au porteur Hitchhiker-G, avis a été donné que l'ensemble détecteur d'orientation sera embarqué sur le premier Hitchhiker-G lancé après la reprise des vols de la Navette, peut-être en 1990. En ce qui concerne le mât à tube enroulable et le radiateur à caloducs, l'inscription au manifeste est en suspens dans l'attente de l'évaluation des disponibilités en perchlorate d'ammonium. Pour les exériences ci-dessus, l'ESA et la NASA négocient actuellement un projet d'accord relatif au service de lancement. Les derniers détails d'un accord sur l'emport de l'antenne spatiale gonflable et rigidifiable dans l'espace à bord de la station spatiale soviétique MIR sont en cours de négociation.

L'expérience 'transordinateur et perturbation sous l'effet des particules élémentaires' ainsi que le panneau solaire à l'arséniure de gallium et les deux échantillons de photopiles seront embarqués à bord du véhicule spatial UoSAT-E de l'Université du Surrey qui doit être lancé en juin 1989 par un Ariane-4 en tandem avec Spot-2.

La réalisation d'une première plate-forme de démonstration dénommée 'Eclaireur' a commencé dans le cadre de la recherche, avec le Département Ariane, de nouvelles occasions de vol. La phase de définition de cette plate-forme est terminée et elle emportera une expérience de mesure du rayonnement environnant en orbite de transfert géostationnaire en vue de futures missions. On projette un lancement en tandem au deuxième semestre 1989.

Operational Calibration of Meteosat's Infrared Channel

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One of ESA's most successful satellites has been its geostationary meteorological satellite Meteosat-2. In addition to providing image information for synoptic forecasters, the image data from Meteosat-2 are used operationally at ESOC to extract specialised meteorological parameters.

All three spectral channels are exploited, but the infrared (IR) channel is the major source of information, as the radiance measured in the thermal infrared is directly proportional to the temperature of the radiating surface, whether that be land, sea or cloud. In order to derive quantitative information from this IR channel, a calibration is needed that allows the readings from the satellite detector to be converted into physical radiance or temperature units.

Introduction
The provision of space-based meteorological services began in Europe more than ten years ago, in November 1977, with the launch of the Agency's first Meteosat satellite. After a failure in Meteosat-1's imagery system at the end of 1979, no images could be provided until Meteosat-2 was launched successfully in June 1981. Although it had a design lifetime of just three years, this satellite was performing very well until the middle of August 1988. Then the new Meteosat-3 took over the task of imaging the Earth and its atmosphere in three bands (visible, infrared and watervapour) of the electromagnetic spectrum.

The Meteosat Operational Programme (MOP) is conducted from ESOC in Darmstadt. In addition to image acquisition, an important aspect of this programme is the derivation of operational meteorological products from the satellite's image data, such as:
— Sea-Surface Temperatures
— Cloud Analysis
— Cloud-Top-Height Maps
— Cloud-Motion Winds
— Upper-Tropospheric Humidities
— Climate Data Sets
— Precipitation Index.

The quantitative exploitation of the Meteosat images, performed at the Meteorological Information Extraction Centre (MIEC) in ESOC, relies on all three of the satellite's spectral channels:
— Visible (VIS): 0.4 — 1.1 micron
— Water Vapour (WV): 5.7 — 7.1 micron
— Infrared (IR): 10.5 — 12.5 micron.

In order to derive meteorological products from these image data, an operational calibration has to be performed for the water-vapour and the infrared channels. Because Meteosat is a spinning satellite, absolute calibration on a once-only basis is not feasible. The satellite's calibration has to be monitored on a day-to-day basis, to cope with the daily variations in the internal temperatures of its detectors and optics and, on a longer time scale, with the contamination of the IR and WV detectors by ice crystals, which also contributes to a loss in radiance sensitivity.

The Meteosat team at ESOC has therefore developed methods for monitoring and calibrating Meteosat's WV and the IR channels on a daily basis. The WV calibration method is described by J. Schmetz & O. Turpeinen in the June 1988 issue of the Journal of Applied Meteorology (Vol. 27, No. 8). This article describes the technique used for the IR channel.

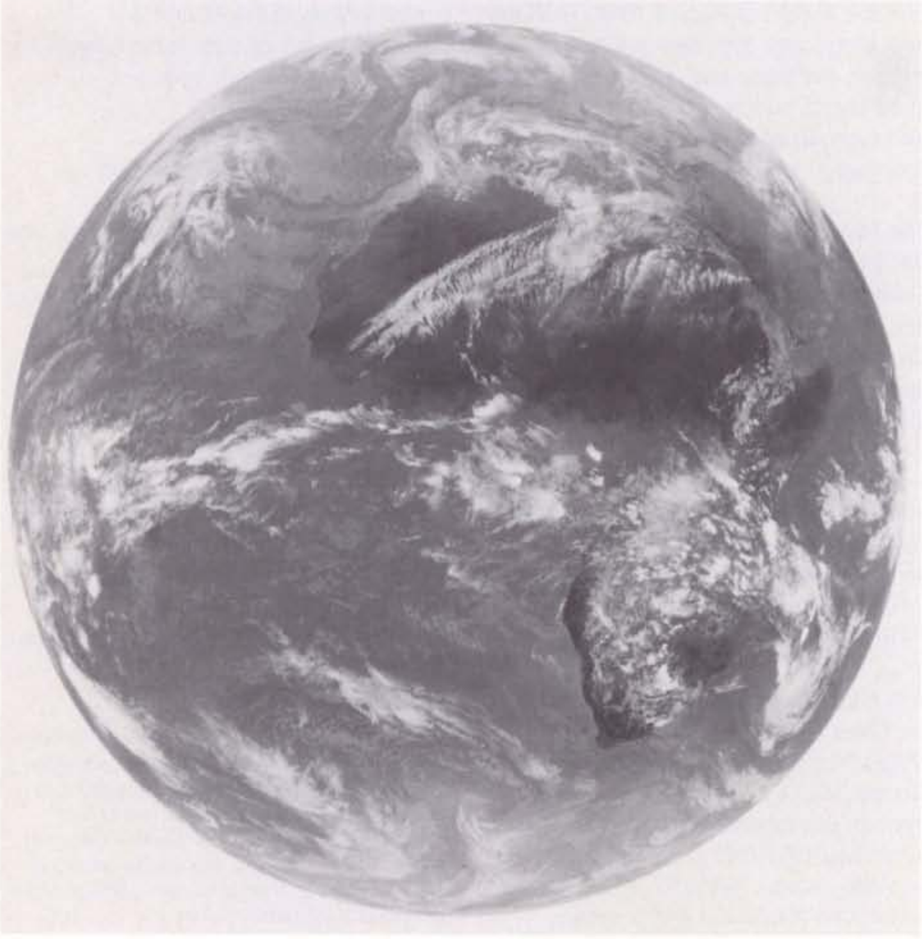
Operational derivation of sea-surface temperature
Figure 1 is a Meteosat IR image* taken at 12.00 GMT on 19 January 1988. The coldest temperatures are represented by

*A Meteosat IR image of the complete Earth's disc contains 2500 x 2500 image pixels, a pixel being the smallest resolvable image unit (resolution of 5 km x 5 km at the subsatellite point; in the visible channel 2.5 km x 2.5 km). The satellite detector's output provides an 8-bit digital count value (0 - 255) for each of these pixels.

Figure 1 — Meteosat infrared image taken at 12.00 GMT on 19 January 1988

bright white areas (high-level clouds), while the warmest temperatures appear almost black (hot desert).

The operational exploitation of such image data is approached in two parts. The first element is an objective analysis of the image, for which the complete image is divided into 32 x 32 pixel segments. To isolate the different physical sources of radiation within each segment, two-dimensional histogram analyses are performed using data from two channels at a time. These analyses are made for all segments within the 55° great-circle arc around the subsatellite point (about 3500). All pixels in the same statistical sample are grouped together to form a so-called 'cluster', for which the mean radiance and the standard deviation are specified.



The second part of the meteorological image processing is the interpretation step in which the cluster radiances are identified with characteristic radiation patterns originating from well-known physical reflectors present in the image segments. The IR radiances are the most important for product derivation.

In its basic form, the Sea-Surface Temperature (SST) product is a direct output of this segment processing. For any cluster identified as sea, it is only necessary to correct the measured radiance for atmospheric absorption before converting it to a temperature using the Planck relationship*. These results are produced every three hours for each segment in which the sea is visible from Meteosat's geostationary orbit, although data are only made available to the user twice per day.

The data distributed to the user are a weighted mean of the results over the last 36 h. They are the end result of an automatic and a manual quality-control scheme applied to the data.

The correction for atmospheric absorption is necessary because, although the spectral region in which the satellite's infrared channel operates is known as the 'atmospheric window', a small amount of radiation is absorbed in the atmosphere, mainly by atmospheric water vapour. For a relatively dry, mid-latitude winter atmosphere, an average atmospheric correction for surface temperature is about 2 to 3°, while for a moist tropical atmosphere it can be more than 10°. When deriving quantitative data from the images, this effect clearly has to be taken into account.

An operational fast radiative transfer scheme has therefore been developed at ESOC which uses short-term forecasts from the European Centre for Medium-range Weather Forecasting (ECMWF) to determine the temperature correction that has to be applied.

Figure 2 shows an operationally derived SST plot for the 19 January 1988, which is typical for Meteosat SST results. It shows that Meteosat provides useful SST data for quite a large ocean area.

A schematic of the operational Meteosat SST retrieval scheme and the calibration procedure that will be described in the next section is given in Figure 3.

Calibration of Meteosat's IR channel
On board the satellite there is an internal 'black body' which can be viewed periodically by the inner elements of the

*The Planck function weighted by the spectral response and integrated over the IR channel from 10.5–12.5 microns provides for every temperature value a radiance value which is related to digital counts.

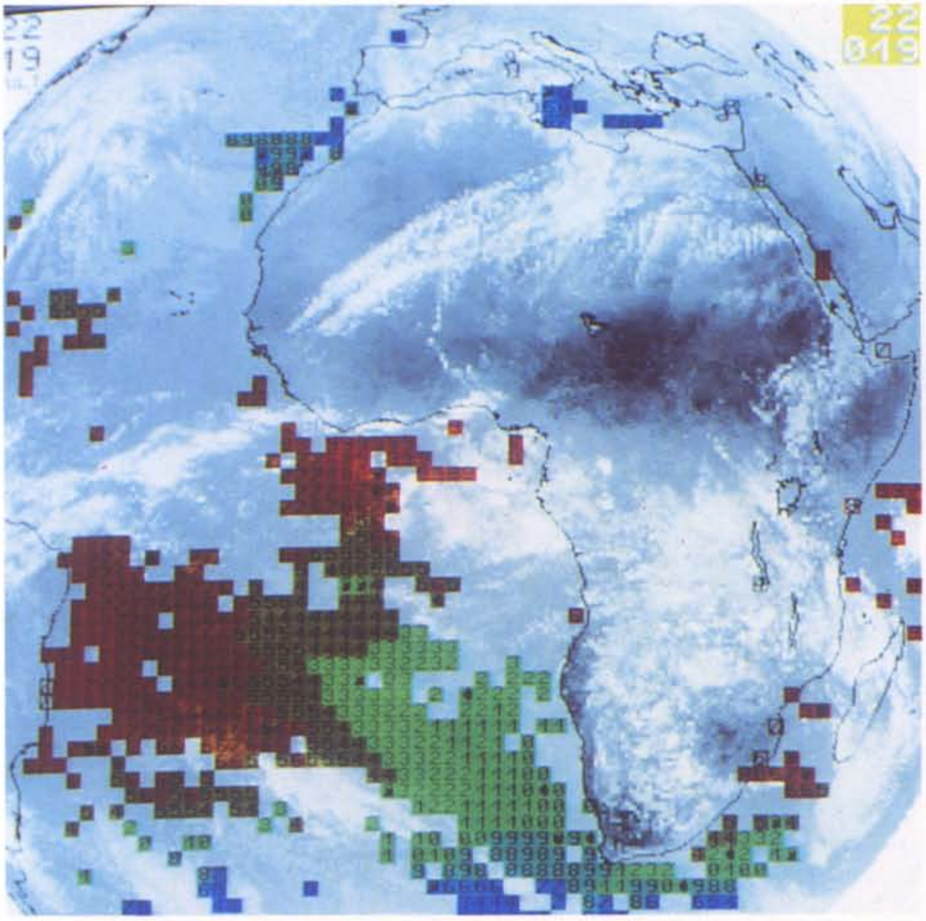


Figure 2 — Meteosat Sea-Surface Temperatures (SSTs) for 19 January 1988 at 11.00 GMT. The last digit of temperature is displayed in a colour-coded field representing the image segment. The colour code is specified for different temperature scales:

blue: 10 — 19° *brown: 24 — 25°*
green: 20 — 23° *red: more than 26°*

optical system (whilst the radiometer is in its retrace phase, before starting its next series of Earth scans). The black-body calibration values are used twice daily to determine the detector's response to temperature variations inside the spacecraft and the influence of ice contamination on the IR detector.

The actual black-body count is set in relation to an ideal black-body count that would be observed by an ideal instrument for a black-body temperature of 290 K. This leads to a so-called 'fine adjustment of gain' factor which is a numerical factor of the order of one. This factor can be used to rescale the image count values before they enter the automatic processing scheme, so that variations in detector sensitivity are numerically corrected.

However, as the black body is not viewed by Meteosat's full optical system, absolute calibration can only be achieved by using an external reference source. It is for this purpose that the operationally derived Meteosat SST data are compared with sea-temperature observations logged by the National

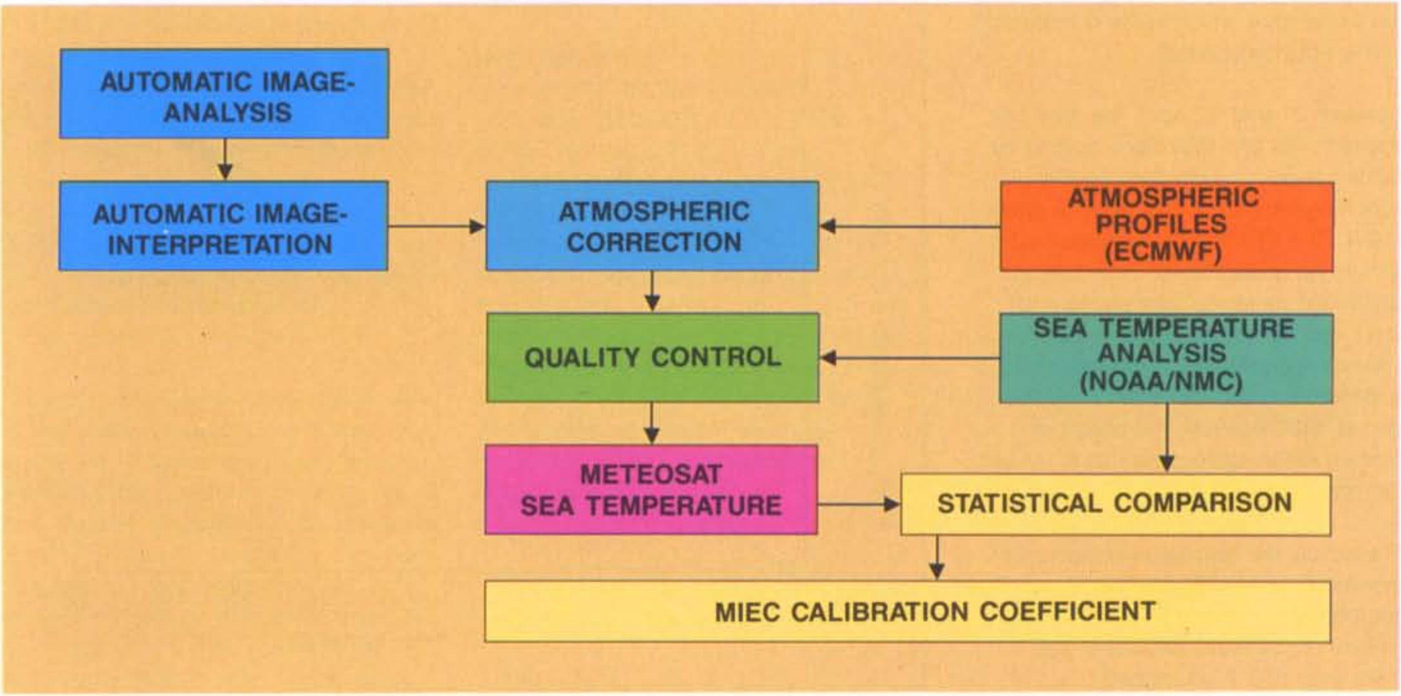


Figure 3 — Schematic of the Meteosat SST derivation and calibration procedure

Figure 4 — Sea-Surface Temperature (SST) analysis for 19 January 1988 as received from the National Meteorological Centre in Washington (colour code same as in Fig. 2)

Figure 5 — Typical calibration relationship for Meteosat's infrared (IR) channel. The straight line connects the space count and the centre of gravity of the points

Meteorological Center (NMC) in Washington.

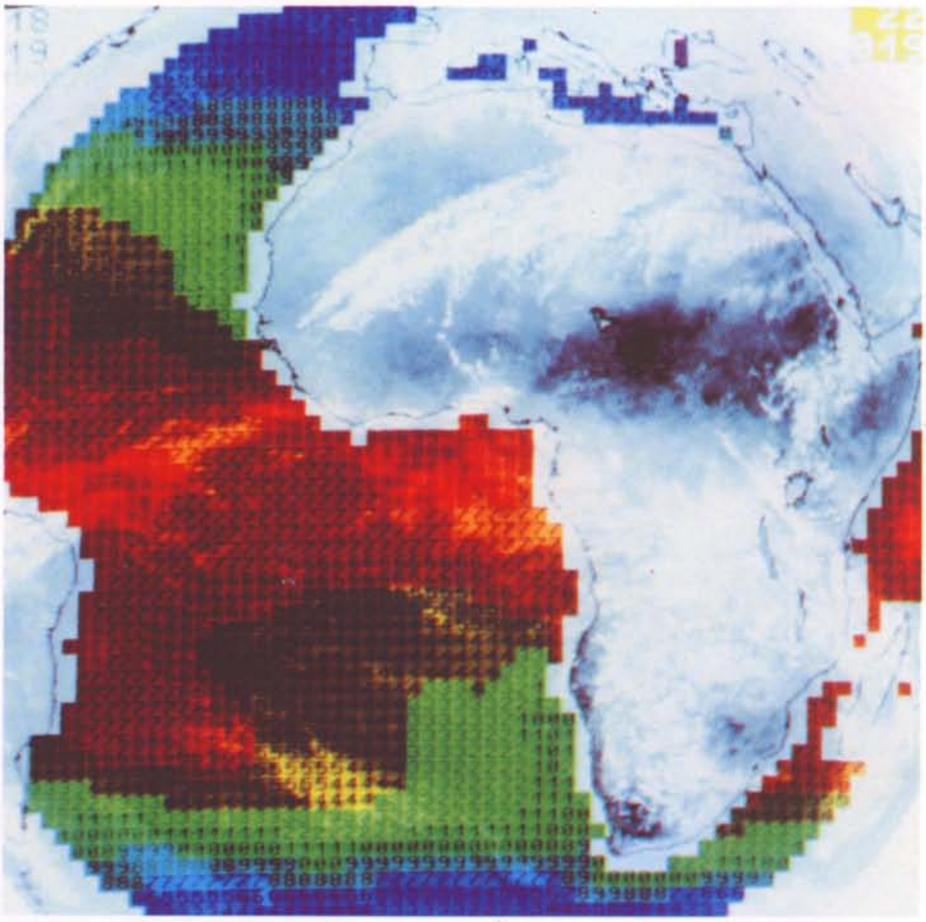
Figure 4 shows the analysis field for 19 January 1988. Based on this comparison, the so-called 'MIEC calibration coefficient' that keeps the bias between Meteosat and the conventional observations within half a degree is selected. For all of those segments in which the sea surface has been identified, the Meteosat radiance (given in units of digital counts) and the SST value of the analysis are compared, the analysis temperatures having been converted to radiances (physical units) using Planck's law. A typical plot of this calibration relation is shown in Figure 5.

The MIEC calibration coefficient is defined as the slope of the line that connects the so-called 'space count' (obtained when the radiometer is viewing space; equal to 5 for Meteosat-2) and the centre of gravity of all points of the scatter plot in Figure 5.

Figure 6 shows the history of the derived MIEC IR calibration coefficient for 1987. It can be seen that at the beginning and end of the year, its value increased strongly, as a result of ice contaminating the IR detector, which is the coldest part of the whole spacecraft.

Between 21 and 23 April, the satellite's detectors (IR and WV) were de-iced by heating them up from their normal operating temperature of 90 K to about 310 K. The IR and WV channels had then to be recalibrated. Thereafter, the calibration remained very stable and there was no need to update the IR calibration coefficient for operational application during the summer. At the end of 1987, however, the effects of contamination again gave rise to a need for more frequent adjustment.

In practice, the calibration coefficient is monitored twice daily, and whenever the comparison of Meteosat and NMC sea-surface temperature exhibits a bias of more than 0.5°, it is updated.



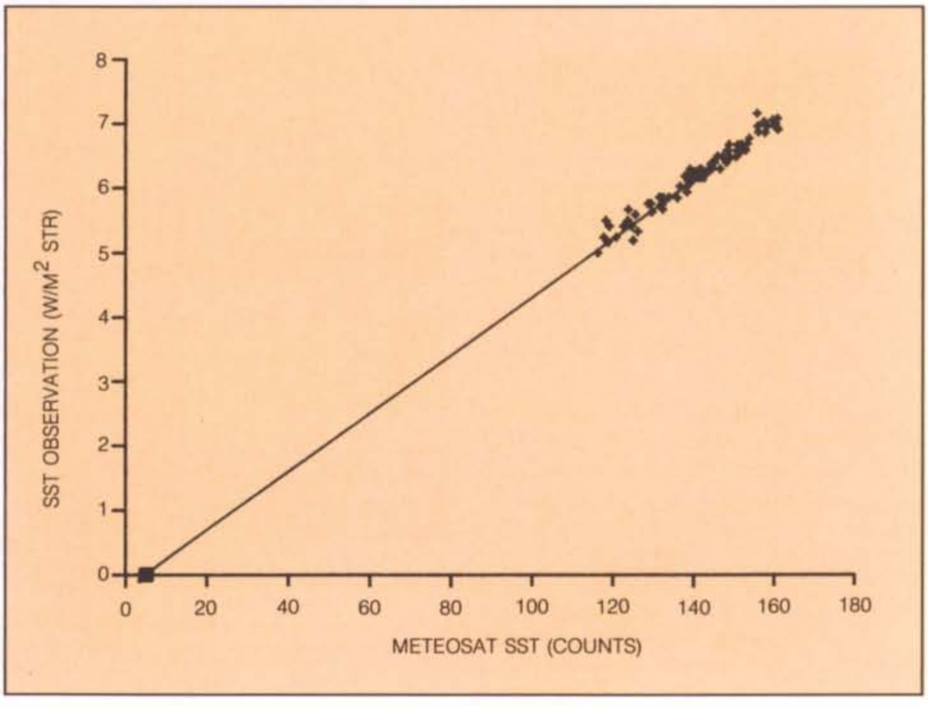
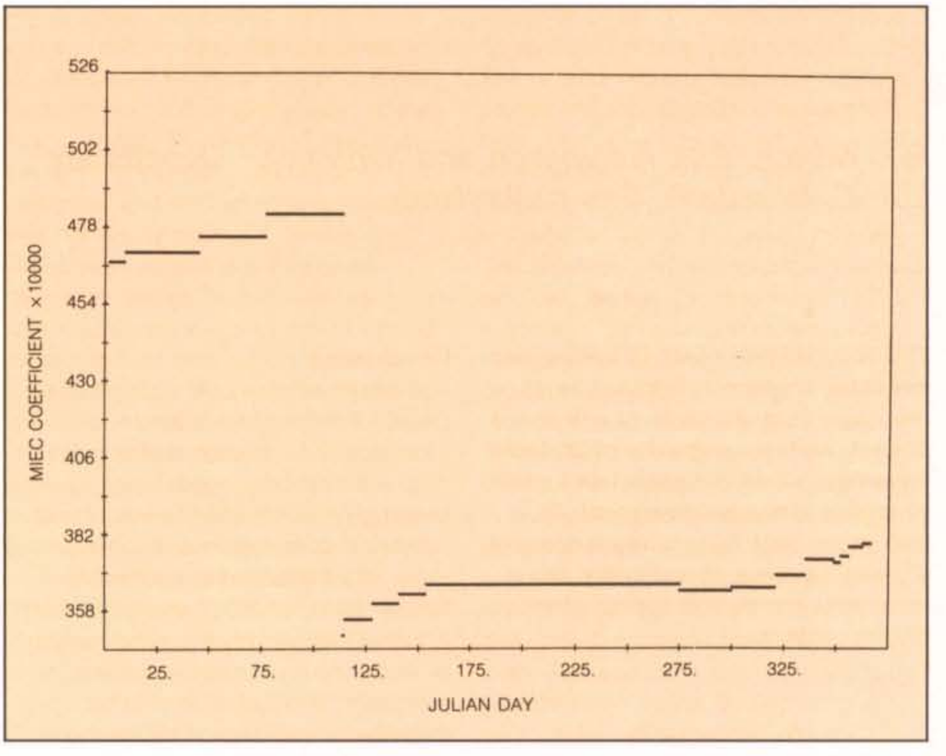


Figure 6 — Time series of MIEC IR calibration coefficients in units of W m^{-2} st^{-1} $count^{-1}$ for the year 1987



Discussion

An inherent feature of the calibration procedure that is applied is that the overall RMS error of Meteosat SST retrievals is only about 1°C. This is ensured a priori by always adjusting the operational MIEC calibration coefficient whenever the overall bias between Meteosat and the NMC SST analysis exceeds half a degree. The derived MIEC calibration coefficient is therefore crucially dependent on the automatic image analysis and interpretation.

The greatest unresolved problem in this process is the so-called 'cloud contamination' effect, due to clouds that are beyond the resolution of the detector, and therefore cannot be resolved, systematically influencing the received radiance. Also, when the temperatures of the sea and low-level clouds are similar, it is not easy to discriminate between the two types of radiators in infrared imagery. In the MIEC processing, cloud contamination does affect the retrieved SST locally, but when averaged over the whole field of view it is compensated for by the selection of the calibration coefficient.

In addition to the cloud-contamination effect, there are some other smaller effects that could have some influence on the derived infrared calibration coefficient. Firstly, no account is taken of the so-called 'skin effect' in radiometric temperature retrieval. This effect results in a slightly colder surface temperature being derived radiometrically, compared with conventional temperature measurements (an average of 0.2°).

Another possible effect of the same order of magnitude could result from the systematic under- or over-estimation of the atmospheric absorption due to the type of parameterisation used. To keep these deviations in perspective, however, they should be compared with the average RMS error of about 1° achieved by comparing the Meteosat and NMC SST observations, or with the digitising error resulting from the 8-bit representation of the infrared radiometer readings, which may result in changes of 0.5° in the temperature range relevant for sea surfaces.

Conclusion

The operationally applied method of calibrating Meteosat's IR channel is a reliable technique that provides calibration information on a daily basis. The greatest uncertainty in the determination of the calibration coefficient, due to the effect of cloud contamination, results in an overestimation of 2 to 3% compared with other independent calibration methods. However, the ESOC method ensures a priori overall agreement between conventional SST observations and Meteosat-derived values.

COES — An Approach to Operations and Check-out Standards

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The accumulated costs of testing and operating a spacecraft form one of the major cost elements of any space project. As the complexity of projects increases, so do the associated costs of testing and mission control. To limit these cost factors, more account of must be taken of testability and operability during the design phases of new projects.

Introduction

There is an obvious cost saving for new projects if the existing ground infrastructure for mission control can be used with little or no modification. Even a seemingly trivial modification can have substantial consequences, since the same infrastructure must continue to service those spacecraft already in orbit. A further cost reduction can be sought by designing test equipment at unit, subsystem, and system level to be mutually compatible, and by reusing it from one level to the next.

With the development of space platforms and reusable carriers, there is a growing requirement for in-flight testing of payloads and subsystems. Tests carried out during spacecraft integration may be repeated as verification tests once the spacecraft is in orbit. The interface to the spacecraft seen by the mission controller and that seen by the test engineer will become the same. The interface between a payload specialist and the payload should also ideally be the same throughout testing and exploitation in orbit.

In fact, the traditional view of testing and operations as different activities is no longer valid: the more correct view is one of 'pre-launch' and 'post-launch' operations.

The extent to which the use of an existing infrastructure or re-use of test equipment is feasible depends on both the services offered by the infrastructure and the requirements of the individual projects.

With these considerations as a background, a committee was set up to investigate the commonalities between testing and operations and to establish standards for harmonising the infrastructure to support these activities, both within a given project and across different projects. It is known as the 'Committee for EGSE and Operations Standardisation', or 'COES' for short. The EGSE (Electrical Ground Support Equipment) element includes all equipment necessary to perform AIT (Assembly, Integration, and Test) activities.

The great problem is how to specify standards that allow the re-utilisation of both hardware and software without restricting the application of advances in technology. This is the fundamental problem that the COES is intending to investigate and resolve.

Objectives

The overall objective is to improve the yield from the Agency's investment, in both financial and manpower terms, for testing and operations, both within a single project and over several projects. There is currently a shortage of trained testing and operations personnel, but with suitable standardisation of methods and procedures the same staff will be able to migrate quickly and efficiently from one phase of a project to the next, or from one project to the next.

In addition, the availability of a familiar and well-tried infrastructure supporting both pre- and post-launch operations vastly reduces the risk factor associated with the unknowns in the project schedule. The experimenters or payload specialists should be able to view their payload in a consistent and familiar way throughout building, testing, integration and exploitation. In the past it has often been necessary for an experimenter to learn the intricacies of at least three different software systems: laboratory test environment, integration test environment, and in-orbit operations. By viewing all three environments as just one single environment having a pre-launch and a post-launch phase, the user can have a coherent and consistent view throughout, with only differences in emphasis when he chooses.

The ultimate objective of any mission is only realised during post-launch operations. The pre-launch operations must therefore fully support the post-launch phase, not only by carrying out the traditional AIT activities, to ensure that the *spacecraft* will function correctly, but also by testing the in-orbit procedures, to ensure that all the *in-orbit operations* will also function as foreseen. The pre-launch phase therefore also provides the necessary training environment for the mission controllers and the proving of the operational procedures for that particular mission.

Any space system consists of a number of 'modules' or 'subsystems', which are first tested independently and then integrated into the system. Before integration, each subsystem undergoes some testing to verify its correct functioning. At this level, each subsystem can be regarded as consisting of a number of 'elements' that have to be integrated together to form the subsystem.

As space systems have evolved, they have become more and more complex, so that the distinction between a 'system' and a 'subsystem', as far as testing is concerned, is only a question of which phase of integration is being considered.

The proposed philosophy behind AIT is to use a *common* standard test system for *all* levels of testing and to re-use both hardware and software employed at one level of testing, for integration testing at the next higher level. Selected tests developed and performed at subsystem level are simply repeated *without modification* as part of the system integration testing. Specific tests at system level are written to coordinate the subsystem-level tests, which in turn are used as building blocks for the system-level tests. As each subsystem is integrated into the satellite, its dedicated test equipment is connected to the checkout system. Ideally, this same test equipment can also serve as the 'user work station' during the post-launch phase of the mission (of particular relevance to telescience; see article elsewhere in this issue).

This approach has significant advantages in terms of cost, schedule, and reliability, as well as simplicity of test operations. If the philosophy is to be successfully applied, however, testing must be carefully planned so that the lower level tests can indeed be used without modification at the higher levels. For this to be successful, some standards, or at least guidelines, must be established — certainly within a given project, and probably across all projects.

It is clear that such an approach is valid for a single project, and is achievable because the project management has the authority to reallocate budget to ensure an overall cost-to-completion saving, but its application across several projects is not so straightforward. The ESA budgetary structure gives a large measure of autonomy to individual projects, which does not encourage inter-project cooperation.

When the 'exploitation' phase of the project is considered — i.e. when the spacecraft is in orbit — it is quite clear that existing networks of control and ground stations should be utilised wherever possible to avoid the expense of 'special-to-project' ground facilities. The ground infrastructure must support several projects simultaneously and the only practical way to achieve this is to consider the ground facilities as providing common 'services' that all projects can use in a standard manner. The provision and maintenance of these services can then be assured with a substantial cost saving compared with servicing the requirements of each project separately.

In the past, the systems and equipment used for AIT (checkout) were considered to be project-specific, largely because the equipment was moved physically with the spacecraft to different environmental test sites. The ground infrastructure, on the other hand, remained physically in one place and was thereby more easily seen as a common facility. By regarding AIT as a pre-launch operations phase supporting post-launch operations, the commonality is brought more into focus. In both phases, for example, telecommands are sent to the spacecraft, and telemetry from the spacecraft is monitored to detect any anomalous behaviour. Clearly, the user interface could be made the same and very probably much of the underlying software could be re-used.

The COES will therefore attempt to identify areas of commonality across projects and produce standards relating to those areas.

Areas of commonality

Before any useful standards can be proposed, the areas of commonality between EGSE and operations must be identified. Figure 1 shows a typical scientific mission's exploitation or in-orbit phase. The 'space segment' is shown communicating with the 'ground segment' via the telecommand (TC) and telemetry (TM) links (also known as the 'up' and 'down' links for obvious reasons). Two 'work stations' are shown connected to the ground segment, one

Figure 1 — Typical scientific-mission system architecture: exploitation or in-orbit phase

Figure 2 — Typical scientific-mission system architecture: integration/testing phase

Figure 3 — Typical scientific mission: laboratory testing of experiment prior to integration into satellite

Figure 4 — Typical scientific mission: experiment standard interfaces

Figure 5 — Typical scientific mission: checkout standard interfaces

Figure 6 — Typical scientific mission: operations standard interfaces

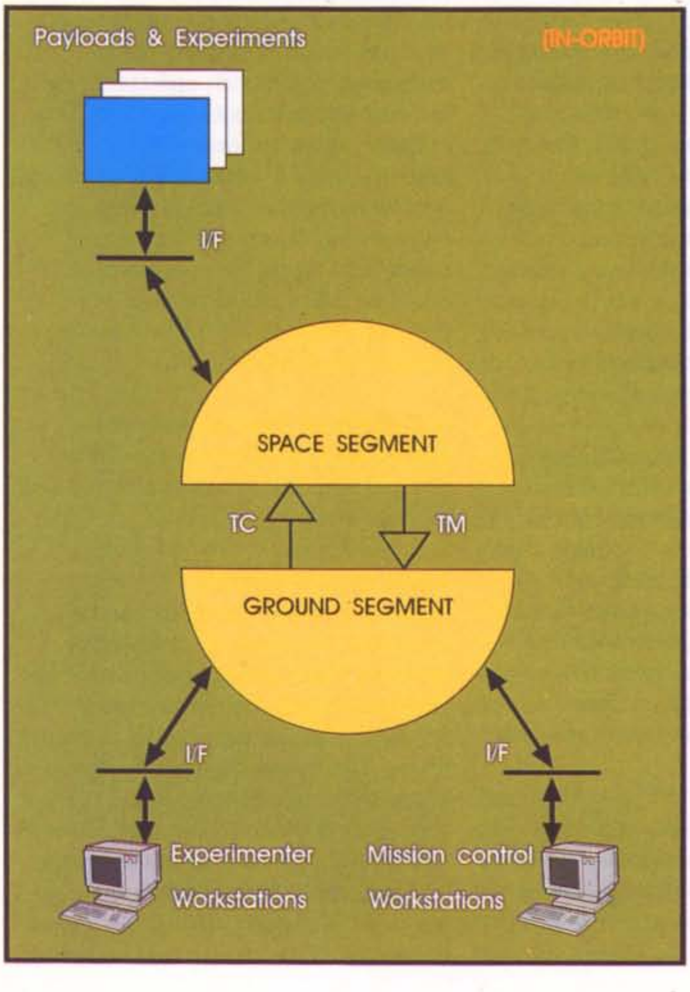
for the 'experimenter' and the other for the 'mission controller'. Basically, the mission controller communicates with the spacecraft, and the experimeter with his experiment.

Figure 2 shows the same scientific mission during the 'integration' testing phase (when all the subsystems and payloads are brought together and built into the spacecraft). Comparing the two illustrations, it is obvious that the 'experimenter' work station could be the same in each. The 'test conductor' work station and the 'mission control' work station also have that potential.

Going back further in the development phases, Figure 3 illustrates the 'laboratory' testing of the experiment before it was integrated into the spacecraft. A 'user' has some 'test equipment' which is interfaced to his experiment so that he can do his development testing.

Figures 4 to 6 are meant to represent the concept that, if a standard interface can be defined for the 'experimenter' work station, the same station can be used for laboratory testing, integration testing and in-orbit exploitation. There is no reason to have a different interface for the 'test conductor' and the 'mission control' work stations, so there can be just one standard interface specification for all work stations. Note that this does not mean that all work stations have to be the same; they only need to be able to support the standard interface in order to connect into the 'check-out system' or the 'ground segment' of Figures 5 and 6. As well as a standard interface for connecting the work station, a 'human/computer' interface could be defined to be supported by all work stations. This would allow the same operator to move physically from one work station to another (perhaps of a different type) and perform the same operations. This would add considerably to the flexibility, giving the choice of moving either the work station or simply the operator (user), or both.

Figure 7 shows the end-to-end data flow for a typical scientific mission. In principle, the telemetry data is freely available to any work station connected to the ground network, but there must be



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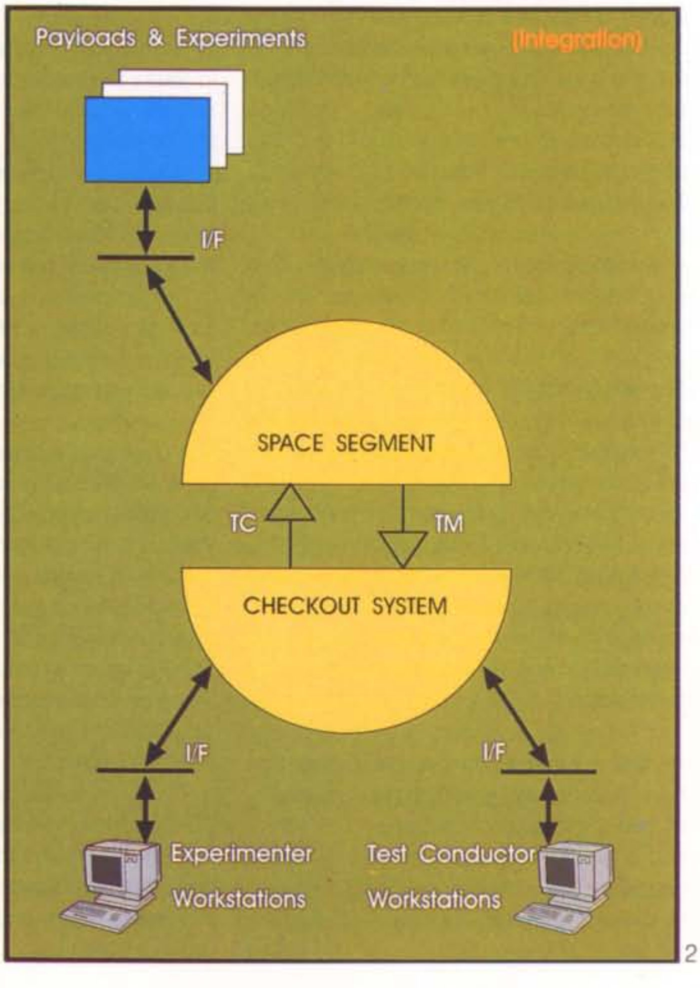

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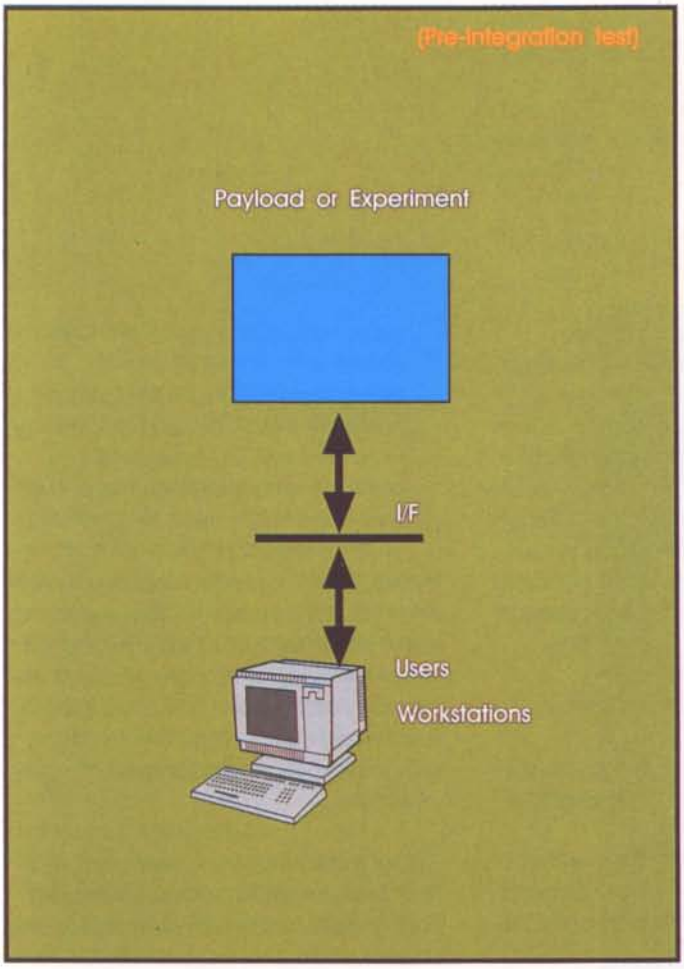
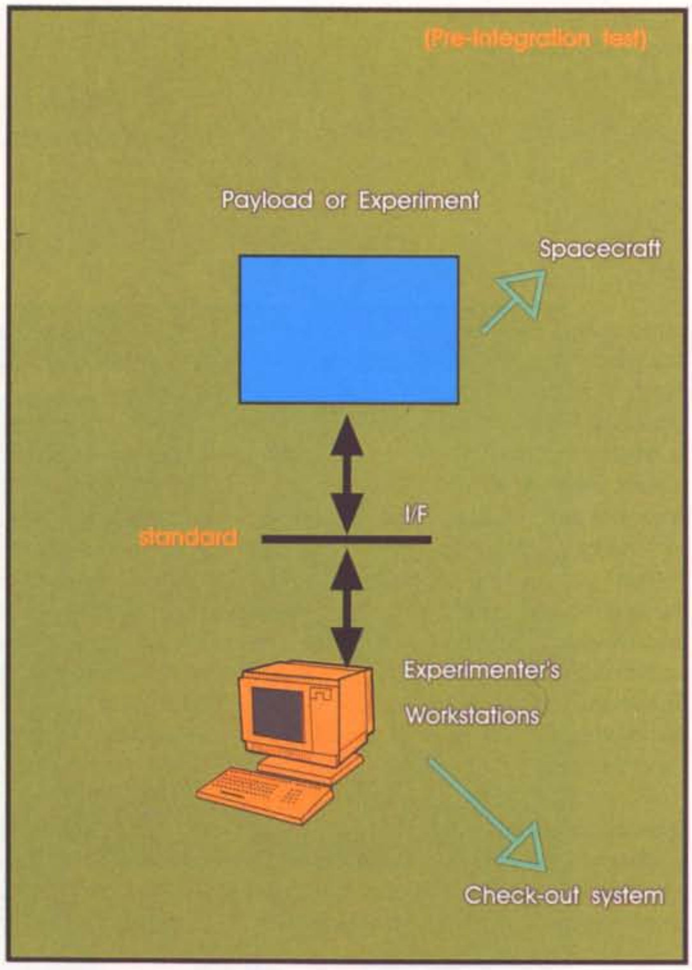
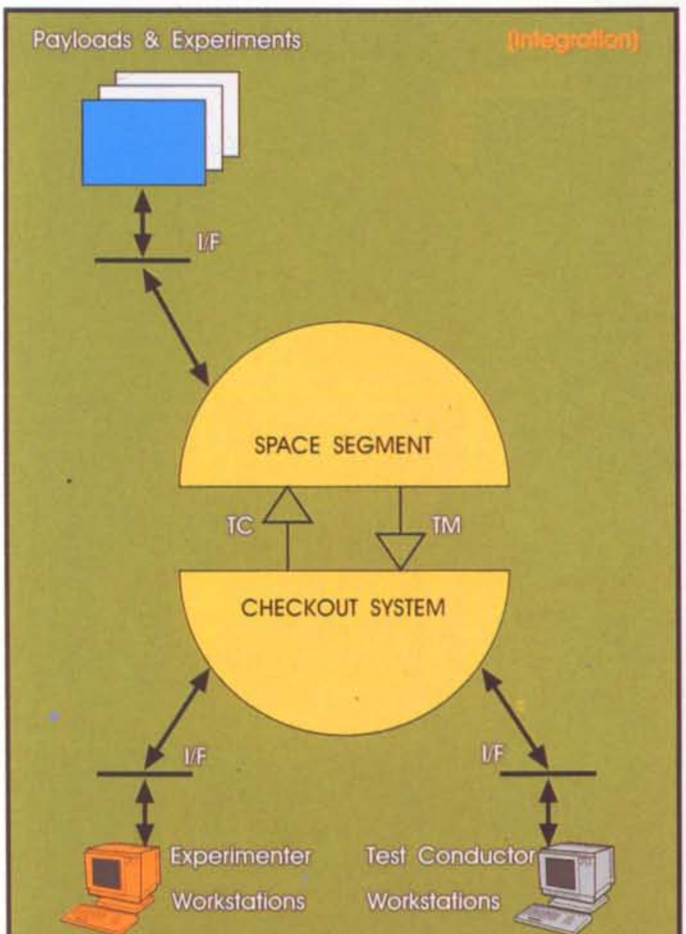

(Pre-integration test)
Payload or Experiment
I/F
Users
Workstations

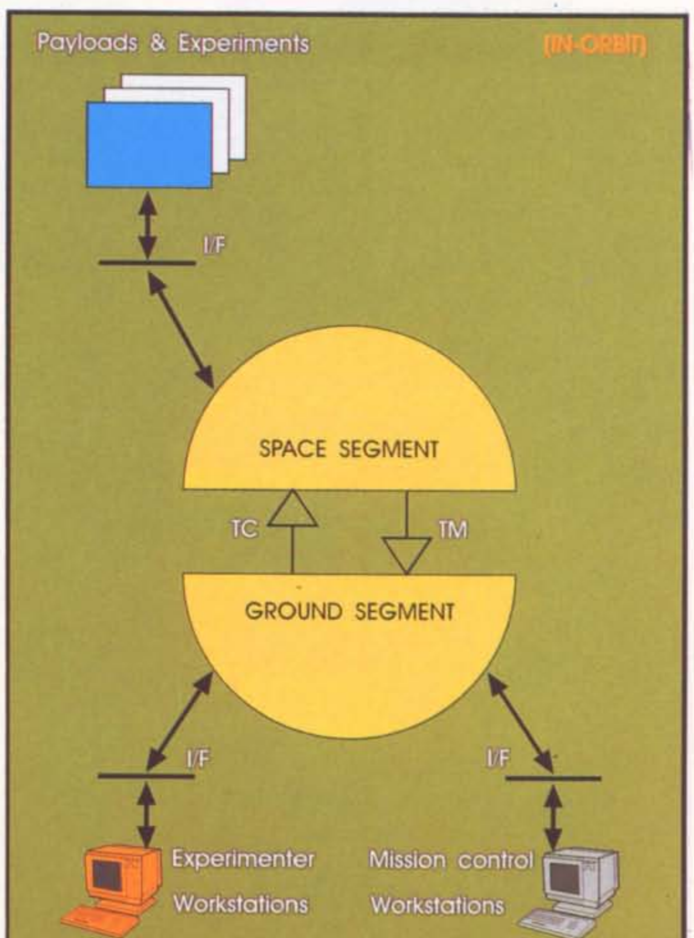
3


(Pre-integration test)
Payload or Experiment
Spacecraft
standard
I/F
Experimenter's
Workstations
Check-out system

4


Payloads & Experiments
(integration)
I/F
SPACE SEGMENT
TC
TM
CHECKOUT SYSTEM
I/F
I/F
Experimenter
Workstations
Test Conductor
Workstations

5


Payloads & Experiments
(IN-ORBIT)
I/F
SPACE SEGMENT
TC
TM
GROUND SEGMENT
I/F
I/F
Experimenter
Workstations
Mission control
Workstations

6

Figure 7 — Typical scientific mission: end-to-end data flow

Figure 8 — Typical manned mission: end-to-end data flow

some control over telecommands sent to the 'space segment'; this is shown in Figure 7 as the 'TC control gate'. A particular experimenter may need additional information such as orbit and attitude data for correlation with his telemetry data. This is shown as 'orbit etc.' in Figure 7, data flowing from 'mission control' to the experimenter via the 'ground segment'. Clearly there is a requirement to specify how this data communication is to take place. From an operations viewpoint, such communication is a general service and should not be 'project-specific'.

Manned missions

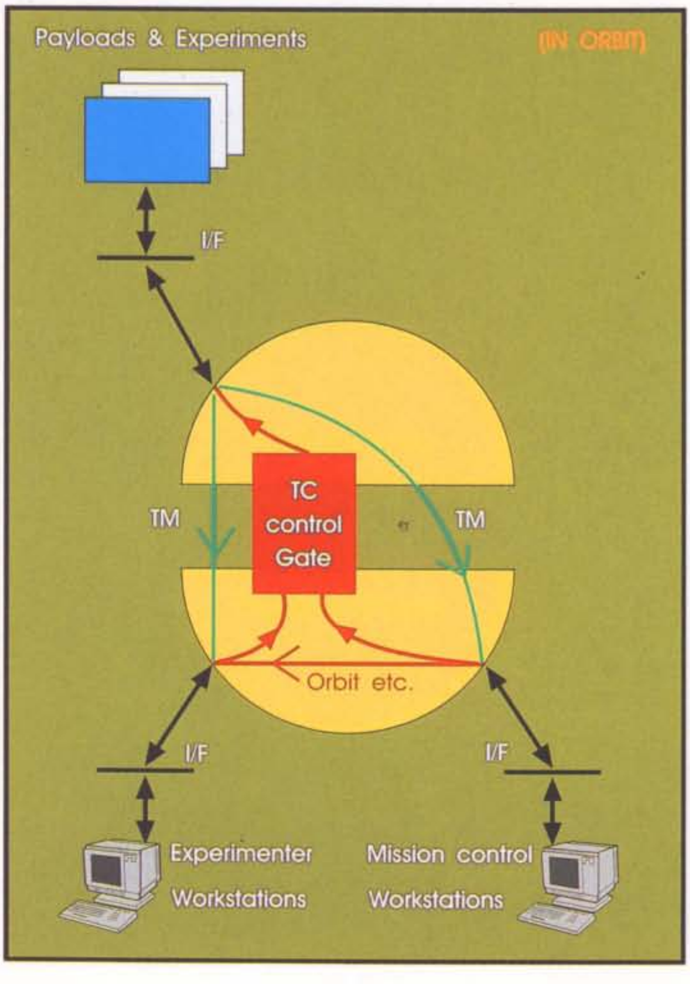
Traditionally ESA has been concerned with satellite missions and what has been presented so far relates primarily to such missions. What, however, are the differences to be expected for manned missions?

Figure 8 shows the additional data flow foreseen for a manned mission. The crew communicates with 'the system' through a work station, but is this a similar work station to the experimenter and mission-control or test-conductor's work station? There would be advantages if the interfaces were made the same, particularly the 'human/computer' interface:

- crew training on the ground could be done initially on any work station at almost any location
- the actual crew work station could be used on the ground for training and simply 'unplugged' from the ground system and plugged into the flight system
- during flight, the crew and ground operators (both control and experimenters) would share a common understanding of their systems.

In the case of manned missions it is not so much the cost advantages that are of major importance, but rather the added safety for the crew brought about by thorough training on familiar equipment, and having crew and ground operators using identical human/computer interfaces.

Figure 8 also shows the telecommands from the crew passing through the 'TC control gate', which is shown as spanning



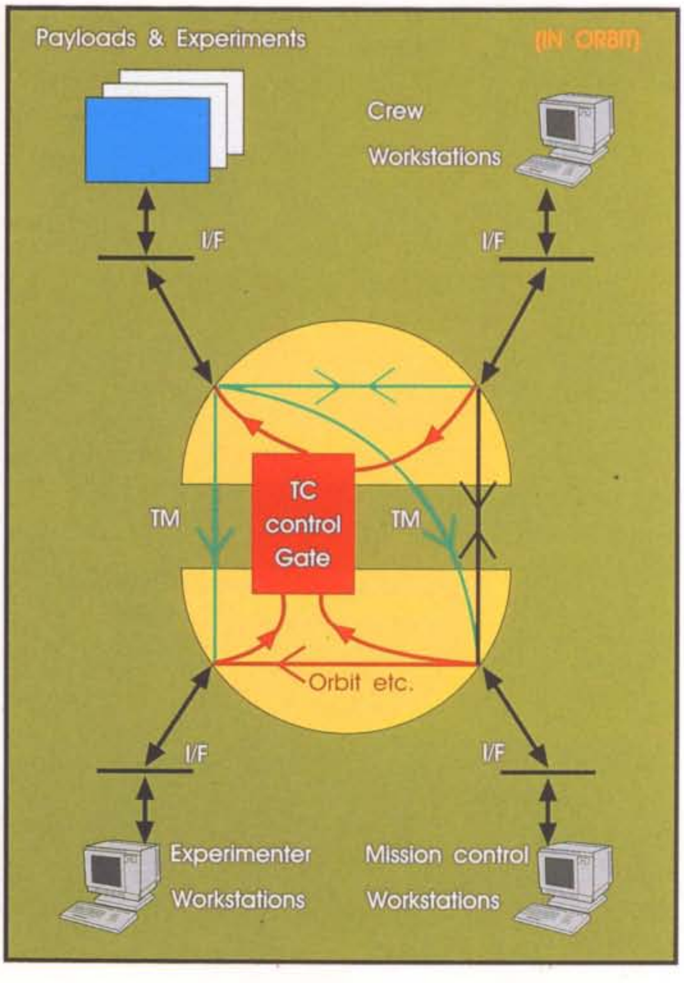


Figure 9 — Typical manned mission: end-to-end architecture

Figure 10 — Standards committees reporting to the Telematics Supervisory Board (TSB)

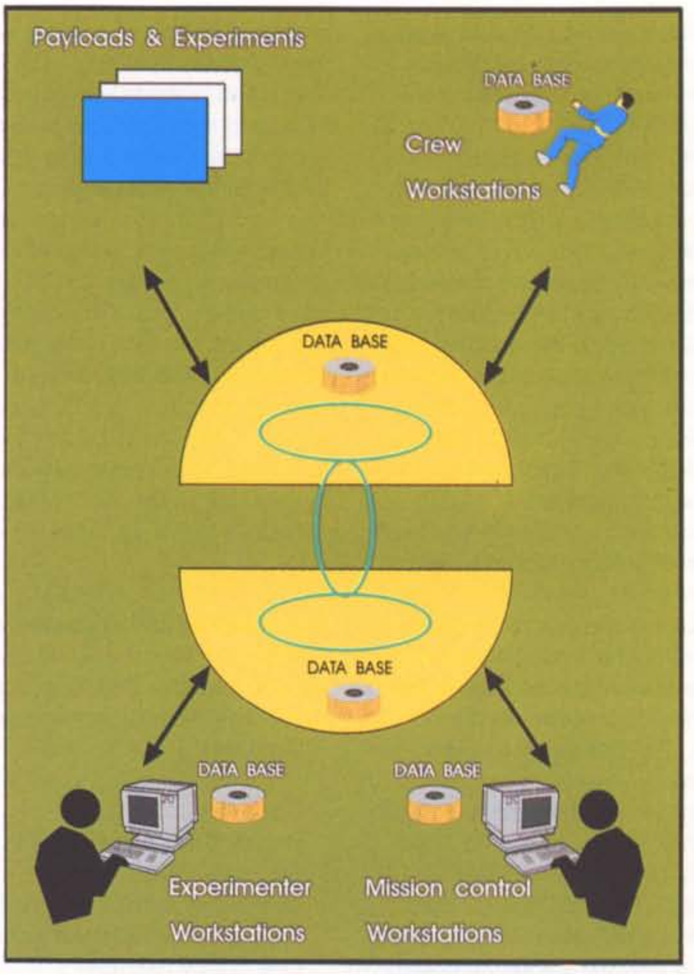
the ground/space interface. The 'TC control gate' mechanisms need to be investigated: there must be adequate flexibility, but rigid safety constraints.

The crew will certainly need access to some telemetry data, which is similar to the ground requirements, but there is another data type shown in Figure 8 that is meant to represent such data as voice and video, which at the moment is not covered by the ESA telecommand and telemetry standards. Here certainly there is a difference between manned and unmanned missions.

End-to-end architecture
Figure 9 is meant to represent the most general end-to-end architecture for a manned mission. The assumption is made that if standards can be developed for manned missions, a subset of those standards will be applicable to unmanned missions.

Figure 9 illustrates that there are standards to be developed for interfacing work stations to the system and for interfacing payloads. These interfaces are shown by the bold double arrows. There are communications standards to be developed; these are shown in Figure 9 by the elipses: onboard communications, ground-to-space communications, and ground-segment communications. Also illustrated in Figure 9 is the requirement for some kind of 'database'. This will probably be partitioned and distributed, but will certainly require standards to regulate development and access. Not obvious in Figure 9 is the 'human/computer' interface, though the appearance of human figures is meant to convey the fact that this interface must also be considered.

Where does COES fit in?
The COES (Committee for Operations and EGSE Standardisation) was set up by the ESA Telematics Supervisory Board (TSB) to which it reports. The TSB, which has representatives from all of the ESA Directorates, supervises the work of



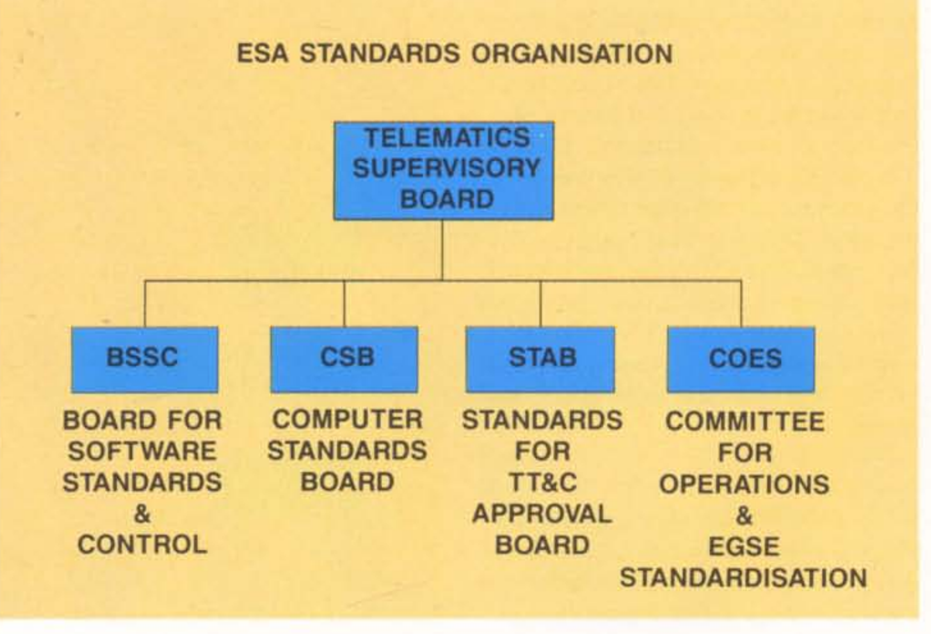


Figure 11 — Interfaces between COES and other committees and agencies

several committees (Fig. 10). The various committees each concern themselves with different areas of standardisation.

The Board for Software Standardisation and Control (BSSC) concerns itself with all aspects of software engineering and standardisation; its main output to date has been the ESA Software-Engineering Standards Document, which defines the software life cycle and the documentation required, and the managerial procedures to be applied, when producing software. These standards are published as ESA document PSS-05-0. This Procedures, Standards and Specifications (PSS) document series is intended to embrace all the future ESA-standards documents.

The Computer Standardisation Board (CSB) has more the role of standardising computer procurement policy than that of setting standards in terms of PSS documents. The CSB approves all computer procurements, to ensure compatibility between all computers used in the Agency.

The Standards Approval Board (STAB) existed before the TSB was set up and is the oldest of the ESA standards boards or committees. STAB is the standards committee for the ESA Telemetry, Tracking, Command and Data Handling Standards. The primary purpose of these standards is to ensure that all spacecraft conform to the existing and future ESA infrastucture for mission control. STAB is also the ESA representative in the Consultative Committee for Space Data Systems (CCSDS), a multi-agency committee coordinating standards for ground/space mission control communications (NASA, ESA, and the national agencies of the United Kingdom, France, West Germany, India, Brazil, and Japan).

The COES then has specific responsibilities in the area of EGSE and operations standardisation. Since there are inevitably software and computers involved in the EGSE and ground systems, there must be a liaison between the COES and the BSSC and the CSB. Very close liaison is required between the STAB and the COES because the former is concerned with the space/ground interface for all ESA projects.

Figure 11 attempts to show the relationships between the COES and other bodies. The COES develops standards in its area of competence in consultation with ESA projects, other national agencies, and European industry. The standards so developed will be issued by the Agency, after approval by the TSB, as part of the ESA 'PSS' series.

Composition and organisation of the COES

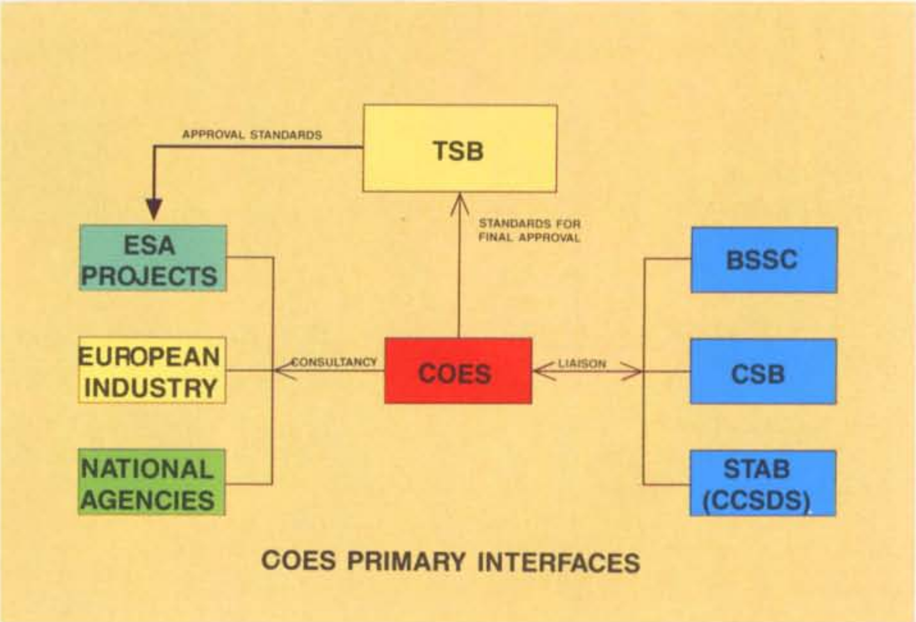
As with the other ESA Committees, the COES has representatives from the major ESA centres:

Chairman (ESTEC)
Deputy Chairman (ESOC)
Secretary (ESTEC)
One further ESTEC member
Two further ESOC members
One ESRIN member.

The responsibilities of the COES are defined in its terms of reference as follows:

- to devise standards, procedures, and guidelines
- to harmonise the utilisation of relevant standards for operation and checkout of spacecraft, payloads, and onboard computers
- to consult the Agency's projects, European industry and the national agencies to establish the requirements for standards
- to prepare plans for the implementation of relevant standards
- to examine and review proposals for standards and updates to standards
- to advise programmes on the adoption of standards
- to define documentation, training and test-beds to support the standards.

The first task was to identify areas of commonality where standards could be applied; this led to three COES panels being set up to consider the different areas in more detail. (The working procedures of the COES specify that a panel will be set up by the committee to study the requirement for a particular standard and draft that standard).



The COES panels
The panels that have been set up are:
- the Systems Panel
- the Human/Computer Interface (HCI) Panel
- the Communications Panel

Referring to Figure 9, the Communications Panel will look at all the communications aspects, including how telemetry and telecommands are transmitted between users, ground stations and control centres, and how user equipment and standard work stations can interface to the communications system.

The HCI Panel will consider the human/computer interface in terms of 'window' techniques, selection devices, menus, etc.

A subgroup of the HCI panel will study the User Interface Language (UIL); this group will consider what standard functions should be available to the 'user' and how these should be invoked. (There are obvious standard functions like sending telecommands, monitoring telemetry, displaying monitored parameters, etc. which require a common terminology and definition standard).

The System Panel will consider the coordination aspects not covered by the other panels, for example the 'control gate' functions (Fig. 9), the application of the CCSDS packet telecommand and telemetry standards. This panel will also consider the overall database requirements.

What next?
There is, of course, a lot of effort involved in producing a standard, but it is not sufficient to produce a standard as a 'paper exercise'; it must also be a practical standard. How can we arrive at practical standards? First consider what we mean by a 'standard'.

One accepted definition of a 'standard' is:

'a technical specification or other document drawn up with the cooperation and consensus or general approval of all interests affected by it, based on the consolidated results of science, technology and experience, aimed at the promotion of optimum community benefits and approved by a recognised body'.

With this definition as a basis, the steps required to produce a standard may be stated as follows:

1. Identify requirements:
   — consult with interested parties to establish the need for a standard.

2. Technical analysis:
   —review existing standards
   — consult with industry and external agencies
   —establish options
   —perform trade-offs
   —select a baseline.

3. Produce draft standard

4. Validate standard:
   —pilot implementation
   —verification using test-beds/simulations
   —review results with industry and external agencies.

5. Issue approved standard

6. Application of the standard:
   —promotion of the standard
   —review the results of application of the standard (including requests for waivers)
   —reiterate from 2 above.

The amount of work involved in each of these steps will vary according to the individual standard, and some steps will involve many iterations before the next step can be started. In the ESA scenario, the 'recognised body' for the approval of standards will be the TSB and its various committees; the standards themselves will be published as PSS documents.

Consultation with industry and other national and international bodies will be required. This consultation will take various forms — study contracts or pilot implementations, workshops, as well as visits and less formal contacts — and is an essential part of standards development. The activities of the ESA standards committees are also supported by the various test-beds and prototyping facilities, which are essential for the validation of proposed standards.

To be able to carry out the standards development activity, therefore, the Agency has to make resources available in terms of manpower, funding for contracts, travel costs, and investments in facilities. Each of these elements is necessary to ensure that the ESA standards are 'based on the consolidated results of science, technology and experience', as the definition of a 'standard' requires.

For some of the proposed standards, the COES is already at Step 3 - Produce draft standard; for others at Step 2 - Technical analysis; and for some only at Step 1 - Identify requirements, which implies: 'consult with interested parties to establish the need for a standard'.
Any reader who is an 'interested party' is invited to contact the secretary to the COES,

R. Worron,
ESTEC (WGE),
PO Box 299, 2200AG Noordwijk,
The Netherlands

or any of the current Committee members:

Chairman	M. Guerin (ESTEC)
Deputy Chairman	J.F. Kaufeler (ESOC)
Secretary	R.F. Worron (ESTEC)
Member	J. Howieson (ESTEC)
Member	H. Uhrig (ESOC)
Member	W. Wimmer (ESOC)
Member	V. Beruti (ESRIN)


esa
ariane

APEX — Ariane-4: Les passagers du premier vol

B. Lacoste, Département Ariane, ESA, Paris

Le vol de démonstration du lanceur Ariane-4 qui devait mettre en orbite la charge utile APEX (Ariane Passenger Experiments) a été effectué avec succès le 15 juin 1988, à 08h 19 mn heure locale de Kourou, à partir du deuxième Ensemble de Lancement Ariane (ELA-2).

D'après les premières évaluations des données de télémesure disponibles en vol, l'ensemble a fonctionné correctement et notamment tous les nouveaux éléments du lanceur Ariane-401 en version 44LP*. Les séparations des satellites ont été normales et l'orbite de transfert geostationnaire (220 km de périgée, et 10° d'inclinaison) a été atteinte avec une excellente précision.

*Ariane-44LP est la version à quatre propulseurs d'appoint dont deux à liquide (PAL) et deux à poudre (PAP)

Le programme APEX
C'est en début 1982 que l'Agence spatiale européenne approuve le programme APEX du vol de démonstration Ariane-401 prévu à l'époque pour octobre 1985.

Comme cela s'était passé avec le programme APEX — Ariane-1 des trois derniers vols de qualification (de L02 en 1980 à L04 en 1981), l'Agence offre l'emport de satellites représentatifs de la future clientèle au lieu d'embarquer du simple lest.

En contrepartie de sévères contraintes programmatiques imposées, des conditions financières de lancement relativement favorables sont proposées aux passagers potentiels.

Pour ce vol de démonstration, la version 44LP est retenue parmi les six versions realisables du lanceur Ariane-4; c'est elle en effet qui implique la mise en oeuvre du plus grand nombre d'éléments nouveaux du lanceur et des installations de lancement. En vue de rechercher une bonne représentativité des missions futures des lanceurs Ariane-4, la partie haute d'Ariane-401 englobant la charge utile (4 m de diamètre et 13,4 m de hauteur) est équipée de la Structure Porteuse Externe de Lancement Double Ariane (SPELDA) courte (32 m^3) et de la coiffe longue (59 m^3). La charge utile, constituée de l'ensemble des passagers et de leurs adaptateurs, représente une masse totale de 3200 kg.

Les passagers — Configuration de lancement
Fin mai 1982, sept candidatures sont examinées, à savoir:
- *Amsat*, satellite scientifique d'étude des astéroïdes ('AMSAT Corporation', RFA)
- *Arsène*, satellite de télécommunications pour les radio-amateurs et l'éducation (CNES)
- *Météosat-P2*, satellite météorologique (ESA)
- *Sigma*, satellite scientifique d'observation du rayonnement gamma (CNES)
- *Sirio-3*, satellite de télécommunications (Ministère italien de la recherche)
- *Voile solaire* (British Interplanetary Society, pour le compte de la US World Space Foundation)
- Version agrandie *d'ECS/Télécom* (CNES et Ministère français des Postes et Télécommunications).

Les candidatures de Sigma et de Sirio-3 sont retirées par leurs promoteurs respectivement en août et octobre 1982.

En novembre 1982, l'Agence se prononce en faveur de l'emport d'Amsat, d'Arsène, de Météosat-P2 et de la plateforme agrandie d'ECS-Télécom sous réserve d'accord ultérieur sur sa charge utile; celui-ci est acquis dès janvier 1983, la France ayant accepté d'adjoindre à la mission principale quelques expériences technologiques de l'ESA, notamment des amplificateurs à l'état solide. Ce projet est alors baptisé ATHOS. Par contre, la proposition de la Voile solaire est écartée par manque de crédibilité technique et financière.

En septembre 1983, AMSAT annonce le remplacement de la mission Astéroïdes, irréalisable dans les conditions de masse

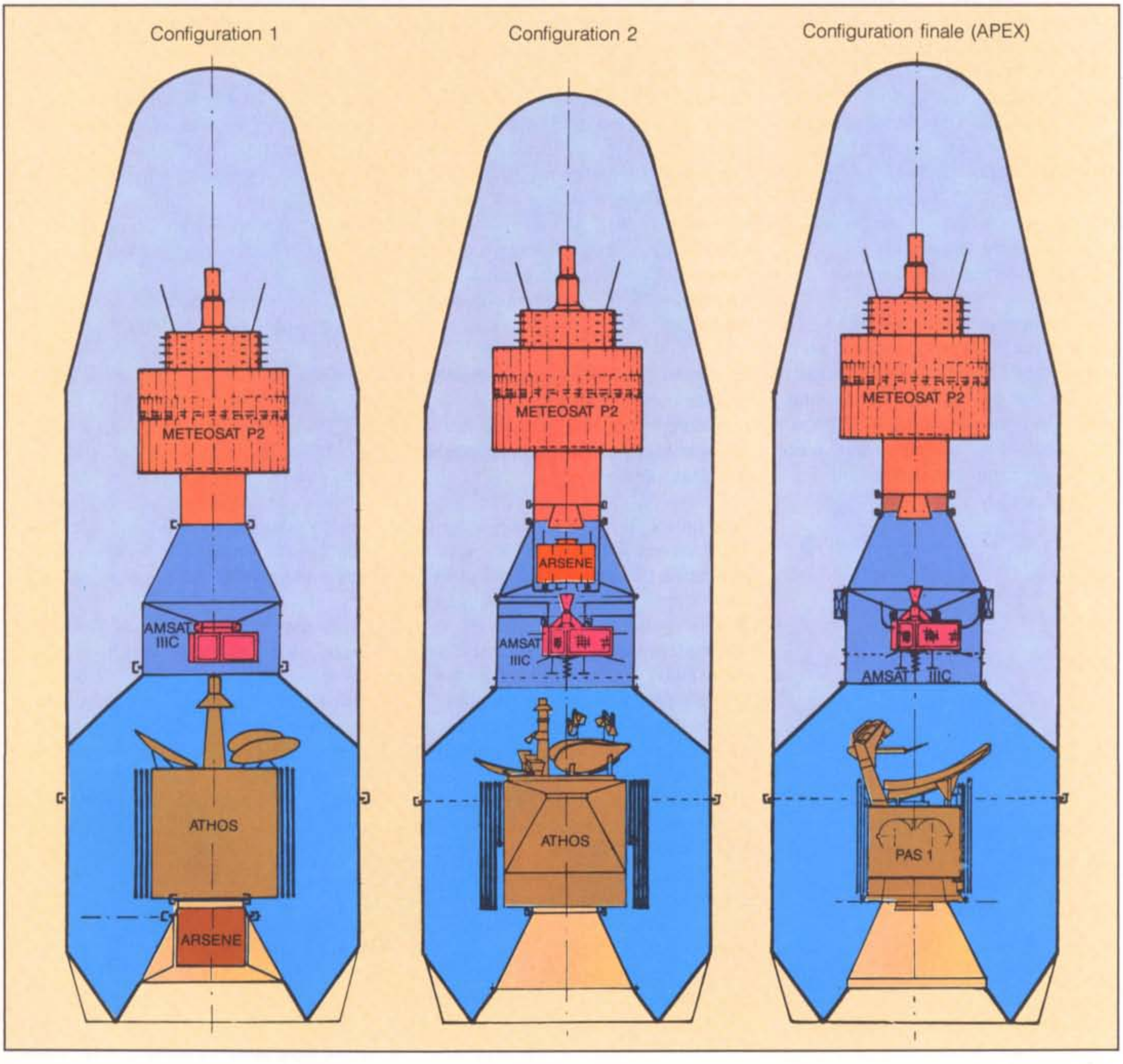
Figures 1 - 3 — Les deux configurations preliminaires pour le vol Ariane-401, et la configuration 'APEX'

et de volume imposées. La nouvelle mission est celle des satellites radio-amateurs de la famille OSCAR Phase-III permettant l'étude de nouvelles techniques de propulsion et de communication.

Ainsi, une première configuration de deux composites chacun constitué de deux satellites peut être élaborée.

En novembre 1983, il est envisagé de réaliser et d'utiliser sur Ariane-401 un adaptateur 937B pour satellites de la classe PAM-D2*, comme ATHOS mais qui n'est plus compatible avec l'emport d'Arsène. Ceci conduit à la réalisation d'une deuxième configuration, où Arsène est transféré du composite bas au composite haut et installé dans l'adaptateur de Météosat-P2.

* PAM-D2 (Payload-Assist Module). Propulseur développé par MDAC utilisé pour injecter les satellites de 1600 à 1800 kg en GTO depuis l'orbite d'attente de la Navette spatiale.



En conséquence du retrait d'ATHOS fin mars 1984 suite à l'abandon du projet par la France, le développement de l'adaptateur 937B n'est pas engagé (il le sera par la suite, en 1986). Après la tentative infructueuse de plusieurs candidats au remplacement d'ATHOS (Télécom-1C, ECS-4 ou Westar-6 avec la société américaine Equatorial), c'est la candidature de Pan American Satellite-1 (PAS-1), proposée par Arianespace qui est enfin retenue en juillet 1985.

Entre temps, en avril 1985, le retrait d'Arsène est inévitable, le projet ne pouvant pas être réalisé dans les délais.

La configuration APEX — Ariane-4 comprenant trois satellites dont Météosat-P2 et Amsat-IIIC sous coiffe en composite haut et PAS-1 dans la SPELDA en composite bas est finalement adoptée (tableau 1).

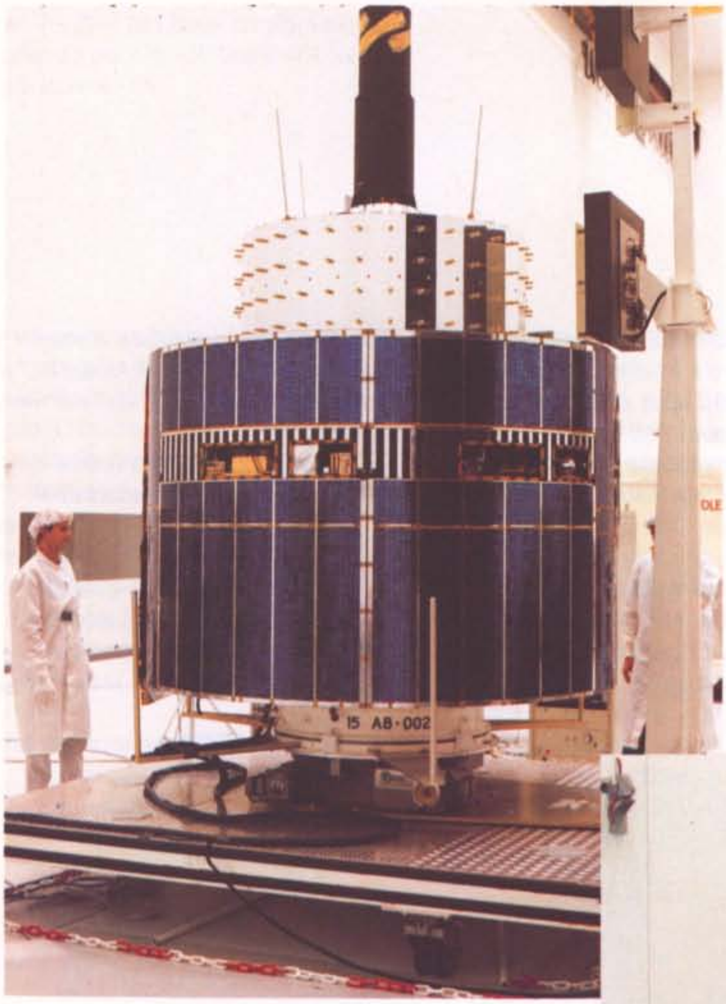
La structure porteuse
La configuration retenue d'un lancement triple impose à l'Agence, avec le support du CNES, Toulouse, le développement d'adaptateurs spécifiques dont certaines éléments pourraient avoir des applications futures dans les programmes Ariane.

Pour la structure porteuse d'accueil des satellites Météosat-P2 et Amsat-IIIC du composite haut, il s'agit des éléments suivants:
— une virole cylindrique (lestée de 450 kg) ainsi qu'un adaptateur conique type 937 de liaison Météosat-P2; ces structures métalliques sont réalisées par la SILAT (Société Industrielle d'Aviation Latécoère);
— un cône de liaison métallique Amsat-IIIC également réalisé par la SILAT;
— un système de séparation par tube pyrotechnique à expansion de diamètre 1920 mm réalisé par

Tableau 1 — Les satellites APEX — Ariane-4

	Météosat-P2	Amsat-IIIC (Oscar-13)	Pan American Satellite-1
Mission	Prise d'images de la terre Distribution des données métérologiques Collecte de données	Communications entre radio-amateurs pour des services d'intérêt public, la recherche scientifique et l'éducation	Communications internationales et régionales: téléphone, données numériques, télex, télécopie, télétexte, radiodiffusion, vidéo
Orbite/Position finale	Géostationnaire, 0° longitude	36 000/2500 km i=57°	Géostationnaire, 45° longitude W
Durée de vie espérée	7 ans	>4 ans	10 ans
Charge utile	Principale: radiomètre à haute résolution Secondaire: expérience de synchronisation par échos laser (Expérience LASSO)	3 répéteurs	24 répéteurs bande C et Ku
Propulsion	MAGE-1S (SEP) Hydrazine	Aérozine et peroxide d'azote 400 N (MBB)	STAR 30C (Thiokol) Hydrazine
Stabilisation	Rotation	Rotation 20/40 tour/mn	3 axes
Maître d'oeuvre	Aérospatiale (F)	AMSAT (RFA)	RCA Astro (E.U.)
Client	ESA	AMSAT	Pan American Satellite (Filiale de Alpha Lyracom)
Opérateur final	Eumetsat	AMSAT	Pan American Satellite
Satellites déjà lancés	F1 en 1977 (Thor-Delta) F2 en 1981 (Ariane-L03)	Oscar-1 en 1961 à Oscar-10 en 1983 (Ariane L6)	

Figure 4 — Les trois passagers du vol Ariane-401



Météosat-P2

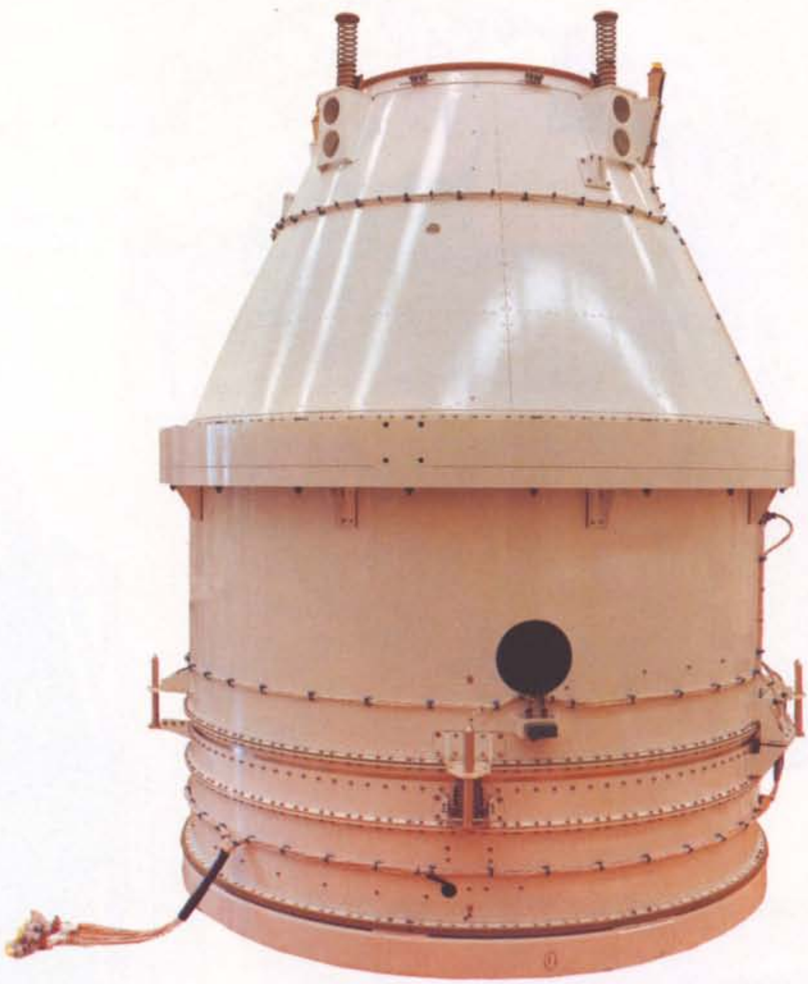
photo: bernard paris/arianespace

PAS-1

photo: w. gladisch

Amsat-IIIC

Figure 5 — Structure porteuse composite haut



AMD-BA (Avions Marcel Dassault-Bréguet Aviation);
— un séquenceur initiant la séparation retardée du satellite Amsat-IIIC réalisé par Amsat-DL.

La qualification de cette structure porteuse est acquise avec la participation des sociétés:
— CEAT (Centre d'Essais Aéronautiques de Toulouse) pour les essais statiques,
— INTESPACE pour les essais d'analyse modale, les essais acoustiques et d'équilibrage.

Pour obtenir la masse imposée du composite bas, il est nécessaire d'adjoindre à l'adaptateur standard 937 de Pan American Satellite-1 un lest métallique d'une masse de l'ordre de 220 kg.

La séquence des séparations
1. Largage de la coiffe, en phase propulsée du 2ème étage, 71 s après la séparation 1er/2ème étage (flux thermique <1135 W/m^2).

Deux secondes après l'extinction du 3ème étage (18 mn après le décollage), le Système de Contrôle d'Attitude et de Roulis du 3ème étage (SCAR) assure les manoeuvres d'injection des satellites.

2. Séparation de Météosat-P2, 132 s après l'extinction du 3ème étage, durée de la manoeuvre d'attitude requise pour l'allumage du moteur d'apogée et de la mise en rotation (5 tour/mn).

3. Séparation du composite structure porteuse—Amsat-IIIC, 5 s après '2'.

4. Séparation de la partie haute de la SPELDA après une manoeuvre d'attitude et l'annulation de la rotation, 73 s après '3'.

5. Séparation de PAS-1, 106 s après '4', durée de la manoeuvre d'attitude requise pour l'allumage du moteur d'apogée et de la mise en rotation (5 tour/mn).

La fin de la mission lanceur intervient après des manoeuvres 'd'évitement' du 3ème étage, 215 s après '5'.

6. Séparation d'Amsat-IIIC de la structure porteuse, initiée par le séquenceur, 1 h après '3'.

Campagne de lancement
Malgré l'aspect novateur des opérations d'encapsulation de la charge utile dans la coiffe et dans la SPELDA effectuées dans les Ensemble de Préparation des Charges Utiles (EPCU), la durée effective des opérations de chaque satellite n'est pas sensiblement différente de celle requise lors de la préparation d'un lancement opérationnel Ariane-2/3.

Toutes ces activités se déroulent sans incident notable; elles permettent de valider les interfaces électromécaniques, les procédures opérationnelles de la partie haute Ariane-4 et les moyens sol associés.

Néanmoins, la durée globale de la campagne satellites est affectée par la campagne lanceur conduite en plusieurs étapes compte tenu des événements suivants:
— interruption fin décembre 1987 dans l'attente de la disponibilité du 3ème étage
— reprise fin mars 1988 avec objectif de lancer le 26 mai, date repoussée successivement au 8 juin, pour permettre le lancement Ariane-2/Intelsat 5-F13 (V23) puis au 10 juin, pour cause d'intervention sur les moteurs Viking et enfin au 15 juin, suite à l'indisponibilité temporaire du calculateur embarqué.

Résultats du vol
A ce jour, Météosat-P2, PAS-1 et Amsat-IIIC sont à poste et rendent totalement le service opérationnel attendu.

Les excellentes conditions de mise en orbite par Ariane-401, le bon fonctionnement des moteurs d'apogée ainsi que la précision des opérations ultérieures ont permis de limiter la consommation des ergols embarqués, ce qui laisse espérer une durée de vie supérieure à celle initialement prévue.

Côté lanceur, les premières évaluations montrent un fonctionnement tout à fait normal du 'Système' et des étages;

Figure 6 — Montage des charges utiles APEX

Pan American Satellite-1 encapsulé dans la SPELDA partie basse

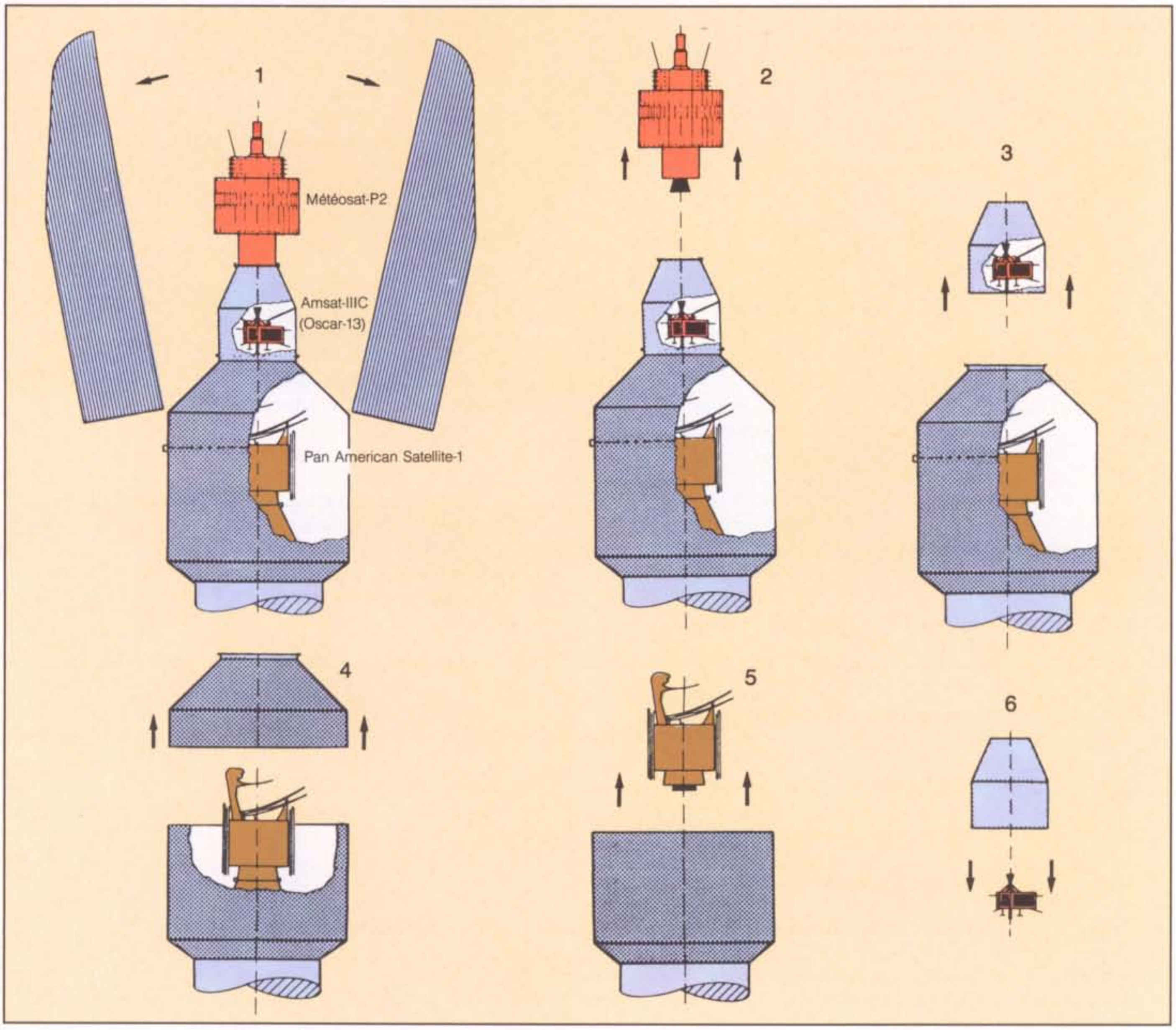
Composite Météosat-P2/Structure Porteuse/Amsat-IIIC sur la SPELDA haute et prêt pour encapsulation dans la coiffe

Pose de la partie haute lanceur sur le plateau de la case à equipement

Table 2 — Calendrier des campagnes lanceur et satellites

Dates	Activites lanceur	Activites satellites
17 nov 87		Arrivée Météosat-P2 et structure porteuse au CSG
24 nov 87		Début préparation Météosat-P2 au bâtiment S1A
29 nov 87	Arrivée 1er et 2ème étages et PAL au CSG	
05 dec 87	Début préparation PAP	
09 dec 87	Erection premier étage	
11 dec 87	Fin préparation PAP Erection PAL no. 1	
13 dec 87		Arrivée PAS-1 (et stockage)
15 dec 87	Erection PAL no. 2	Fin essais fonctionnels Météosat-P2 (et stockage)
17 dec 87	Interruption campagne lanceur	
14 jan 88		Début préparation PAS-1 au bâtiment S1B
27 jan 88		Fin essais fonctionnels PAS-1 (et stockage)
24 mar 88	Reprise campagne	Arrivée Amsat-IIIC au CSG
28 mar 88	Erection deuxième étage	
29 mar 88		Début préparation Amsat-IIIC au bâtiment S3B
01 avr 88	Erection troisième étage	
12 avr 88		Fin essais fonctionnels Amsat-III C
18 avr 88		Fin remplissage Amsat III C
21 avr 88		Transfert PAS-1 au bâtiment S3A
22 avr 88		Transfert Météosat-P2 au bâtiment S3B
29 avr 88	Transfert lanceur en Zone de Lancement	
02 mai 88	Erection PAP no. 1	
03 mai 88	Erection PAP no. 2	
05 mai 88		Fin remplissage et assemblage moteur Météosat-P2
06 mai 88		Assemblage composite haut au bâtiment S3B
11 mai 88	Interruption campagne lanceur (pour V23, le 17 mai)	
18 mai 88		Fin remplissage et assemblage moteur PAS-1
19/21 mai 88		Assemblage composite bas au bâtiment S3A
24 mai 88	Contrôle global lanceur	
J-10 25 mai 88	Début des opérations combinées (POC)	
J-10 25 mai 88	Début encapsulation composite haut dans coiffe au S3B et composite bas dans SPELDA au S3B	
J-9 26 mai 88	Répétition de la Chronologie Lanceur (RCL)	
J-8 27 mai 88	Transfert composite bas du S3A au S3B	
J-7 30 mai 88	Fin encapsulation composites haut et bas au S3B et transfert en zone de lancement	
J-6 31 mai 88	Pose composite satellites sur lanceur	
J-5/J-4 2/3 juin 88	Répétition générale de lancement (RG)	
4/7 juin 88	Contrôles additionnels partie haute lanceur	
J-2 10 juin 88	Armement lanceur et satellites	
11 juin 88	Revue aptitude au lancement (RAL)	
J-1A 12 juin 88	Remplissage N_2O_4 2ème étage et PAL	
13 juin 88	Remplissage N_2O_4 2ème étage et PAL	
J-1B 13 juin 88	Remplissage N_2O_4 2ème étage et PAL	
14 juin 88	Remplissage UH_{25} 1er/2ème étages et PAL	
J0 14 juin 88	Remplissage UH_{25} 1er/2ème étage et PAL	
15 juin 88	Remplissage N_2O_4 1er étage et chronologie finale	

Figure 7 — Séquence de séparation de la coiffe et des trois satellites



notamment, l'ambiance vibratoire a été calme et l'ambiance acoustique conforme aux prévisions. Il convient bien sûr d'attendre le dépouillement détaillé de tous les paramètres pour connaître le résultat définitif du vol, mais la précision d'injection et les informations reçues des trois satellites sont déjà des indicateurs excellents.

Conclusion

Le lancement réussi d'Ariane-401 met un point final au programme de développement Ariane-4 conduit par l'Agence spatiale européenne et sous maîtrise d'oeuvre du CNES; il a duré six ans et était destiné à doter l'Europe d'un lanceur modulable, puissant et souple répondant à l'évolution du marché à l'horizon 1990.

Ses performances sont presque deux fois supérieures à celles d'Ariane-3 puisqu'il peut mettre en orbite de transfert géostationnaire des charges utiles d'une masse allant de 1900 à 4200 kg.

Le succès de ce vol ouvre la porte à l'utilisation commerciale d'Ariane-4, 'cheval de bataille' de l'espace européen dans les dix années à venir, qui permettra à l'Europe, par les soins d'Arianespace, de consolider sa part de 50% environ du marché mondial dans un climat de concurrence croissante.

APOLLO – A Satellite-Based Information Distribution System

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APOLLO is one of several satellite-based small terminal data-communications systems. Its particular strength is that it allows many users, located anywhere in Europe, to share a common satellite channel to access an unlimited number of low-cost receive-only earth stations. Users can easily be connected via the public switched network, but the system can also be operated as a closed user-group network.

The APOLLO (Article Procurement with On-Line Local Ordering) concept was orginally devised to complement on-line searching and ordering of bibliographical references with electronic delivery of the document(s) of interest. Early investigations into the market and application requirements were initiated by the European Commission. It was soon concluded that only a satellite link could provide the transmission capacity needed and, since no practical system concept existed at that time, the Commission, Eutelsat, Members of the CEPT*, and the Agency formed a joint working group to explore the various possibilities. In the course of 1983 this group elaborated outline specifications for an electronic document-delivery concept.

The Agency's Joint Communication Programme Board approved APOLLO as a cooperative programme in 1984, with the Agency providing the APOLLO-specific equipment and the participating PTT Administrations making transmit earth stations available. Detailed specifications for the APOLLO system were then developed by Agency staff in close cooperation with the other participants. The major objective was to realise APOLLO as a data-dissemination service with a limited number of transmit stations and as many low-cost receive-only earth stations as required.

*La Conférence européenne des Administrations des Postes et Télecommunications

The APOLLO application requirements

APOLLO is intended to provide the means to deliver information in the form of either text, images or computer files, from a relatively small number of sources to a large number of destinations (known as 'sinks').

The information flow is highly imbalanced, since most of the data flows from the source to the destinations. Furthermore, the amounts of information to be transferred are very large (ranging from a few to several hundreds of megabits), implying that the system must have a high capacity. The APOLLO system is not intended to be operated in real time, nor in interactive mode, but the latter is not precluded as a later development.

User requirements

In order to provide an attractive service to potential users, the cost of the user equipment and the tariffs need to be kept as low as possible. At the same time, users expect the system to provide high quality and resolution, that document delivery will be fast, and that a number of facilities, e.g. implementation of closed user groups, broadcast facilities, etc. will be made available.

The system architecture and interfaces should also comply as closely as possible with industry standards and with the relevant CCITT Recommendations. It should also be possible to connect the user equipment to existing archives in a customer environment, e.g. paper

Figure 1 – Architecture of the APOLLO system

DSC(TX):	*Data Station Controller (Transmit)*
SAC:	*Satellite Access Controller*
ROES:	*Apollo Receive-Only Earth Station*
DSC(RX):	*Data Station Controller (Individual receive)*
DSC(MRX):	*Data Station Controller (Multiport receive)*
SDOCT:	*Apollo Standard Document Terminal*
EDOCT:	*Apollo Enhanced Document Terminal*

archives, electronic-document databases, etc.

Operator requirements

APOLLO services will be provided via the Eutelsat Satellite Multisystem Service (ECS/SMS) transponders. These transponders provide specialised services for business applications and the like. Any of the Signatories of Eutelsat should be able to offer the sevice when and where required. Earth stations should also be able to interface with a variety of standard terrestrial transmission links.

Unlike leased-line services, APOLLO offers a kind of switched service whereby users can access (and pay for) the system only for the time required for the actual transmission. Consequently, the system must also cater for the associated administrative and billing functions.

System architecture

In order to satisfy the requirements of both users and operators (telecommunications administrations), the architecture of the APOLLO system has been developed with the following premises:

- Concentration of traffic from several sources into typically one Eutelsat/SMS earth station per European country. These stations are accessed via land lines.
- Use of a relatively high-rate satellite channel (1536 kbit/s information rate). This channel is shared sequentially by all the transmitters of the system. The rate was chosen to provide an acceptable throughput for up to twenty transmit stations in any access cycle.
- The quasi-unidirectional nature of the information flow favours the use of receive-only earth stations. This results in a strict 'connectionless' (one-way communication) environment with no direct return link since the information flows exclusively from source to destination over the satellite channel. This mode of communication is especially suitable for broadcast or multicast (restricted broadcast) applications. However, provisions have been made in the system design for the later implementation of a return link.
- The access sequence is demand-based with distributed control, allowing the efficient assignment of capacity to the transmit stations as a function of the throughput demand that each station perceives from its sources. In this multi-access environment, it is necessary to control

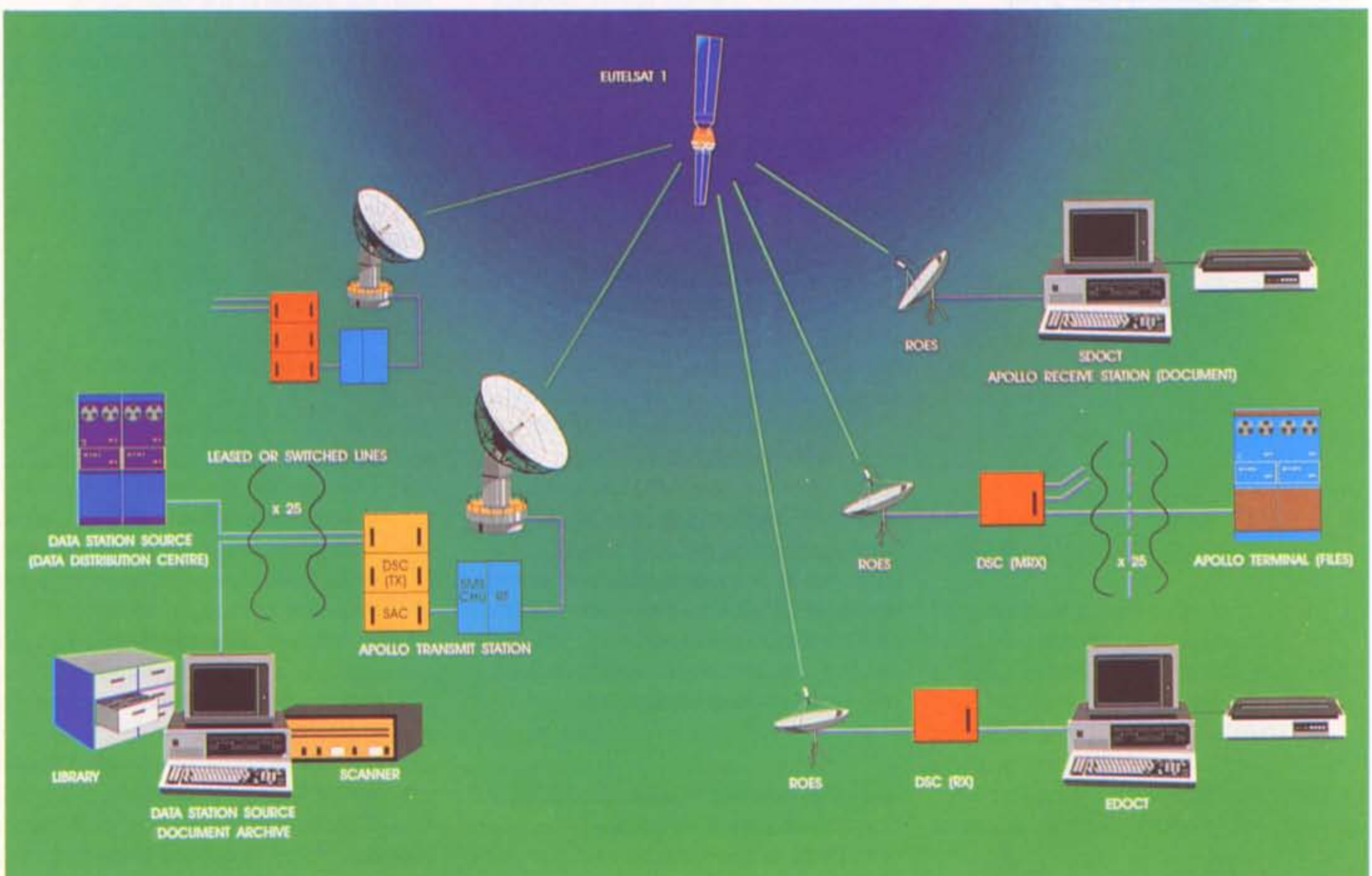


Figure 2 – The Satellite Access Controller (SAC)

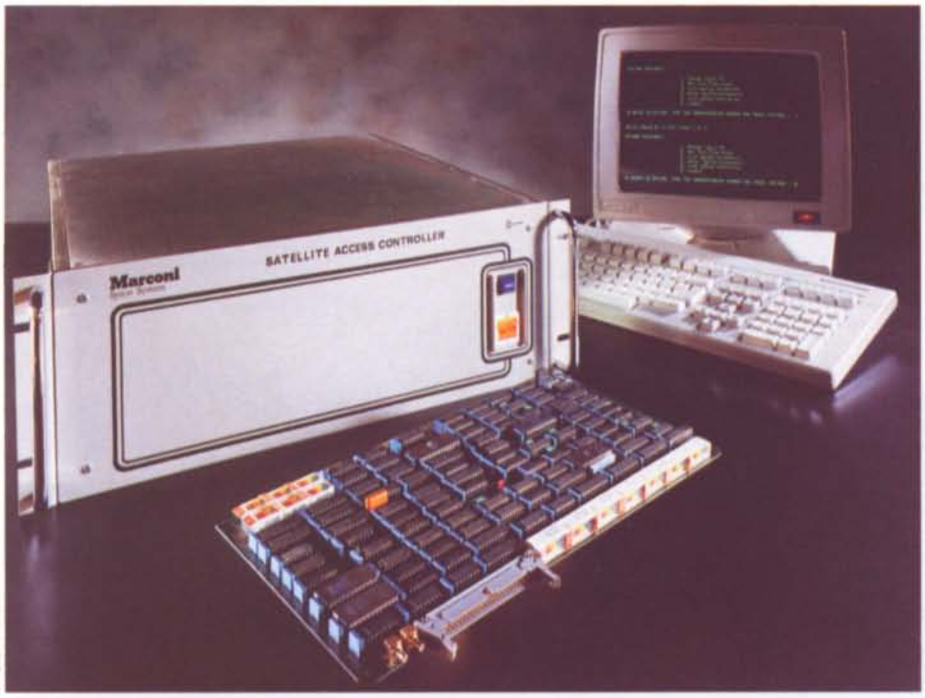


Photo: Marconi

the information flow from the sources to the APOLLO transmit stations, which is made possible with standard flow-control procedures over the terrestrial duplex link.

- The favoured receive configuration involves the use of receive-only earth stations on individual subscriber premises. However, in some cases, for either technical or economic/ regulatory reasons, the delivery to the sinks can be made over terrestrial connections from a receive gateway serving multiple users.

The overall system architecture is illustrated in Figure 1. Data are sent from source stations via public terrestrial connections to standard ECS/SMS transmit earth stations. Several sources can be connected to the same transmitting station.

The Data Station Controller in the transmitting station temporarily buffers data until it is granted access to the satellite channel via the Satellite Access Controller. At this moment, it starts sending data in a burst at a speed of 1536 kbit/s to the transmit channel unit. This encodes the data and modulates it for transmission over the satellite. The burst is made up of data products which are individually labelled with the address of their destination.

Data are received by all the earth stations, but only the station(s) with the appropriate address(es) will pass the data through to the receive terminal. This function is realised with the counterpart to the Transmit Data Station Controller, either as an Integrated Data Station which is equipped to handle directly the data received by the receive-only earth station, or as a Receive Data Station Controller where a terrestrial connection between the receive station and the sink terminal equipment is unavoidable.

Transmission design

A basic goal governing the choice of the transmission system for APOLLO was compatibility with the ECS/SMS system. This is to allow PTTs to re-use existing earth-station equipment and to benefit in the longer term from less expensive, standardised equipment. To this end, the modulation parameters, error correcting, channel coding, framing and scrambling have been made identical to those specified by Eutelsat for the SMS system.

To allow the use of small receiving terminals, the APOLLO carrier needs to use a substantial proportion of the total SMS transponder power. Because the APOLLO system operates in burst mode, it was feared that this might cause interference to other SMS carriers due to non-linear cross-talk and intermodulation. On the basis of analyses and laboratory tests, the APOLLO carrier level has been set to about one eighth of the total SMS power. This will not cause problems to other users and will still allow antennas of about 2 m diameter to be used at the edge of the satellite coverage. (The connectionless service guarantees a bit error rate of less than 10^{-6} for 99% of the time).

Operations and communication protocols

The end-to-end data transfer is effected according to application-dependent higher layer protocols. For the document delivery, this protocol has been defined on the basis of Group 4 facsimile transmissions. For the transparent data transmission within the inner APOLLO system (between Transmit and Receive Data Station Controllers), a lower-layer protocol has been derived from the X.25 standard.

The sequential access to the satellite follows the Satellite Access Protocol, implemented by the Satellite Access Controller (SAC), shown in Figure 2. This protocol assigns variable-length time slots to individual transmit stations within repetitive access cycles.

In designing this protocol, particular attention has been paid to ensuring that only one earth station will transmit at any given time (collision-free operation). This is achieved by starting every new access cycle with short reservation bursts and by the application of an explicit token-passing technique between consecutive data bursts. Software routines are

Figure 3 – The outdoor (left) and indoor (right) elements of an APOLLO receive-only earth station

Photo: Newtec CY

employed for controlling the minimum and maximum length of individual data bursts. These routines are flexible and need to be agreed among participating transmit earth stations. In practice, one earth station will be assigned the responsibility for transmitting marker signals to indicate the beginning of each new access cycle.

The receive-only earth station
A major design challenge for the equipment to be used in the APOLLO system was that of the receive-only earth station. This must be small enough to be mounted at the premises of individual customers. Most importantly, an inexpensive design was needed, because cost is expected to be the significant factor in the growth of the APOLLO system.

In considering the latter, it should be remembered that the APOLLO receive-only earth station is required to receive and process a signal structure as defined for the ECS/SMS system, with the extra feature of a simple form of burst-mode operation, yet it should cost about a fiftieth of the cost of a standard ECS/SMS earth station.

This led to a combining of the technology commonly used in the front-end sections of satellite TV cable-head receivers with that used in the ECS/SMS modem equipment, to achieve a low-cost, high-performance receive-only earth station for the APOLLO carrier. The basic configuration of the earth station is divided into two main parts, the outdoor equipment and the indoor equipment (Fig. 3).

The outdoor equipment consists of a 1.8 or 2 m diameter, prime-focus antenna and a low-noise converter (LNC). This size of antenna allows the equipment to be used throughout most of the Eurobeam footprint of the ECS satellite, with the constraint of the satellite power allocated to the APOLLO carrier. A slightly larger antenna can be provided for operation outside the normal coverage.

The indoor equipment consists of a radio-frequency (RF) unit, followed by a quadrature Phase-Shift Keying (QPSK) demodulator and baseband processing circuits. The intermediate frequency unit accepts a signal within a 250 MHz wide bandwidth and converts the wanted carrier to a 70 MHz IF by means of a crystal-controlled or synthesised local oscillator.

The PSK modulator recovers the data from the incoming signal centred on nominally 70 MHz. As part of this process, it includes a sophisticated adaptive frequency control system. This is the key to achieving fast signal acquisition (from the start of a received data transmission) as well as good continuous-mode performance in low-cost equipment that embodies relatively low-stability oscillator sources.

The APOLLO terminals
The first application of the APOLLO system has been for the delivery of documents in facsimile form. To this end three types of document terminal, based on personal-computer configurations, have been developed:
- Document Archive (DOCA), as shown in Figure 4. This unit allows high resolution scanning and local storage of documents. It can also obtain data from existing electronic archives through an Earthnet interface. It delivers the data to the APOLLO Transmit Data Station Controllers through high-performance X.25 interfaces.
- Standard Document Terminal (SDOCT) and Enhanced Document Terminal (EDOCT). These terminals receive the data either from the receive-only earth station or the Receive Data Station Controller and transfer it either to a

Figure 4 – APOLLO Document Archive (DOCA)

printer (SDOCT) or to a Group 3 facsimile machine (EDOCT).

System implementation

The APOLLO equipment is being developed by several European manufacturers, to whom development contracts were awarded in 1986. Six receive-only earth stations have already been acceptance-tested and delivered. Derivatives of these will also be used for SPACEMAIL, the Agency's own document distribution system (applying communication routines developed by British Telecom International).

The other APOLLO equipment items are currently undergoing acceptance-testing. An integrated test of the Satellite Access Controllers and Data Station Controllers over a baseband satellite link simulator will be completed in the course of September 1988 and will immediately be followed by satellite transmission tests. These will be supported by British Telecom International, Swedish Telecom, Telecom Denmark and Telespazio (Italy). Detailed test plans have been elaborated with these organisations and we expect to conclude the satellite transmission tests with a comprehensive end-to-end system demonstration towards the end of this year. The equipment will then remain with the PTTs for pre-operational use.

The first operational use of APOLLO is likely to be for the distribution of high-resolution images from earth-observation satellites and for document distribution services as originally planned. The former application is being pursued within ESA's Earth-Observation Programme Office and its implementation is planned for 1989, shortly after completion of the APOLLO system tests. Specific plans for equipment deployment are currently being developed, and additional funding for the early implementation and operation activities is being sought from the European Commission.

Acknowledgements

APOLLO is the result of the cooperative efforts of many people both inside and outside the Agency. I would like to thank in particular colleagues from the European telcommunications authorities and from Eutelsat for many stimulating discussions; colleagues in industry for the implementation of APOLLO; and my colleagues in the Agency for their dedicated support and initiatives.

In Brief

Meteosat on Station

Having been launched successfully aboard the first Ariane-4 test flight on 15 June 1988, the European Meteorological satellite Meteosat-P2 is now on station in geostationary orbit over the Gulf of Guinea. It has been fully operational since 11 August, providing Earth imaging, disseminating meteorological data, and collecting environmental data.

Like its forerunners, Meteosat-P2 is controlled and operated from the Agency's European Space Operations Centre (ESOC) in Darmstadt, Germany, on behalf of Eumetsat, the European Organisation set up for the commercial exploitation of meteorological satellites.

About 1000 user stations receive Meteosat data daily and there are 400 registered data-collection platforms. More than 300 000 images of the Earth's disc have been taken in the course of the Meteosat programme, begun with the launch of the first Meteosat spacecraft in 1977. Each day, more than 50 000 wind vectors (velocity, direction and height of the wind) are extracted from the image sequence and made available to meteorologists around the World.

Meteosat P2, the last of the pre-operational series, will bridge the gap until the launch of the first Meteosat Operational Programme satellite, MOP-1, scheduled for January 1989.

Contributions to the Ariane-4 Development Programme

Several recent articles and publications have mentioned different contribution schemes for the Ariane-4 Development Programme. The definitive breakdown of contributions is as follows (slices 1 – 4 and 6):

Belgium	4.05
Denmark	0.17
France	62.60
Germany	16.28
Ireland	0.07
Italy	5.87
Netherlands	1.76
Spain	1.77
Sweden	1.15
Switzerland	1.55
United Kingdom	4.64
Non covered	0.09

Ariane Goes from Strength to Strength

With the highly successful 25th launch of Europe's Ariane launcher on 8 September from Kourou, French Guiana, 34 satellites have been placed in orbit by Ariane since 1979. The Ariane programme has, in fact, captured 50% of the international launch market for commercial and scientific satellites.

This 25th launch (an Ariane-3 vehicle) carried two US telecommunications satellites, G Star-III and SBS-5 into geostationary orbit.

Although the majority of the satellites launched by Ariane to date have been for telecommunications applications, several Earth-observation, meteorological and scientific satellites have also been launched during the almost 10 years since the European launcher's first flight.

The Phobos Mission: First Results from the Plasma-Wave System and Low-Energy Telescope

The two Soviet Phobos spacecraft launched from Baikonur on 7 and 12 July 1988 will arrive in the vicinity of Mars on 25 and 29 January 1989. During their journey, they will carry out studies of the Sun and the interplanetary medium, the ionosphere and magnetosphere of the red planet, and one of the Martian moons, Phobos, after which the mission is named. The scientific payloads of both spacecraft include two experiment modules developed largely by ESA Space Science Department: the Plasma-Wave System and the Low-Energy Telescope (see ESA Bulletin No. 55, page 98).

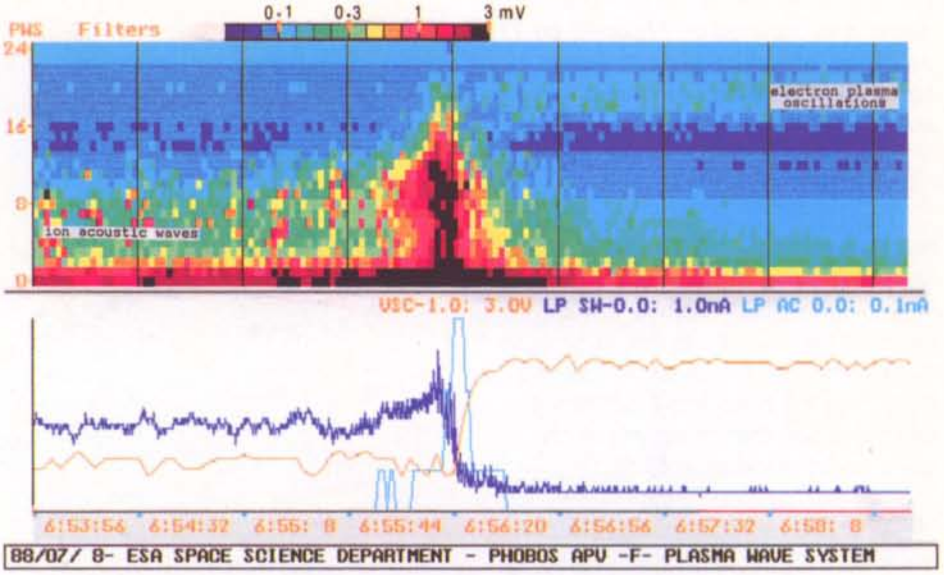


Figure 1 — Summary of the data sequence taken with the PWS instrument, when Phobos-1 was crossing the Earth's bow shock on 8 July 1988. The upper panel is a spectrogram made up of the 25 signals obtained with the filters connected to the electric antenna; the root mean square voltage delivered by each filter can be evaluated with the help of the colour scale shown at the top. Every plot in the lower panel is identified by a label of the same colour followed by the minimum and maximum voltages (V) or currents (nA) of the range covered by the ordinate axis; VSC is the spacecraft potential with respect to a reference electrode; LP SW is the current collected with the plasma probe and LP AC is the root-mean-square fluctuation of this current in the frequency range 0.1-50 Hz. The bottom axis common to the two panels gives the universal, or Greenwich, time in hours, minutes and seconds.

The Plasma-Wave System (PWS), which forms part of the APV-F instrument, consists of a radio-receiver with a 1.5 m long antenna which measures electric signals associated with plasma instabilities and electromagnetic waves, and a plasma collector (6 cm^2 in area) which measures electron fluxes.

Its primary scientific objectives are to study space plasmas* and related wave phenomena in the Martian environment. PWS will also participate in two of the highlights of the mission, on 7 April and 13 June 1989, during the low-altitude (50 – 100 m) hovering encounters with Phobos. The spacecraft will bombard Phobos with a laser and a krypton ion gun, causing the release of ionised surface material, which will subsequently be analysed with onboard mass-spectrometers. The PWS will monitor the spacecraft's potential (charge) during these operations.

The results presented were obtained during the days immediately after the launches when the spacecraft were crossing the Earth's bow shock at geocentric distances of the order of 200 000 km.

The interaction between the Earth's magnetosphere, the volume of space that encompasses the planetary magnetic field, and the solar wind, a hydrogen plasma that blows past the Earth at 400 km/s, gives rise to an electromagnetic shock comparable to the acoustic phenomenon that develops in the atmosphere around a supersonic aircraft. The bulk velocity of the solar wind drops to about 50 km/s downstream of the shock; the solar plasma is subsequently deflected by the magnetopause, which is the boundary of the magnetosphere. The turbulent plasma layer located between the shock and the magnetopause is called the magnetosheath.

An example of the results obtained by the PWS on Phobos-1 is illustrated in Figure 1. The upper panel, a raster of 25 contiguous lines, numbered from 0 to 24, represents the antenna signal processed through 25 filters with nearly adjacent frequency bandwidths, which together cover the range from practically DC (filter 0) to 150 kHz (filter 24). The level of every filtered signal is given by the colour of the line, so that red and black correspond to the strongest signals and dark blue to the weakest; medium levels are shown in green and yellow.

The bow-shock crossing occurs at 06.56 UT and is accompanied by a sharp increase in signal in the range 0-55 kHz (filters 0-21). Earlier, in the magnetosheath, ion acoustic waves are observed in a more restricted frequency domain, 0-4 kHz (filters 0-13). Thereafter, in the solar wind, electron plasma oscillations are seen in a frequency band centred around 24 kHz (filter 19).

The three curves in the lower panel of Figure 1 show a number of features quite characteristic of the transition from the magnetosheath to the solar wind: the increase in spacecraft potential (yellow), the decrease in electron current (dark blue), and the peak in current fluctuations (light blue).

These first results demonstrate that the PWS system is performing well. They are also extremely valuable because they provide a reference for the evaluation of similar phenomena that will subsequently

* A plasma is an ionised gas, i.e. a mixture of positively charged atoms or molecules (ions) and negatively charged electrons.

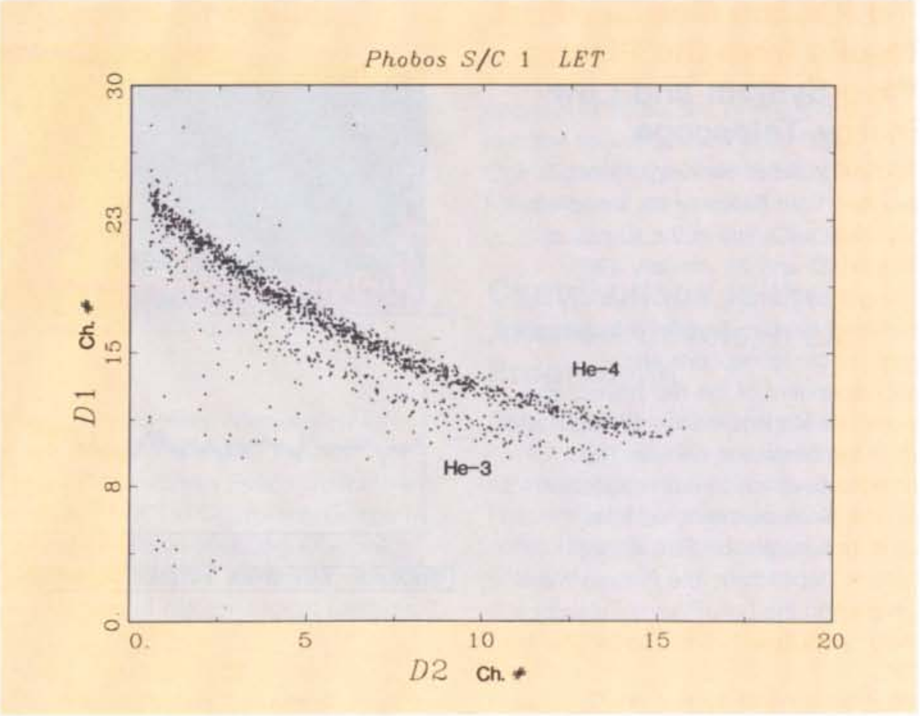


Figure 2 — Scatter plot of LET pulse height data acquired on Phobos-1 on 21 July 1988, showing the characteristic tracks corresponding to the isotopes He_3 and He_4.

be observed in the Martian environment. Unlike the Earth, which behaves like a huge magnet, Mars has only a weak magnetic field — if it has one at all — so that the Martian bow shock will probably result from the direct interaction of the solar wind with the ionosphere much closer to the planetary surface.

The Low Energy Telescope (LET) experiment forms part of the ESTER complex of instruments that will perform studies of the solar wind, the suprathermal and energetic particle populations, and low-energy cosmic rays. Specifically, the LET measures the flux, spectra and elemental composition of nuclei from hydrogen up to iron, in the energy range ~1 MeV/n to ~75 MeV/n, using a silicon detector telescope. Isotope separation can also be achieved for light nuclei such as He. The sensor is mounted on a rotating platform to permit coarse directional measurements of low-energy protons.

Measurements of low-energy cosmic rays and solar energetic particles were originally included onboard the two Phobos spacecraft to provide a reference in the ecliptic plane for a similar experiment on ESA's Ulysses spacecraft, which should have been climbing to high solar latitudes during the time frame of the Phobos mission. Unfortunately, as a result of the hiatus in Shuttle operations, the launch of Ulysses has been delayed until October 1990. Nevertheless, the LET will enable detailed studies of the characteristics of the charged-particle population in interplanetary space during the rising phase of solar cycle 22. Equally important, as part of the ESTER instrumentation, the LET will search for particles trapped in the Martian magnetosphere, assuming this exists.

The LET experiments were switched on on 19 July (Phobos-1) and 25 July (Phobos-2), and initial data show that, with the exception of the rotating platform on Phobos-1, the instruments on both spacecraft are functioning nominally. As an example of the data received thus far, Figure 2 shows a so-called pulse height matrix in which the energies lost in two of the silicon detectors by helium ions coming to rest in the Phobos-1 instrument are displayed in the form of a scatter plot. In such a plot, data points corresponding to particles possessing a given nuclear charge and mass are grouped together along characteristic tracks, thereby allowing the identification of each ion detected by the LET. The data shown in Figure 2 correspond to a ~20 h period starting at 06:34 UT on 21 July, and demonstrate the clear separation by the instrument of the isotopes He_3 and He_4. In general, the results obtained to date from both spacecraft confirm the good species resolution available with the LETs on Phobos, and provide a preview of the exciting data to be expected from the LET experiment on Ulysses.

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

The ESA team that has contributed to the development of the PWS includes D. Klinge, A. Butler, K. Hjortnaes, H. Christensen, J. Bouman, A. Fransen, J. Heida and R. Scheper.

Institutes collaborating on the LET experiment are ESA Space Science Department, the Space Research Institute, Moscow, the Max-Planck-Institut für Aeronomie, Lindau and the Central Research Institute for Physics, Budapest. Major contributions to the success of the LET experiments have been made by the following members of ESA/SSD: J. Henrion, L. Smit, J. Fleur, J. Bouman, R. Scheper and J. Dalcolmo.

Note added in proof
In the first week of September, experimenters were informed by the director of the Phobos project, Academician R. Sagdeev, that the Moscow Control Centre had lost contact with the Phobos-1 spacecraft. Attempts are continuing to re-establish the telecommunications link with the probe, which is assumed to be in an uncontrolled attitude.

R.J.L. Grard and R.G. Marsden

Success for the 'Dutch Viking' and ESA's PRODAT

On 22 July 1988 the 'Dutch Viking' arrived safely at Almere in The Netherlands, having successfully completed its Atlantic crossing from St. John's, Newfoundland (see ESA Bulletin 55, page 101). The 6.5 m polyester capsule is the smallest boat in the World to have been equipped for satellite communications.

Dutch Viking was fitted with a PRODAT terminal, a mobile communications system conceived and developed at ESTEC, built by SNEC/RACAL.

During the 2335 mile journey, the tiny craft experienced heavy rolling due to bad weather, but PRODAT remained unaffected and all transmissions were error-free. In total more than 700 telex messages were sent. Essential weather forecasts were remotely routed to the Dutch Viking from KNMI, the Dutch weather forecasting service. The main sponsors, SKALA, also offered their customers the opportunity to question the two-man crew, Henk Brinkman and Willem Hageman, via PRODAT. Status messages were displayed in all SKALA shops during the crossing.

The 6.5 m Dutch Viking capsule (above); within the 'cockpit' (left) the compact PRODAT terminal can be seen in the centre of the photograph

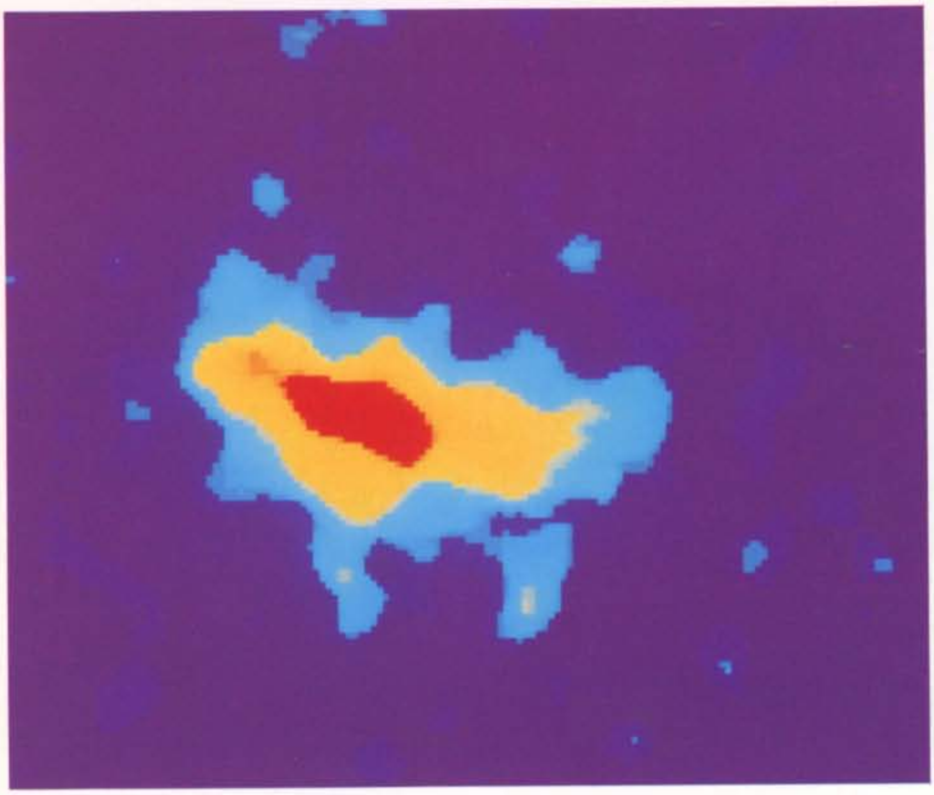
The advantages offered by PRODAT are not confined to maritime applications. Terminals have already been installed in aircraft, and a full-scale experiment has been conducted by an international road haulage company. Further information on the PRODAT system is available from:

ESA Telecommunications Directorate
ESTEC
Postbox 299
2200 AG Noordwijk.

ESA Awarded the 'Christopher Columbus' International Prize for Communications

The Agency has been awarded the 1988 'Christopher Columbus' International Prize for Communications by the City of Genoa, Italy's largest port and the birthplace of Columbus. This distinction, awarded at the proposal of the International Institute of Communications, is conferred annually on a person or organisation having made a major contribution to progress in communications in the form of a technological, scientific or social discovery, work or research activity that has brought economic benefits, increased human well-being or promoted international cooperation.

The prize was presented to Mr Giorgio Salvatori, ESA's Director of Telecommunications Programmes, on behalf of the Director General, Prof. Reimer Lüst, in Genoa on 12 October 1988, Columbus Day.



Glowing hydrogen gas produced by 4C41.17, the most distant galaxy found to date, taken through the 4 m Mayall telescope at the Kitt Peak National Observatory. The gas is more than 100 000 light years across. The light which produced this picture has been travelling through space for about 15 billion years (Courtesy National Optical Astronomy Observatories, Chambers, Miley and van Breugel).

Most Distant Galaxy Detected

Research sponsored by NASA, ESA, the US National Science Foundation, The Hopkins Ultraviolet Research Project and the Space Telescope Science Institute, has uncovered the most distant galaxy ever seen.

The discovery was made by Ken Chambers, a graduate student at the Johns Hopkins University; George Miley, Professor of Astronomy on leave from the University of Leiden in The Netherlands and currently stationed by ESA at the Space Telescope Science Institute; and Will van Breugel of the University of California at Berkeley.

The newly-discovered galaxy, 4C41.17, is located at an estimated distance of 15 billion light years. Observations of such remote galaxies are of particular interest because they contribute to our understanding of the evolution of the Universe.

Chambers, Miley and van Breugel pinpointed the galaxy through a unique all-sky search technique they have developed for locating extremely distant radio galaxies. It was first identified in a survey of 51 distant radio galaxies.

Detailed radio observations were then made at various frequencies using the very large array radio telescope facility near Socorro, New Mexico. An optical search with 2.1 m telescope at Kitt Peak National Observatory then followed. A long-exposure charged-coupled device image revealed 4C41.17's optical component and characteristic elongated shape. Having optically identified the galaxy, the researchers then ascertained that its redshift (and hence its distance from our Galaxy) was greater than that of any galaxy ever observed.

The three astronomers also discovered that such distant high redshift galaxies have unique enigmatic properties, in that the visible light appears to be stretched out along the direction of their radio emission. Although this effect is not fully understood, it indicates a very close relationship between the starlight presumed to be producing the optical radiation and the powerful radio emission. This radio emission may be produced by twin jets of extremely fast particles spewed out from a massive black hole rotating at the core of the galaxy. These jets also compress gas and dust along their paths, triggering new star formation concentrated along these paths, creating the elongated appearance.

In the last few years attempts have been made to draw conclusions about the evolution of the universe by assuming that these distant radio galaxies are similar to the nearby and more familiar galaxies. The discovery of the strange elongated appearance of 4C41.17 and other extremely distant radio galaxies has forced astronomers to rethink some of their previous deductions. The three researchers say that their discovery establishes conclusively that, in contrast to earlier theories, galaxies were forming only a few billion years after the 'Big Bang'.

ESA at Farnborough '88

This year the Agency once again offered specialists and the general public an opportunity to bring themselves up to date with Europe's space programmes by exhibiting at the Farnborough International Air Show on 4 – 11 September. Models, pictures and video-displays illustrated ESA's present and future programmes, and the Directors of the various Programmes and other Agency staff were on hand to provide further information.

The models on display included:
- Hipparcos, a scientific satellite due to be launched in 1989;
- the Infrared Space Observatory (ISO), due to be launched in 1992;
- Olympus, a direct-broadcast television satellite, due to be launched in 1989;
- the European remote-sensing satellite, ERS-1, due to be launched in 1990;
- the Man-Tended Free Flyer (MTFF), an important element of the Columbus Programme, Europe's contribution to the International Space Station; and
- Ariane-5, the European launcher for the year 2000 which will put Space Station elements and the Hermes space plane into orbit, as well as conventional spacecraft.

Publications

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

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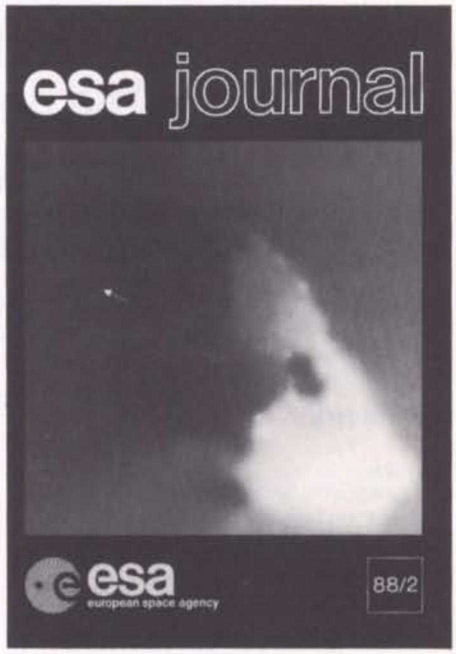

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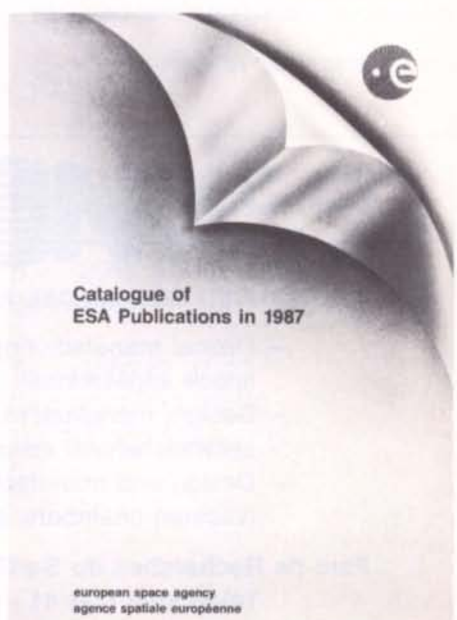

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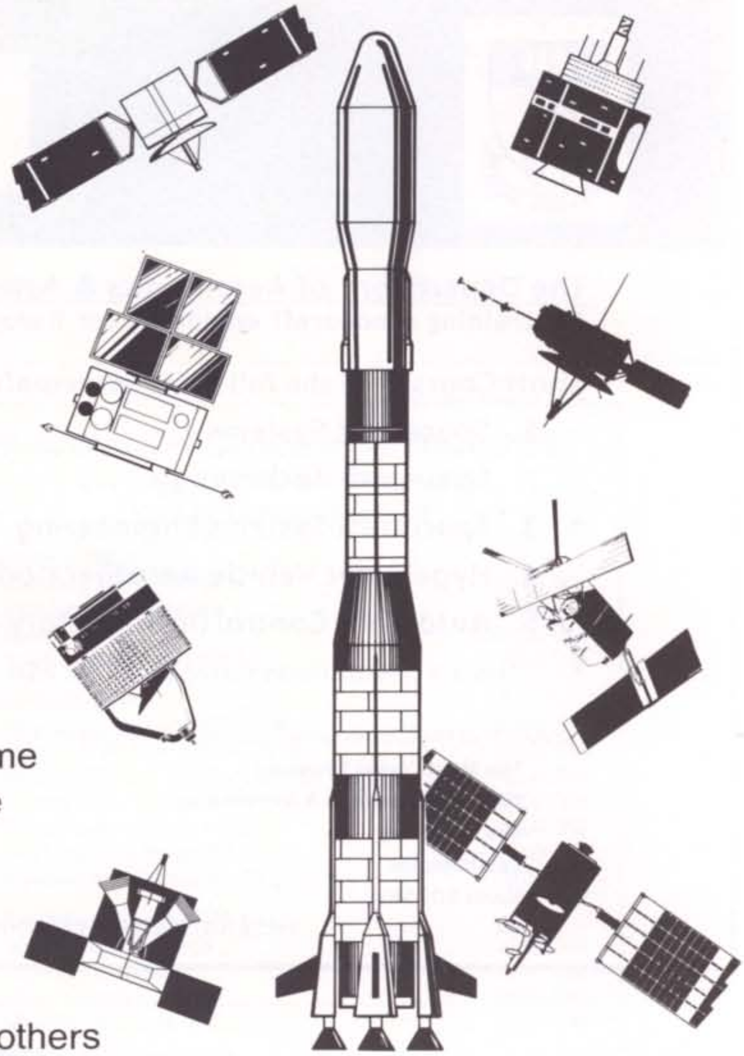

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