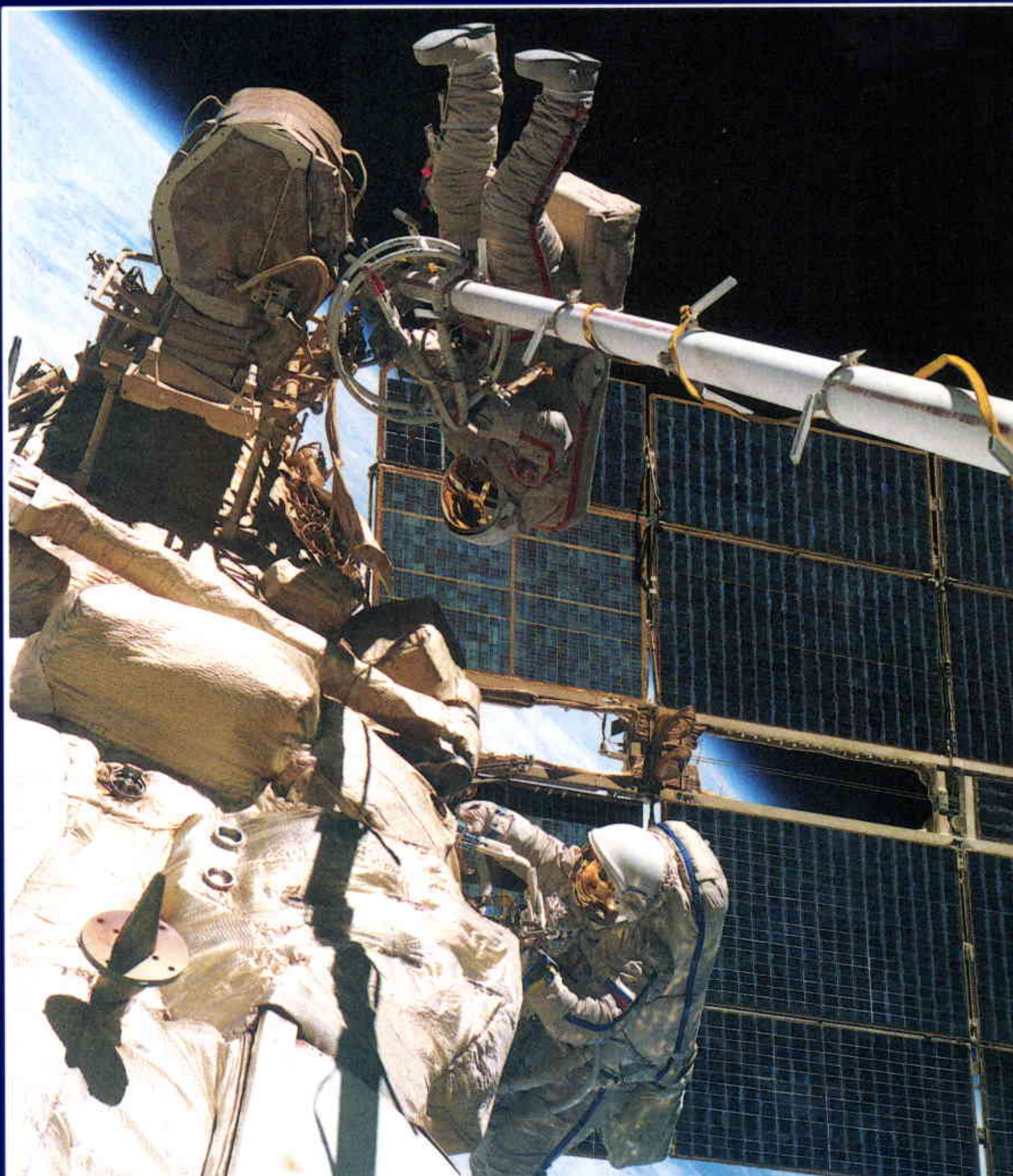
esa

bulletin

number 88 - november 1996



European Space Agency
Agence spatiale européenne

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, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. 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 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: H. Parr

Director General: J.-M. Luton.

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 Finlande, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. Le Canada bénéficie d'un statut d'Etat coopérant.

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

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

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

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence 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

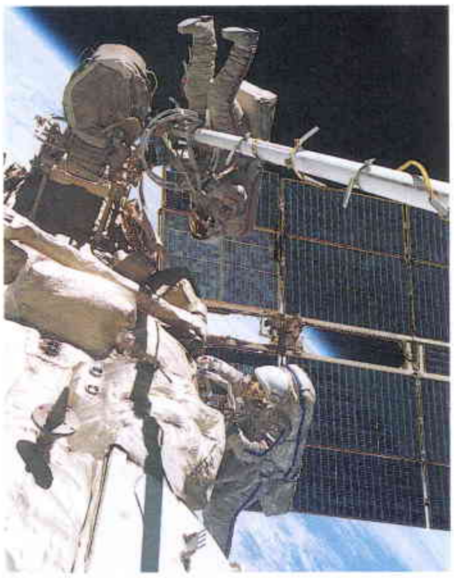
Président du Conseil: H. Parr

Directeur général: J.-M. Luton.

ESA bulletin

contents/sommaire

number 88 - november 1996



Cover: Russian Cosmonaut Yuri Gidzenko (top) and ESA Astronaut Thomas Reiter (bottom) photographed by Cosmonaut Sergei Avdeev through one of Mir's observation windows during the Euromir 95 mission

Editorial/Circulation Office

ESA Publications Division
c/o ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31).71.5653400

Editors
Bruce Battrick
Duc Guyenne
Dorothea Danesy

Layout
Carel Haakman

Graphics
Willem Versteeg

Montage
Keith Briddon
Paul Berkhout

Advertising
Brigitte Kaldeich

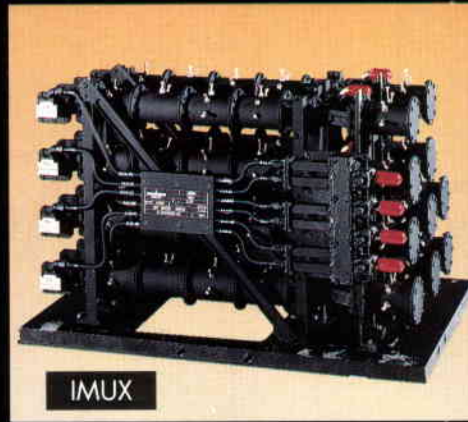
The Bulletin is published quarterly by the European Space Agency. Individual articles may be reprinted provided that the credit line reads 'Reprinted from ESA Bulletin', plus date of issue. Signed articles reprinted must bear the author's name. Advertisements are accepted in good faith; ESA accepts no responsibility for their content or claims.

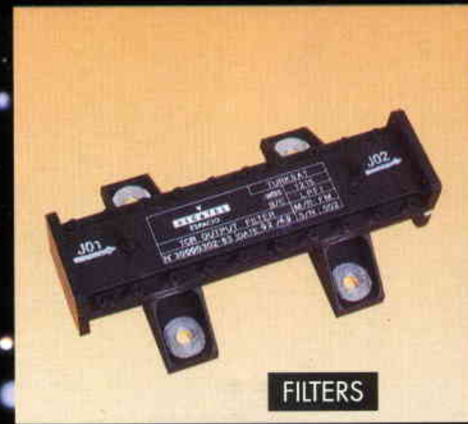
Printed in The Netherlands ISSN 0376-4265

European Space Agency
Agence spatiale européenne

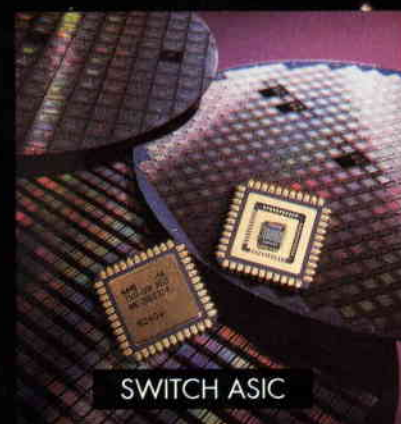

THE FAR INFRARED AND SUBMILLIMETRE UNIVERSE
A Symposium
jointly organised by ESA and IRAM devoted to the
Far Infrared and Submillimetre
Telescope (FIRST) mission
15 – 17 April 1997
Venue: ENSIEG
Domaine Universitaire de Grenoble
France
For further information, please contact the Symposium organiser or the FIRST Project Scientist:
Dr S. Volonte, European Space Agency
8 – 10, rue Mario Nikis
F – 75738 Paris Cédex 15
France
Tel.: 33 – 1.53.69.71.03
Fax: 33 – 1.53.69.72.36
Email: svolonte@hq.esa.fr
Dr G. Pilbratt, ESA Astrophysics Division
ESTEC/SA, P.O. Box 299
NL – 2200 AG Noordwijk
The Netherlands
Tel.: 31 – 71 – 5653621
Fax: 31 – 71 – 5654690
Email: gpilbratt@astro.estec.esa.nl
WWW address: http://astro.estec.esa.nl/SA – general/Symposia/Grenoble/grenoble.html
esa
IRAM
Institut de
Radio-Astronomie Millimétrique


TTC TRANSPONDER


IMUX


FILTERS


BPSK MODULATOR


SWITCH ASIC


RTU


APMD


CDPU


ARIANESPACE
The world's space transportation company
Arianespace is tying together telecommunications networks with satellite operators and constructors as partners and customers. These global networks support direct television broadcasting, offer enhanced meteorological capacity, make it easier to observe the Earth and open the way to space-based scientific programs.
With the arrival of Ariane 5 alongside Ariane 4, Arianespace is not only gaining greater launch capacity but also making its complete service even more adaptable and readily available.
By placing at least ten satellites in orbit every year, Arianespace is making space work to make life easier for everyone.
arianespace
The world's first commercial space transportation company
Arianespace, boulevard de l'Europe, BP 177, 91006 Evry Cedex, France, Tél. +(33 1) 60 87 60 00
Arianespace, Inc., 700, 13 th Street, N.W., Suite 230 Washington, D.C., 20005 U.S.A. Tel. +1 (202) 628-3936
Arianespace Tokyo, Hibiya Central Building 1-2-9, Nishi-Shimbashi-Minato-ku, Tokyo 105, Japan. Tel. +81(3) 3592-2766
Arianespace , Shenton House # 25-06, 3 Shenton Way, Singapore 058805
Deslegan/BBDO
PHOTO B. PARIS

Foreword

Jörg Feustel-Büechl

The first six articles in this issue of the ESA Bulletin recount the planning, execution and results of the Euromir manned missions. The 31-day Euromir 94 mission and the 179-day Euromir 95 mission were the first large-scale projects of this nature to be conducted by ESA and the European space community in partnership with the Russian Space Agency and Russian industrial entities. They also represented ESA's first steps into long-duration manned missions, as precursor flights for Europe's planned participation in the building and operation of the International Space Station.

Euromir has certainly been a unique experience for those involved in all of its stages, from the early negotiation of the flight opportunities and contracts, through the selection and building of the various experiments, to their timely delivery, installation and successful operation aboard the Russian Mir station.

Mr Jean-Marie Luton (front left), ESA's Director General, and Dr Yuri N. Koptev (second from the right), Director General of the Russian Space Agency (RKA), at a reception in Moscow to celebrate the successful completion of the Euromir 95 mission

Just one example of the novel nature of these missions is to be found in the fact that the transport of equipment to, and the return of items from, the Mir station took place in four different ways for Euromir 95: inside the Spektr module which was launched to the Mir station in May 1995; with the astronauts in the Soyuz manned spacecraft; via three supply flights by a Progress unmanned cargo vehicle; and on three docking flights by the US Space Shuttle. Many inventive solutions had to be devised to accomplish the timely handover of items between the many parties involved and to satisfy the various legal, safety and customs requirements associated with the overall transportation logistics.

The experience gained in this and the many other unique aspects of men and women of different nationalities working together routinely in the exploitation of space will undoubtedly be of great value to us and our International Partners in the future cooperative utilisation of the International Space Station.

In the following pages, the Euromir experience is recounted from various points of view by the specialists intimately involved in the preparation and operation of Euromir 94 and Euromir 95. It is my pleasure to acknowledge here the great success of both missions and to thank those involved – the Russian and European Project Teams and all associated personnel at the various control and support centres – for their valuable efforts in preparing and operating these missions. Together with the scientists responsible for the onboard and associated ground experiments, and particularly the Russian cosmonauts and European astronauts who carried out the two missions, they merit our deepest thanks for their perseverance and dedication.

J. Feustel-Büechl
Director of Manned Spaceflight and Microgravity

The Euromir Missions

R.D. Andresen & R. Domesle
Space Station Utilisation Division, ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

The 179-day flight of ESA Astronaut Thomas Reiter onboard the Russian Space Station Mir drew to a successful conclusion on 29 February 1996 with the safe landing of the Soyuz TM-22 capsule near Arkalyk in Kazakhstan. This mission, known as Euromir 95, was part of ESA's precursor flight programme for the International Space Station, and followed the equally successful Euromir 94 mission by ESA Astronaut Ulf Merbold (3 October – 4 November 1994). This article discusses the objectives of the two flights and presents an overview of the experiment programme, a preliminary assessment of its results and achievements, and reviews some of the lessons learnt for future Space Station operations.

Introduction

One of the major objectives reflected in the Resolutions adopted at the ESA Council Meeting at Ministerial Level in Granada (E) on 10 November 1992 was a widening and strengthening of international cooperation. In the light of the evolving geopolitical scene, particular emphasis was given to the intensification of cooperation with the Russian Federation.

Consequently, ESA and the Russian Space Agency subsequently signed an Agreement to cooperate on manned space infrastructure and space transportation systems in the 1993–1995 time frame. Two major space station elements, the European Robotic Arm (ERA) and the Data Management System for the Russian Service Module (DMS-R) are being developed within the framework of this intensified cooperation. The Euromir 94 and 95 missions, with ESA astronauts working on board the Russian space station Mir, were also a direct result of this cooperation.

As Columbus Precursor Flights, Euromir 94 and 95 had the following general objectives:

- to prepare the European space user community, i.e. ESA and the Participating States, for their involvement in the International Space Station
- to provide continuing flight opportunities for the user community to bridge the period until the International Space Station becomes operational
- to provide in-flight validation of design concepts for the Columbus Orbital Facility (COF) and its payloads, e.g. serviceability and telescience, and to introduce, as far as feasible, the operations concepts intended to support experimentation aboard the COF
- to build-up and maintain a core of ESA astronauts and to provide them with flight opportunities in order to improve European experience in crew space operations.

A specific objective of the Euromir missions was also to intensify relations with the space institutions of the Russian Federation through missions onboard the Mir station. This included the flight and accommodation of astronauts and payloads, which at the same time was also part of the Agency's preparations for the use of future inhabited international space infrastructures.

The major scientific and technical objectives of the Euromir missions were:

- the establishment of a valuable multidisciplinary scientific experiment programme which broadens our knowledge and experience of manned spaceflight, e.g. through medium and long-duration flight programmes
- familiarisation with the operational concept of the Mir space station, and active participation in onboard system operations, including Extra-Vehicular Activities (EVAs).

The Euromir 95 experiment programme

The experiment programme for the Euromir 95 mission concentrated on the effects of long-term weightlessness on the human body. In total, there were 18 life-science experiments addressing:

- renal function and drug metabolism
- the neurovestibular system
- radiation effects and dosimetry
- muscle physiology and motor control
- the cardiovascular and cardiopulmonary systems
- bone density.

Additional experiments were undertaken in the materials-science (8) and astrophysics (5) domains, dealing respectively with the processing and testing of new materials and with the analysis of space environmental effects.

A further 10 experiments were related to the advancement of space-related technology, e.g. sensing and monitoring technology, multimedia technology using computer and video devices, etc.

An average of 4.5 h per day of astronaut work-time was allocated exclusively to experiment work, aside from the time that had to be devoted to flight-engineering tasks. Two EVAs, each lasting several hours, contributed directly to the overall scientific goals of the mission in that they made it possible to install and retrieve material samples and sensors fixed to the outside of the Mir station using the European Space Exposure Facility (ESEF).

Several multi-user facilities have been installed on board Mir to support many of these experiments: the RMS-II, a respiratory monitoring system to study the astronaut's lung function and blood flow through the heart and lung system; the BDM (Bone Densitometer Measurement) system, an ultrasonic device for monitoring differences in bone density; the CSK-4 furnace, a six-zone tubular furnace, called TITUS, capable of achieving temperatures of up to 1250°C; and the above-mentioned ESEF, which was attached to the Mir module Spektr prior to the Euromir 95 flight. A 'BSU-Kit' for the collection of blood, saliva and urine, and a freezer for their storage, were two other multi-user facilities delivered to the station in preparation for the two Euromir flights.

Euromir 95 mission achievements

Although the activities conducted aboard Mir by the astronauts are the most critical and most visible, they represent only a part of the great number of tasks and activities undertaken by the entire team of astronauts, engineers, scientists, operations staff and managers before, during and after the actual flights.

Mission preparation and crew training

The Euromir 95 project team was able to build upon some of the infrastructure put into place for, and the experience gained from, the Euromir 94 mission. Nonetheless, specific preparations for the Euromir 95 mission were necessary in three major areas:

Astronaut training and onboard activity planning

Some 3500 hours of training were completed by the two ESA astronauts, Thomas Reiter and Christer Fuglesang, during their preparations for the Euromir 95 mission. This training took place partly at the European Astronaut Centre (EAC) in Cologne (D), and partly (in the later stages exclusively) at the Cosmonaut Training Centre (TsPK) in Star City near Moscow (Fig. 1). It included not only experiment-specific training, but also more general training in space-vehicle navigation, as well as Russian language training. A large part of the training was devoted to the Mir systems and to EVA operations, enabling the ESA astronaut to assume the role of onboard engineer for specific subsystems and to participate in two EVAs during the flight.

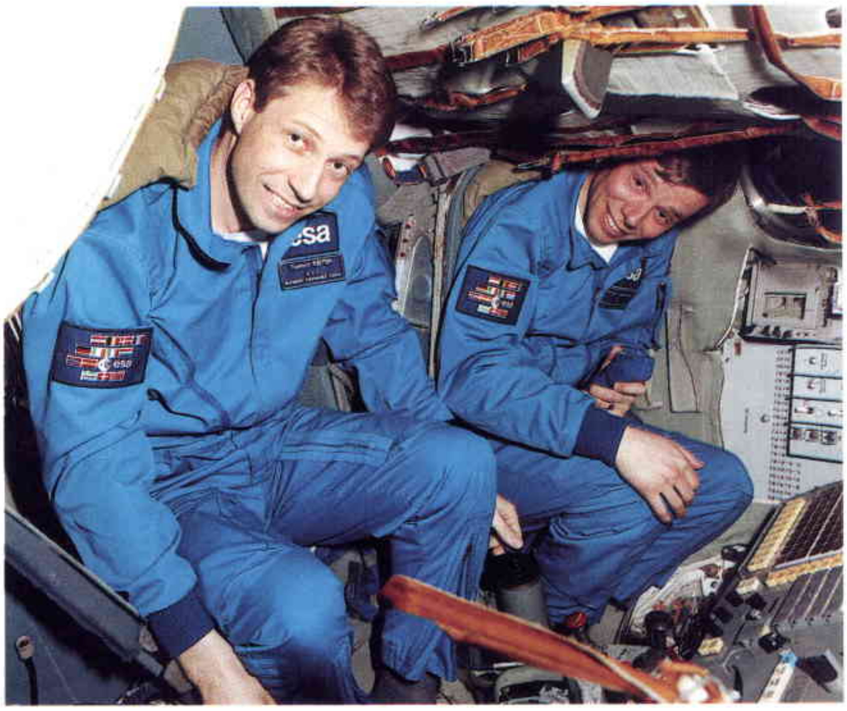


Figure 1. ESA Astronauts Thomas Reiter from Germany (left) and Christer Fuglesang from Sweden (right) training in the Soyuz-TM capsule simulator, at the Cosmonaut Training Centre (Tsentr Podgotovka Kosmonavtov = TsPK) near Moscow, in preparation for Euromir 95

In parallel with this training, flight procedures for all of the experiments were developed and refined, and the timeline for all onboard activities was drawn up on the basis of often contradictory requirements in terms of the number and duration of experiment runs, the envisaged onboard engineering tasks, the necessary crew rest time, the prescribed physical activities, etc. Each of these documents had to be negotiated with our Russian counterparts and agreed upon by both sides.

Experiment preparation

Every experiment went through a selection and approval cycle. As for the hardware, the flight model, spare model, training models and sometimes engineering models for each experiment had to undergo both qualification and acceptance testing. There was also a sophisticated shipment schedule for their transportation between Western Europe and Russia. The specification documents had to be generated and agreed upon in both English and Russian. In addition, upload and download agreements had to be negotiated not only with our Russian counterparts to ensure transport capacity on the Progress Transport Vehicle and on the Soyuz capsule, but also with NASA for the use of the Space Shuttle as the downloading transport vehicle from the Mir station.

Integrated into the pre-flight (and post-flight) experiment activities was the Baseline Data Collection (BDC) programme, by which medical data were obtained from the astronauts in a controlled way during pre-specified periods before and after the flight. Besides the ESA astronauts, the Russian Cosmonaut Sergei Avdeev also participated in some of the life-science experiments, and therefore also took part in the BDC programme.

Operations/communications set-up

For Euromir 94, the control centre for all payload operations (called SCOPE: System for Control of Operations of Payloads for Euromir) had been located at CNES in Toulouse (F), and for Euromir 95 it was sited at the DLR German Space Operations Centre in Oberpfaffenhofen. The operational infrastructure therefore had to be adapted accordingly and revalidated in order to ensure proper working of the basic communications setup. SCOPE was connected both to the Russian Flight Control Centre (Tsentr Upravleniya Polyotami = TsUP) in Kaliningrad near Moscow, and to fifteen remote Payload Operation Centres spread throughout Western Europe.

During Euromir 95, extensive use was made of worldwide data distribution via the Internet and of the DICE system via Eutelsat, mainly for video conferences and public-relations events. In contrast to Euromir 94, the project-management team largely remained at ESTEC throughout the flight and thereby relied extensively on these modern communications tools.

An overview of the communications setup is shown in Figure 2.

The day-to-day operations were directed from SCOPE, with the support of a small ESA team at TsUP. Additional support to SCOPE was provided on a call-in or fly-in basis.

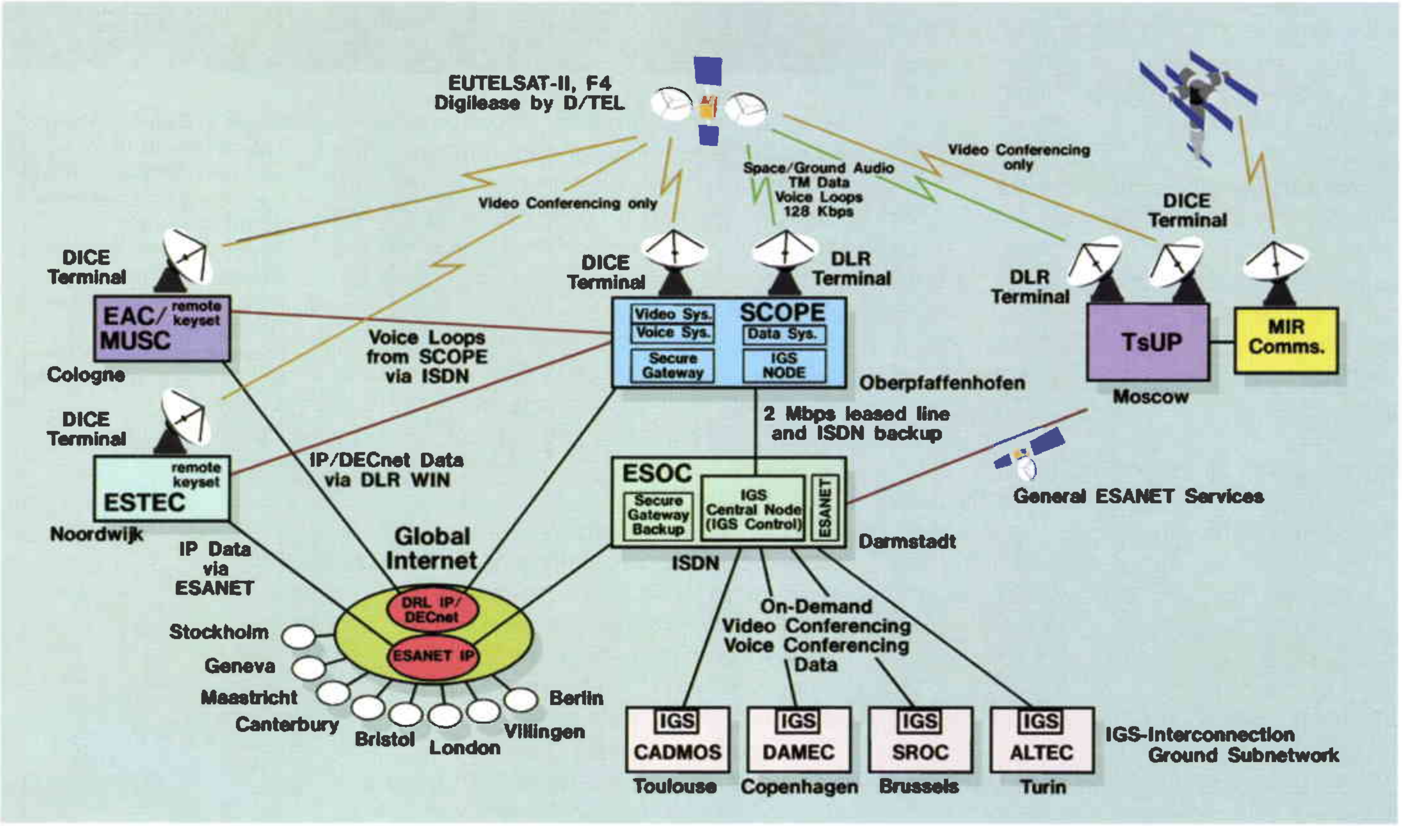
Mission operations

The Euromir 95 flight was the longest ever undertaken by an astronaut not from the former Soviet Union. It was originally scheduled to last 135 days, and was then extended in the course of the flight to 179 days. As a result, this flight gave the best preview to date of future long-term missions by ESA astronauts to the International Space Station.

Onboard operations

The mission drew a large measure of its success from the fact that ESA Astronaut

Figure 2. Schematic of the overall communications setup for Euromir 95



Thomas Reiter and his two Russian colleagues, Commander Yuri Gidzenko and First Engineer Sergei Avdeev, formed an exceptionally harmonious team. Thomas Reiter's good command of the Russian language meant that onboard communication between the three was excellent and never once throughout the entire flight was intervention or interpretation from the ground necessary.

The excellent cooperation onboard was also displayed by the flawless teamwork during the two scheduled EVAs and during the repair work needed on one of the station's cooling loops. The good team spirit on Mir also had a stimulating effect on the Euromir ground team.

Ground operations

The six months of uninterrupted ground support needed for the Euromir 95 manned mission had no precedent in ESA nor, for that matter, in NASA. Nevertheless, they provided an excellent demonstration, like Euromir 94, of the feasibility of: (a) conducting the operations monitoring and control from a remote centre distant from the Russian Flight Control Centre at Kaliningrad, and (b) relying on voice, data and video links to the various supporting centres. The key to this operations concept's success with such a long-duration mission was the cooperative collaboration with the Russian control authorities, which provided daily real-time communications with the Mir station – not only for the ESA Crew Interface Coordinator and the Crew Surgeon at TsUP, but also on an as needed basis for the Payload Operations Manager at SCOPE, for management personnel at ESTEC, and for the scientific team coordinators at the various User Support Centres.

Strict structures were implemented for lines of reporting and for filtering/distributing information in both directions (up to and down from Mir), with daily planning conferences scheduled at the times of the shift-team changeovers on the ground. The fact that different team members could monitor various voice communications loops was a particularly helpful feature of the operations scenario.

Both the flexibility and the quick-response capability of the ground operations system allowed the operations team to react speedily to schedule changes and even to large-scale planning adaptations, including the decision process regarding the 45-day mission extension.

Public relations

A major consideration due to the long-term nature of the mission was the need to keep the awareness and interest of the general public alive throughout, and to be able to react quickly and effectively to enquiries, especially at times of increased media interest (e.g. EVAs, mission extension, onboard malfunctions, launch/landing, special occasions like Christmas, etc.). A series of public relations (PR) events were therefore planned throughout the mission, usually based on 40-minute video links with the Mir station (see Table 1).

ESA's Public Relations Division was charged with all PR-related aspects of the mission, starting with the generation of pre-mission PR material, defining (and negotiating with their Russian counterparts) PR-relevant activities, organising the various in-flight PR events, and ending with the support given to some of the major post-flight public engagements of ESA's astronaut after landing. The Headquarters staff were supported in these taks by the PR representatives of the European Astronaut Centre in Cologne (D) and of DLR at Oberpfaffenhofen (D). A member of the project's management team at ESTEC served exclusively as PR coordinator throughout the mission (incl. pre- and post-flight periods), matching the PR requirements and the needs of the media with the constraints and resources of the ongoing mission operations.

Figure 3. Yuri Gidzenko and Thomas Reiter preparing for a video documentation sequence

As a result of these efforts to achieve a well-planned and well-coordinated public-relations campaign throughout Euromir 95, manned spaceflight was portrayed very positively in nearly all of the related media coverage. The excellent video capabilities established with Russia for in-flight

Table 1. Key Euromir 95 events and PR activities

Event		Date	Remarks
Progress TK-228	Launch Docking	20 Jul 1995 23 Jul 1995	Upload of ESA equipment (348 kg)
Nomination of crew		11 Aug 1995	Prime: Gidzenko, Avdeev, Reiter Back-up: Manakov, Vinogradov, Fuglesang
Soyuz TM-22	Launch Docking	03 Sep 1995 05 Sep 1995	Start of Euromir 95 flight (with prime crew on board) Upload: 10 kg PR event at SCOPE during docking
PR event (public event)		07 Sep 1995	Chancellery Garden, Bonn (Minister Rüttgers)
Soyuz TM-21 (Dedocking & Landing)		09 Sep 1995	Return of previous Mir crew (Solovyev, Budarin) Download: 1.5 kg
PR event (public/media event)		16 Sep 1995	TV interviews — recorded Live link to medical congress at Nuremberg
PR event (public event)		07 Oct 1995	Disneyland Paris (live TV coverage)
Progress TK-229	Launch Docking	08 Oct 1995 10 Oct 1995	Upload of ESA equipment (104 kg)
PR event (public event)		18 Oct 1995	Recorded video session at SCOPE (Bavarian Prime Minister Stoiber, Minister Waigel)
PR event (public/media event)		19 Oct 1995	Ministerial Conference Toulouse
First EVA		20 Oct 1995	Duration: 5 hours 11 minutes
STS-74	Docking	15 Nov 1995	Preview of International Space Station (Russian, German, Canadian and American crew onboard Mir-Shuttle complex)
PR event (public/media event)		17 Nov 1995	United Nations VIP call (Secretary General) and multi-Agency media event (jointly by NASA, CSA, RKA, ESA)
STS-74	Dedocking	18 Nov 1995	ESA download (ca. 23 kg)
PR event (media event)		30 Nov 1995	'Art in Space' at Redu, Belgium ASI event in Turin, Italy
PR event (media event)		02 Dec 1995	TV interviews (recorded), live interview on German national TV (ZDF 'Sportschau')
PR event (public event)		18 Dec 1995	VIP call (Minister Rühe)
Progress TK-230	Launch Docking	18 Dec 1995 20 Dec 1995	Upload of ESA equipment incl. additional supplies for mission extension (63 kg)
PR event (media event)		23 Dec 1995	TV interviews — recorded
PR event (media event)		25 Jan 1996	Multi-point TV interviews — recorded (HQ, SROC, SCOPE)
PR event (public/media event)		05 Feb 1996	'Classroom in Space' (ESTEC), TV interviews — recorded
Second EVA		08 Feb 1996	Duration: 3 hours 9 minutes
PR event (media event)		09 Feb 1996	TV interviews — recorded
Public event		16 Feb 1996	VIP call (Ms. Yzer, Ministry of Research)
Onboard event		20 Feb 1996	'Mir station 10 years in orbit'
Soyuz TM-23	Launch Docking	21 Feb 1996 23 Feb 1996	Arrival of new Mir crew (Onufrienko, Usachev)
PR event (public events)		26 Feb 1996	'Farewell' (SCOPE) 'Hotline' (Deutsches Museum Bonn)
Soyuz TM-22 (Dedocking & Landing)		29 Feb 1996	Return of crew (Gidzenko, Avdeev, Reiter) Download: 8 kg End of Euromir 95 flight
STS-76	Launch Landing	22 Mar 1996 31 Mar 1996	Arrival of additional crew member (Lucid) ESA download (34 kg)
STS-79	Launch Landing	16 Sep 1996 26 Sep 1996	ESA download (24 kg)

Lessons learnt for International Space Station operation

From the project-management viewpoint, the following conclusions can be drawn from the Euromir experience which are of relevance for future Space Station operations:

- The six-month Euromir 95 mission was very representative of the operational cycle of the International Space Station (ISS), i.e. the six-month period for which an ESA astronaut would remain onboard the Space Station or a similar pre-defined period of unmanned payload operations.
- ESA's participation in the ISS operation would be best served by creating an integrated ESA operations organisation responsible for planning, preparation, implementation and post-increment activities (BDC, etc.). This organisation should be under one manager for all activities.
- At least two years are needed between project start, i.e. selection of baseline programme, and the beginning of mission implementation, e.g. astronaut launch.
- A multilateral agreement is required for each mission increment with ESA participation, in order to 'freeze' the most important parameters such as schedule, uploading, on-board resources and downloading.
- ESA's astronaut crew (prime and back-up per mission increment) should be nominated at the start of the project.
- The selection of ESA's prime astronaut should take place approximately four months before launch, based on inputs provided by the training authorities, the project management and the investigator working groups involved.
- ESA's project team should participate in key payload-selection (resource allocation, accommodation and technical aspects) and payload-development reviews, since the project has responsibility for overall accommodation, safety, hardware acceptance and hand-over to the launch/retrieval authorities.
- A PR plan must be agreed upon well in advance by all parties concerned and its implementation should be facilitated by defining clear responsibilities for the parties and ensuring a fast and effective consultation and feedback cycle between the parties (and, during the mission, with the onboard astronaut).
- During the astronaut's stay onboard – nominally six months at a time – ESA's key project members should be stationed at Europe's ISS Operations Centre to lead ESA-related activities, covering at least the following positions: Project/Mission Manager, Payload Operations Manager, CIC, Crew Surgeon, Head of Timeline/Replanning Group, Safety Officer, Discipline Coordinators, PR Coordinator, Secretariat.
- The Euromir 95 mode of operating from one primary centre (SCOPE) and 15 remote Payload Operations Centres distributed across Europe has proved to be a most successful approach to long-term manned missions. Due to resource limitations and factors such as crew health, systems-engineering activities, contingencies, and coordination with partners, it is vital that overall control, planning and coordination of payload activities be carried out from Europe's ISS Operations Centre in order to ensure efficient operation and utilisation of resources (crew time, power, etc.).
- A two-shift system is required for the ESA positions during the mission implementation phase in order to follow a typically 14 h working day. A reduced team will be needed at night if automated payload operations are continuing. It is recommended that individual payload automation be pursued for non-crew-tended experiments, which would then be controlled from the ground (like MIPS on Euromir 95).
- Compared to Spacelab missions, the long-duration manned-mission increments provide more opportunities for replanning, and therefore introduce a degree of flexibility unavailable with short-duration flights.
- The Euromir mission demonstrated that a limited amount of real-time data transmission is sufficient, with the physical return of mass data storage devices to the ground being the recommended solution.

transmissions and the enthusiastic participation of the astronauts/cosmonauts in the various PR events were key factors in this success.

Appraisal of scientific return
Almost without exception, the Euromir 95 programme was successfully implemented exactly as planned. The extension of the mission beyond the foreseen 135 days made it possible to conduct some of the scientific experiments more often than originally planned.

The data and film material accumulated from the 41 experiments conducted aboard Mir are now in the hands of the scientists on the ground, who are currently analysing them, together with the sample material that has been returned in the meantime.

In the life-science domain, for example, blood, saliva and urine samples were collected during the flight and stored in a frozen (conserved) condition awaiting a full on-ground analysis by the Principal Investigators concerned. These investigations, together with the post-flight BDC activities immediately after landing, are expected to provide unique results with important physiological implications for future long-duration space flights.

Since the conclusion of the flight, various briefing sessions involving both the scientists and the astronauts, as well as a plenary meeting of the Investigator Working Group, have taken place with a view to consolidating the results and formulating concrete conclusions.

One already evident and important result from this flight has been the remarkably quick recovery and re-adaptation to our normal gravity environment of every member of the crew.

The detailed results of the Euromir life-sciences investigations, as well as those of the material science, technology and astrophysics experiments, are being published in separate papers in the scientific literature.

In the light of the positive feedback already received from the scientific community, efforts are underway to continue research onboard the Mir station with ESA-provided experiments. A third Euromir flight might also be envisaged, given that the Russian Space Agency (RKA) and NASA have already reached agreement to continue use of the Mir Station well into the next decade. On the assumption that NASA will operate additional Space Shuttle flights to Mir beyond those currently planned up to 1998, strong pressure can be expected from the European science community for an additional flight opportunity on Mir.

Conclusion
The success of these record-setting space flights by European astronauts on the Russian Mir station can be summed up from several viewpoints:

- **Managerially**, ESA succeeded in keeping both projects exactly on schedule and well within the allocated budgets, despite a number of unique difficulties: the extremely short lead time, the particularly complicated and time-consuming payload-selection process, the management of the project by ESA without the benefit of representation by an industrial prime contractor in Western Europe, the unfamiliar interfaces with the Russian space transportation system, and the unusually complex language and documentation problems.
- **Scientifically**, this mission gave Western European scientists their first opportunity to perform biomedical investigations in space for prolonged periods of several months. Moreover, ESA gained new technical experience in preparing and operating experimental equipment for long-duration flights.
- **Technically**, the two Euromir flights gave ESA the opportunity to train its astronauts for the International Space Station, and to gain first-hand experience in the operation of a space-station system and in using the remote and decentralised payload operations concept planned for the ISS Columbus Orbiting Facility.
- **Politically**, the accomplishment of this first major project between the Russian and European space agencies has been a tangible demonstration of the active cooperation between Western Europe and Russia in the field of manned space flight.
- **Commercially**, ESA has gained valuable experience in the negotiation and implementation of contracts with Russian industry.
- **Publicly**, the many events in which politicians, school children and the press could communicate directly with the ESA astronaut and the Russian crew members stimulated public interest in manned spaceflight and created a favourable media attitude towards European participation in the International Space Station.

Euromir 95 Operations and Mission Planning

P. Granseuer
Operations and Ground Segment Division, ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

J.D. Schiemann
Space Station Utilisation Division, ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

M. Bridle
Booz-Allen & Hamilton, Amsterdam, The Netherlands

The Euromir 95 mission began with the launch on 3 September 1995 and a planned duration of 135 days. It was subsequently extended so that the landing eventually took place on 29 February 1996, flight day 180 of the mission log. It has been ESA's longest manned space mission and was conducted to gain experience of long-duration space flight, working with the Russian space programme, and as a precursor for the Columbus/International Space Station operational concepts.

The mission operations

The Euromir 95 crew consisted of the Russian cosmonauts Commander Yuri Gidzenko and Engineer Sergei Avdeev, and ESA Astronaut Thomas Reiter. Thomas Reiter had been trained to undertake onboard engineering tasks, experiment operations and Extra-Vehicular Activity (EVA). The payload that they were to operate consisted of more than 500 kg of equipment which was uploaded with the Spektr module in May 1995, two Progress flights in July and October 1995, and the Soyuz capsule. This equipment supported a scientific programme consisting of 41 experiments in the life sciences, materials science, technology and space-science disciplines. Following the extension of the mission, a third Progress upload in December 1995 was negotiated to include additional equipment required to support the extension of the science programme.

The payload download of 50 kg utilised the Space Shuttle missions STS-74 in November 1995, STS-76 in March 1996, STS-79 in September 1996 and the Soyuz capsule used for the crew's return in February 1996.

The operational infrastructure included a Payload Operations Control Centre team at the German Space Operations Centre (GSOC) in Oberpfaffenhoffen, a small team providing the interface to the Mir Flight Control Centre (TsUP = Tsentr Upravleniya Polyotami) staff in Kaliningrad, User Support Operation Centres (USOC) in six countries providing facility support personnel and facilities for Principal Investigator (PI) support, and User Home Base (UHB) capabilities at PI laboratories or work places throughout Europe. Euromir 95 was the first mission for which such a highly decentralised operational approach had been used for PI, facility and engineering support.

The payload operations were completed successfully with almost all experiments logging more operations time and data than originally planned, thanks mainly to the mission extension. The schedules for experiment operations were usually maintained, with some replanning due to experiment and system troubleshooting and repairs. Some maintenance was required during the mission, including the uploading of spare parts with the Progress flights in October and December in order to repair failed units.

The mission was highly representative of future Space Station operations as it included cooperative joint operations with Russian entities and NASA, long-duration operations (initially 4.5 months extended during the mission to 6 months), uploads of equipment on several Progress flights, and downloads using both Soyuz and Space Shuttle flights. The mission also included two EVAs – the first by

Figure 1. The approach of the Space Shuttle 'Atlantis' viewed from Mir

an ESA astronaut – by Thomas Reiter, the second of which was added after the mission extension announced in October 1995.

Mir's operational capabilities and constraints

The main characteristics of Mir and its operational infrastructure that affect payload operations are the communications systems, power availability and command and data system limitations.

The communications coverage is mainly provided by ground stations within the former USSR, which implies eight to ten passes per day of between 8 and 25 min duration depending on the ground track. The timing of these passes varied throughout the mission, sometimes restricting the communication periods available to the crew, who operate on a fixed shift basis. The Russian LUCH data-relay satellites are therefore typically used once or twice per day to cover periods of limited ground-station coverage or special events.

Euromir space-to-ground access was primarily used for station operations, payload activities, private medical conferences as required, family contacts typically once per week, audio and video conferences, and public-relations (PR) events approximately once per month. There was minimal voice communications in support of payload operations at times of limited ground passes during the crew working day, when additional crew were onboard Mir, as during the handover periods or the STS-74 Shuttle docking, or when critical operations were taking place such as EVAs or system troubleshooting. Video of sufficient quality for PR events or science evaluation depends on use of LUCH, and was therefore also limited. One science video downlink was scheduled each week so that science- or engineering-related video recorded on board could be downlinked during these sessions.

Power availability for payloads did not have a significant impact on mission planning except for the TITUS furnace, operation of which had to be rescheduled due to limitations originating from other systems, such as the ability of the station's thermal-control system to remove dissipated heat. TITUS was therefore operated overnight when there was adequate power available, at which time the microgravity environment was also optimum in that the crew was sleeping and no other major operations were in progress.

During the mission there was no real-time science data downlink and most payloads were designed to store their own data for scheduled downlinking during nominally four of the 10 min ground-station passes each day. Data downlinking was via a direct telemetry interface for two experiments, TITUS using its own computer interface, and for other experiments using the NASA MIPS-2 system. No direct payload command uplink was used during the mission from GSOC or the user centres. Commands for the European Science Exposure Facility (ESEF) were sent from TsUP by the Russian ground controllers, and the video control experiment, VISC, was controlled from TsUP over a modem link.

Euromir 95 operational infrastructure and teams

A distributed infrastructure was implemented to support payload operations from Western Europe and experiment teams from national User Support Operations Centres or User Home Bases. Financial and schedule constraints meant that this system was implemented mainly using existing control centres and communications systems, a matter of months before the mission.

SCOPE operations

The main Payload Operations Control Centre, the System for the Control of the Operations of Payloads for Euromir (SCOPE) was located at GSOC in Oberpfaffenhofen (D) and based on an existing facility used previously for the Spacelab-D2 mission and other national

satellite projects. The SCOPE team's responsibilities included payload operations management and coordination with TsUP, ESTEC, the European Astronauts Centre (EAC) and the USOCs, real-time operations coordination of nominal and contingency payload operations, scientific and technology experiment activity coordination, mission-planning activities for all planning stages, flight-data-file support activities, data management for onboard data downlink requests and ground distribution, communications management and coordination and medical coordination.

The key operations personnel located at SCOPE were the Euromir Payload Operations Manager, Planner, Data and Facility Coordinator, Communications Coordinator, Medical Coordinator, Life Science Discipline Coordinator, and a Translator.

TsUP operations
The Russian Mir Operations Control Centre (TsUP) was responsible for overall activity on the station. A small ESA EuroMir Mission Operations Support Team (MOST) was based at TsUP for direct interfacing with the Russian control teams. They included a MOST Coordinator as the prime interface with the TsUP Shift Flight Director and operational staff, a Crew Interface Coordinator, a Crew Surgeon interfacing with the Russian medical team, and an EAC Representative providing support both to the ESA Astronaut and his family.

ESTEC operations
The Euromir Project Manager used ESTEC as his main location during the mission, travelling to TsUP or SCOPE for specific events such as launch and docking, EVAs and landing. The ESA Facility Interface Engineers were mainly located at ESTEC, and the Science Discipline Coordinators were available at ESTEC when not located at SCOPE. The two Quality Assurance and Safety Engineers were based at their normal work locations, one at ESTEC the other at MUSC. ESTEC was also used as an operations centre for the ESA Technology Experiments, with specific Principal Investigators being available there when required.

EAC operations
The European Astronauts Centre personnel involved in the Euromir project all provided support from their home base in Cologne. This included astronaut support, astronaut family support, and advice on astronautics-related issues. Support for the onboard laptop computer was also provided from EAC.

ESOC operations
ESOC in Darmstadt (D) was responsible for the development and subsequent operational support of the Interconnecting Ground Subnetwork (IGS) system. During the mission, ESOC personnel manned the IGS control position and were responsible for trouble-shooting and maintenance for the IGS and DICE-based communications systems. The PR events organised during the mission at various sites throughout Europe relied on a varity of communications systems depending on the available infrastructure, including portable DICE equipment and Codec/ISDN links.

USOC operations
For the mission itself, all Principal Investigator teams operated remotely from the SCOPE, except those from the local Munich area. Facility Responsible Centres (FRCs) were located throughout Europe, at the following sites:
- ALTEC, Turin (I), for the Italian Technology Experiments
- CADMOS, Toulouse (F), for the BDM facility and ESEF
- DAMEC, Copenhagen (DK), for the RMS-II facility and 01-DK life-science experiment
- ESTEC, Noordwijk (NL), for the ESA Technology Experiments
- MUSC, Cologne (D) for TITUS and experiments 15-D and 18-D.

Together with the ESA experiment engineers located at ESTEC, they coordinated the operations of the facility and provided the interface to the Principal Investigators (PIs). They were also responsible for routing data to the PI User Home Bases, after receipt from SCOPE. The support at each centre varied depending on the particular facility and the involvement of centre personnel in the facility's development and operations planning.

SROC in Brussels operated as an Experiment Support Centre (ESC) for the Belgian experimenters. It acted as a node for communications with the PI's university laboratories, to which connections were made using ISDN lines. These PIs then interfaced directly with the FRCs responsible for the facility which they were using.

For national PI experiment support, in countries not supported by an FRC or ESC, direct links to the appropriate FRC or SCOPE utilised general services such that the PIs could operate from their User Home Bases (UHB) as Internet/telephone sites. The Internet was used for both experiment and operational data services, while telephone access was provided to the Voice Intercom System (VIS) at SCOPE. One UHB used a DICE ground terminal to receive video downlinks. The UHBs were at Geneva, Villingen and Zurich in Switzerland, Bristol, Canterbury and London in England, Stockholm in Sweden, Maastricht in The Netherlands, and Berlin and Munich in Germany.

Standard daily operations

With a distributed operations scenario of the type implemented for Euromir 95, it was crucial that all personnel were aware of the operational events in which they should participate, based on a standard daily operations schedule.

The schedule included shift start and stop times, voice conferences to review real-time status, any instructions to the crew, or reactions to reports from them, briefings with the Crew Interface Coordinator (CIC), space-to-ground contacts, planning product generation, planning conferences, briefings with the project manager, shift handovers, and the generation of daily reports.

The ground operations plan was generated several days in advance, so that all personnel could review it on a regular basis. It included indications of when specific remote sites needed to be active in order to support ongoing operations. Certain events were kept at standard times, especially planning conferences as the maximum number of personnel were required to participate in them.

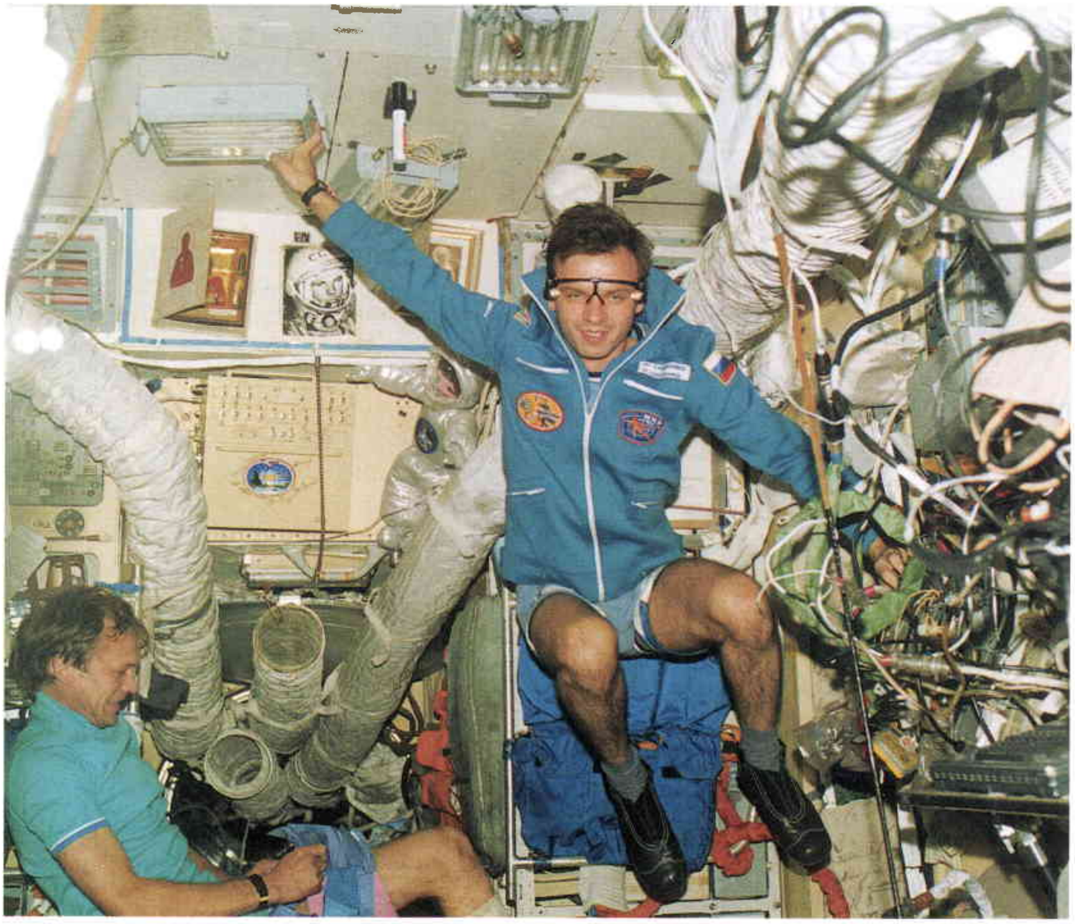


Figure 2. Cosmonauts Gidzenko (right) and Avdeev at work during Euromir 95

Prior to the mission, it was decided to have minimal manning at the weekends, with most staff only being on call. This did not always prove feasible, however, and extensive experiment operations were sometimes needed at those times, particularly at the beginning and end of the mission, and to recover time-critical life-science operations after troubleshooting or other activities had adversely affected the nominal plan. Weekend contact sessions were also often needed for PR events or to catch up on information to be transmitted to the crew, to have longer more general conversations with the ground teams beyond the purely technical discussions, and to support family contacts from Moscow and Germany.

Mission planning

An ESA astronaut working day of 8.5 h Monday to Friday, with weekends regarded as personal time, was used as the baseline for the pre-mission planning. This included 4.5 h for Euromir payload activities, 2 h of physical exercise, and 2 h for onboard engineering tasks. Particularly at the start of the mission, some time during the weekends was used for payload operations, and also later in the mission to catch up on experiment time lost due to maintenance activities. Towards the end of the mission, additional medical countermeasures and exercises were required, which reduced the time available for experiment operations. Despite these glitches in planning, all of the foreseen experiment objectives were achieved.

Other events that impacted on experiment operation time included the EVAs, which required a week of preparatory activity to check out the equipment, perform medical checks and take extra rest prior to these strenuous periods. The Progress, Soyuz and STS-74 dockings also ate into the time available for experiment operation.

Overall, however, the 42.5 h work week proved about right for a long-duration flight of this nature and should be used as the baseline for ESA's Space Station planning.

The mission planning cycle used by the Russians used the pre-mission plan as the baseline. From that, a Monthly Station Plan was derived and agreed with the Russian side. The next step included the bi-weekly generation of a Two-Week Plan and a Detailed Daily Plan four days in advance, which was uplinked to the crew on the day prior to its implementation.

There is a limited uplink capability to Mir for planning and procedure data, and therefore any short-lead-time/real-time information was transferred verbally during space-to-ground voice passes. After the Euromir 95 launch it was discovered that the Russians had a new modem link available for computer file transfers. This was subsequently used extensively for technical information, personal messages, PR and project information and proved very effective, particularly as these communications could be in English.

Despite some shortcomings in terms of planning documentation and a lack of flexibility to accommodate late changes, the Russian planning approach could certainly serve as a basis for the future planning activities associated with the International Space Station. It proved adequate in terms of the timing and quality of the resulting planning products for Euromir – the increment plan, one-month plan, two-week plans and detailed plans four days in advance – also ensuring that the many remotely located staff and PIs were available when needed, and the appropriate communications systems scheduled, for timely operations. The efficiency of the process can be further improved by having all planning constraint information available to the planning team and by applying the latest state-of-the-art planning tools. Moreover, extensive iteration loops with discipline experts and PIs need to be avoided in the day-to-day planning work.

The daily planning conference proved satisfactory for the Euromir mission needs. For the International Space Station a more relaxed scheme not requiring everyone to gather every day, but still retaining a regular scheme, is recommended. The geographically distributed staff not actively involved on a particular day can still follow the mission on a regular basis and plan their work days appropriately.

In Euromir's case, the planning conference was also used to convey general mission information as the maximum number of key personnel were monitoring proceedings at this time. Video conferencing was not used routinely, but this capability should certainly be available in future for special needs.

Crew information interface

It is important for long-duration missions to provide adequate communication links to the crew not only for the traditional things such as system- and experiment-related items, medical information and family contacts, but also more extensive personal mail, contacts with the extended family and friends, and confidential interfaces with the project management team. For Euromir, we were limited for these

Figure 3. A view of the Mir Space Station from the docked Space Shuttle 'Atlantis'

communications to voice contacts on space-to-ground channels and a packet link for computer files. None of these systems were truly confidential and computer files often contained a mixture of information types.

For future missions, implementation of the following systems and procedures is recommended:

(a) Clear responsibilities should be defined for the provision, review, uplinking and distribution of information provided to and received from the astronauts during long-duration flights, based on the nature of the information involved.

(b) The ground and flight data systems used for the transmission of the information should be designed to afford write/edit access only to agreed personnel responsible for processing that particular data, and read-only access to an agreed distribution list. The system should also archive the information uplinked and downlinked for later review on the same basis.

(c) Confidential or scrambled voice channels should be available not only from the Main Control Centre, but also from remote centres and for dial-in capabilities to facilitate family, medical and management contacts.

Ground-operations aspects

The fact that the constant availability of support personnel cannot be ensured for long-duration missions means that the systems and procedures need to be designed to compensate for this eventuality. Adequate expertise and documentation must be maintained at the Control Centre (usually through the auspices of the Science Discipline Coordinators and Planners) to still allow quick and reliable responses when remote staff cannot be contacted.

The operations profiles of certain of the Euromir experiments and staffing shift arrangements meant that some personnel were away from their stations for extended periods. Summaries of operational impacts, changes, planning, problems, unexpected events, status on problem resolution, etc. therefore need to be provided methodically via the Operations Data System so that personnel who are not directly involved in the mission every day can access such information wherever they wish.

Finally, the Control Centre for future long-duration missions can be a more open-office-like environment with low separators, plenty of windows and good lighting, etc. as the staff will be expected to work standard 8 h+ days in this environment for long periods. The needs will therefore be quite different to those for short-duration missions such as the Shuttle flights, for which the traditional large open control-room setup is sufficient.

Working Aboard the Mir Space Station

T. Reiter
ESA Astronaut, European Astronauts Centre (EAC), ESA Directorate of Manned Spaceflight and Microgravity, Cologne, Germany

For more than ten years, the Mir station has been the World's only permanently manned laboratory in low earth orbit. With an orbital inclination of 51.6°, its ground track covers more than 85% of the Earth's surface, where approximately 95% of the population lives.

For the transfer of up to three crew members per trip to and from Mir, the 6.9 t Soyuz spacecraft is used. In general, the station's crew is changed every six months, with an overlap during the exchange of between one and two weeks. A Progress spacecraft (an unmanned derivative of the Soyuz vehicle) visits the station every three months to resupply it, with up to 2.1 t of payload, and to reboost it to maintain its nominal orbital altitude.

The station's core module, injected into orbit in February 1986, contains the central control post for most onboard systems, the computer for attitude control, and the telemetry and communications system. It also contains the station's largest work space, which is 7.0 m long and varies in width between 1.5 and 2.5 m.

The station elements

The layout of the station during the Euromir 95 mission is shown in Figures 1 and 2. The Kvant module, which contains many astrophysical sensors and experiments, has been attached to the station (along the +X-axis) since April 1987. Three more modules have been docked to the central node of the station since then:

- Kvant-2 in December 1989 (along the +Y-axis), containing systems for earth-observation and the airlock for EVA operations
- Kristall in June 1990 (along the −Z-axis), containing furnaces for materials-science experiments and astrophysical sensors, and
- Spektr in June 1995 (along the −Y-axis), containing cameras and systems for earth-observation.

During Space Shuttle flight STS-74 in November 1995, an Interface Module was permanently attached to Kristall's APDS-port (Androgynous Peripheral Docking System) to facilitate future Shuttle dockings. In March 1996, the station achieved its final configuration when the fifth module, Priroda, was attached along the +Z-axis. Two docking ports on the central node (−X) and the Kvant module (+X) are available for the Soyuz and Progress spacecraft. There are two more APDS-ports on the rear end of Kristall and on the Interface Module.

With Priroda's arrival, the total mass of the Mir complex reached 120 t and it now contains a hermetic volume of approximately 350 m^3. A maximum of 35 kW of electrical power is provided by the station's solar arrays and the power supply to all modules is based on a 27 V direct-current bus.

The station's attitude is generally controlled with the help of 12 gyrodynes, located on the Kvant and Kvant-2 modules. Its reaction-control system is activated only briefly when the gyrodynes need to be desaturated.

Mir's Environmental Control and Life-Support Systems (ECLSS)

The station has five generic ECLS systems on board:

- oxygen-production and air-filtering systems
- an air-conditioning system
- a ventilation system
- water-regeneration systems
- a thermal-control system.

Oxygen is produced by two electrolysis units – one in Kvant and one in Kvant-2 – which use water distilled from the urine-collection system. Nominally, these units are operated sequentially. A contingency system, also located in Kvant, uses pyrotechnic cartridges for oxygen production.

For the removal of carbon-dioxide and other detrimental pollutants from the station's atmosphere, a total of four systems are available. The two main units, located in Kvant, employ regenerative filters, which are periodically connected to vacuum venting lines. For contingency operations, there are two more systems in the core module which use LiOH catridges for carbon-dioxide filtering and

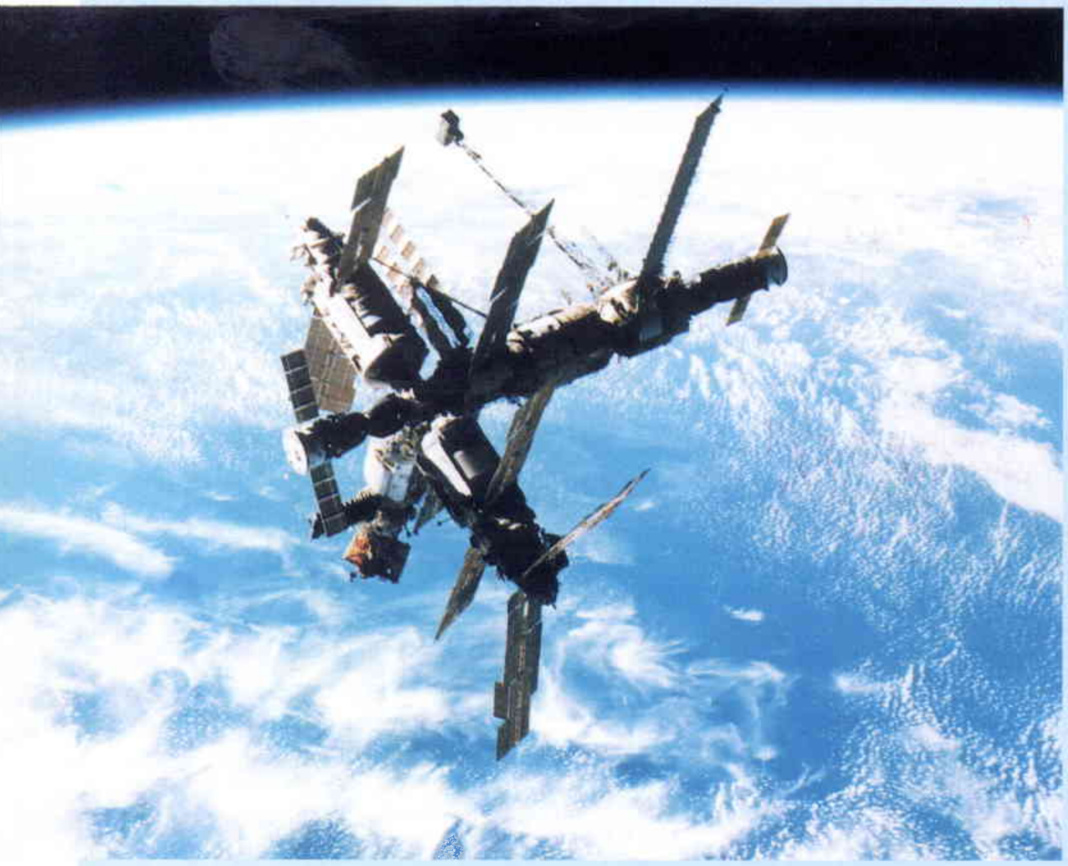
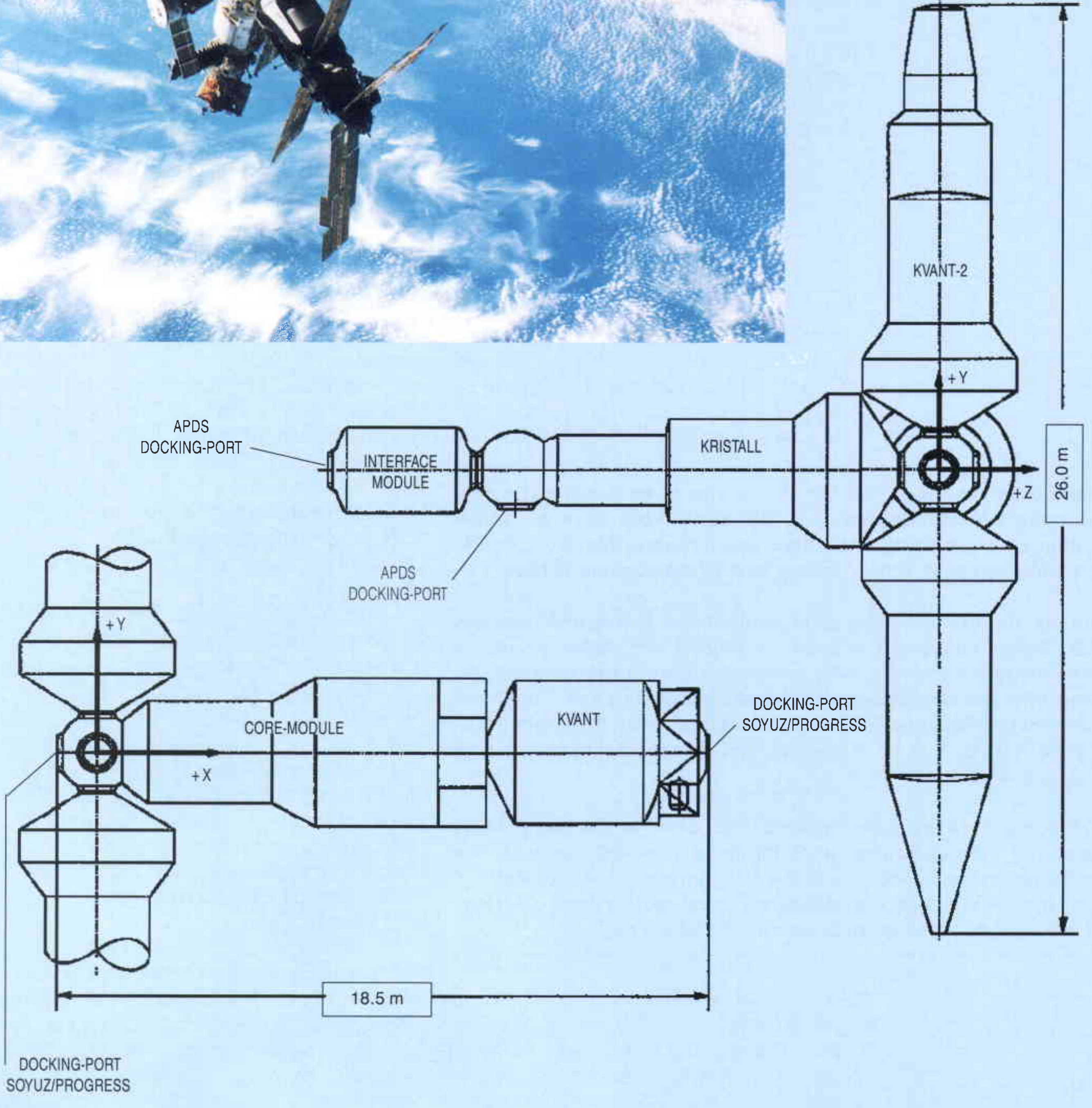


Figure 1. The Mir station, photographed from the Space Shuttle

Figure 2. Schematic of Mir's configuration at the time of the Euromir 95 mission



cartridges containing other materials for the pollutants.

There are two air conditioners in the core module, one connected directly to one of the module's cooling loops and one using a conventional freon loop for efficient cooling and dehumidifying. If necessary, moisture removal from the station's atmosphere can be supported by the air conditioner in the Soyuz capsule.

To ensure a standard flow pattern within each module and air exchange between all modules, numerous ventilators are used (approx. 30 in the core module and 20 in the other modules). In the nominal flow pattern, air is routed from the region beside the front hatch through the free working space. Via lattices in the rear part of the modules, it enters the area behind the panels and moves in the opposite direction towards the front again, passing through air-liquid heat exchangers and dust filters.

Air exchange between the various modules takes place via flexible ventilation ducts (Fig. 3), driven by ventilators, installed at 5 to 7 m intervals.

There is a unit for regenerating distilled water from the urine collection system installed in the Kvant-2 module. As already mentioned above, this water is used for oxygen generation in the two electrolysis units. Another system installed in the core module regenerates drinking water from the condensate produced by the air conditioners. In this unit, the condensate is filtered, sterilized and re-mineralized, mainly for food preparation purposes.

Every module of the Mir station is equipped with its own thermal-control system. In general, internal thermal-control loops are used to maintain the temperatures of the station's atmosphere, internal structure and onboard systems within a given range. Excessive heat is initially transferred to external thermal-control loops via heat exchangers and then radiated into space.

In contrast to the Kvant module, which contains only one internal and one external circuit, all other modules are equipped with redundant internal and external thermal-control loops. The core module even contains two types of redundant internal circuits, namely two low- and two medium-temperature loops.

The Kristall module has a separate loop cooling the furnaces, while in Kvant-2 another separate loop removes heat from the electrolysis unit.

Discrete temperatures for the cooling fluid in the external thermal-control loops can be selected by the crew or by ground control. The selected temperature is then maintained by an electronic unit, regulating the flow of cooling fluid through the radiators. In this way, a constant temperature difference is maintained between the internal and external circuits in the heat exchangers. The radiators either contain coils of the cooling loop or a single cooling line to which heat pipes are connected.

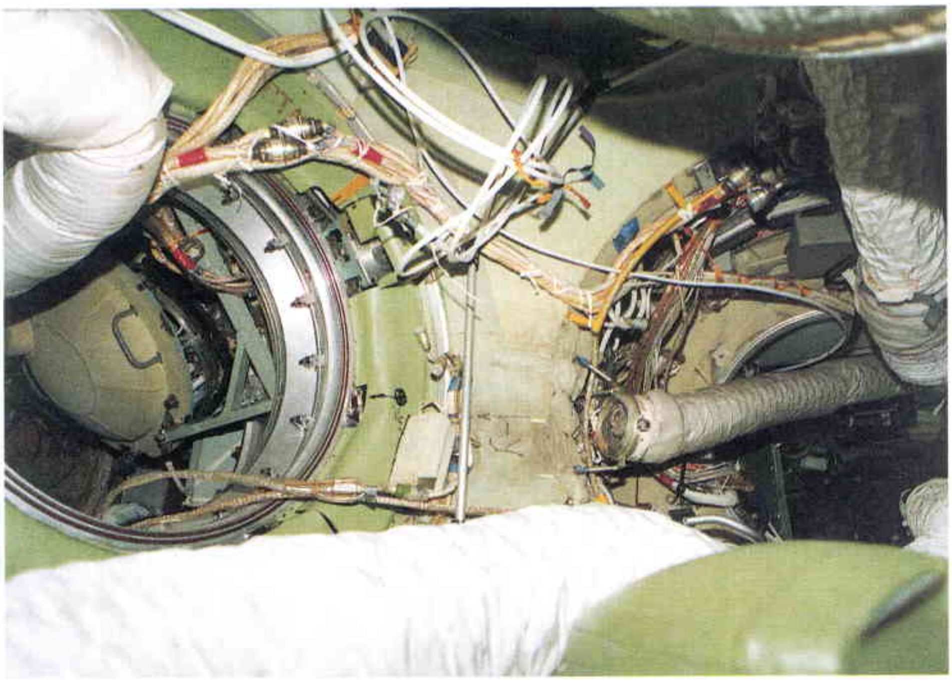


Figure 3. Some of Mir's flexible ventilation ducting

Operating routines

The daily work routine onboard a space station is mainly determined by four factors:

- available resources (such as hardware, consumables, energy, crew time, etc.)
- functionality of onboard systems and experiment equipment
- skills of the various crew members, and
- available ground support.

Daily schedule and crew time

In contrast to short-term missions, where the crew usually works in shifts, where the daily networking time is comparatively high and where experiments are run to a very tight schedule, long-term missions require more balanced planning in order to maintain good crew performance. Consequently, the daily work aboard Mir is planned in a very similar way to that in a 'normal' working environment on the ground.

During nominal operation, a Mir working day consists of 6.5 nett working hours (experimental work and/or system maintenance). In addition, 2 h per day are planned for physical fitness activities to counteract the effects of long-term weightlessness on the human body. One hour each evening is foreseen for debriefing sessions with the ground staff and preparations for the next day's activities.

This schedule is maintained for the 5 working days each week. At weekends, the work schedule is slightly reduced, to 3 – 5 h, including normal 'housekeeping tasks', but the 2 h of physical-fitness training is maintained.

Given that the two main objectives of the Euromir 95 mission were execution of the scientific programme and the acquisition of operational experience in conducting normal maintenance and repair work onboard Mir, approximately 70% of the total working time was allocated to the experiment programme, and the remainder to the onboard engineering tasks.

Experiment hardware and data handling
As there were no spare payload racks available, all of the Euromir 95 experiment equipment had to be self-contained, apart from being connected to the station's power supply. Only in two cases was equipment connected directly to Mir's telemetry system (the TITUS materials-science furnace and an active astrophysical sensor on the ESEF platform).

Experiment control, as well as acquisition and storage of experiment data, was performed either by subsystems within the equipment or via a laptop computer connected to the hardware. The experiment hardware was not equipped with special diagnosis electronics, nor was the laptop configured to perform a detailed failure analysis in the event of a subsystem malfunction. Many of the experiment systems were equipped, however, with electrical connectors 'for ground test only'.

In most cases, experiment data were stored doubly-redundantly on different data carriers: primary data were either collected on the laptop's hard disk, on PCMCIA memory cards or on PCMCIA hard disks. Data compression and backup was performed automatically on PCMCIA hard disks and manually onto a magneto-optical disk via the NASA-MIPS2 (Mir Interface Payload System) controller. Data recorded manually on questionnaires or in tables were also typed into the laptop (.txt files) and backed-up electronically as described above.

Communication and telemetry
Voice communication with the Russian Flight Control Centre (TsUP) was established via three duplex channels: two UHF channels for a direct link via different ground stations and one channel via a geostationary satellite. All three channels used fixed frequencies. The ground stations were mainly located on Russian territory. On a few occasions, however, a UHF link with the TsUP was established via an American and a German ground station. Communication times ranged from 5 min to a maximum of 20 min for the direct (UHF) links, depending on orbit orientation, and up to 40 min for the satellite link. The UHF-2 channel was available to the Euromir team only occasionally and over discrete ground stations.

In parallel with the UHF voice link, the daily schedule and procedures were uplinked via modem and printed with a teletype. This operation neither interrupted nor restricted normal voice communications on that channel. Packet file transfer to and from the station was also effected via one of the three voice channels, but no voice communication was possible on that channel while a transfer was in progress.

A video link (SECAM, down, up or up/down) was nominally arranged via a geostationary satellite, with duplex voice link at the same time. Black-and-white video could also be downlinked using one of the UHF channels.

Scientific data could only be downloaded offline via the NASA MIPS2 controller, connected to the Mir telemetry system. The controller was set up for data transfer using the crew's laptop. There was no online data downlink available whilst experiments were in progress during the Euromir 95 mission.

Onboard system maintenance
As several of the station's modules have already spent a long time in orbit, planned and unplanned maintenance and repair activities absorb a considerable amount of crew time. Spare parts for all of the different ECLS systems and the electrical power-supply system were always available, with depleted stocks re-supplied via the Progress spacecraft visits.

As only a limited number of system parameters were displayed to the crew, a thorough assessment of system performance could only be made at the TsUP, where the complete telemetry data set was available. All maintenance and repair activities were therefore performed in close consultation with the respective system specialists at the TsUP.

Problems encountered during experiment operations

The combination of the specific working environment onboard the station and the designs of some of the Euromir 95 scientific equipment caused difficulties with the execution of some experiments. As a consequence, the allocated experiment time was exceeded and, in a few cases, the quantity and quality of the scientific data was degraded.

However, due to the extended mission duration and the fact that some of the time allocated for onboard engineering tasks could sometimes be used as a buffer for experiment operations, the additional unscheduled experiment time needed could be easily accommodated.

In general, three major problem areas, related to the allocation of space for equipment installation, the design of certain experiment equipment, and the technical means for communication, were identified during the Euromir 95 mission.

Allocation of space

Space for the installation and stowage of equipment proved to be one of the most critical resources aboard Mir. In a few cases, the locations foreseen for the installation of particular equipment items during the Euromir 95 flight were not available in practice, because other equipment had already been stowed there. Alternative locations therefore had to be identified and prepared on an ad-hoc basis.

One biomechanical experiment required a large working volume with an unrestricted field of view. The only area in the Mir station that came close to fulfilling these requirements was the core module. However, as the requirements were difficult to satisfy even there, excessive time was needed both for the equipment's installation and calibration and for experiment execution.

Experiment hardware design

As already mentioned, the Euromir 95 experiment equipment had to be largely self-contained. Generally speaking, it was assembled at the beginning of the mission, provisionally stowed and then installed in a suitable 'working-position' each time an experiment run had to be performed. With a few exceptions, the manufacturers had not provided their systems with adequate means for easy handling (loops, eyes etc.), nor were there sufficient aids for fixing the equipment in its storage/working location (rubber bands, belts, etc.). It turned out that adhesive velcro patches could rarely be used, especially if the equipment was larger than about 30x30x30 cm^3. Time was therefore lost in making improvised installations.

Figure 4. ESA Astronaut Thomas Reiter executing one of the many life-science experiments

The experiment hardware was operated for extended periods during this long-duration mission and consequently the probability of subsystem malfunctions increased with time. Of the total of 25 different experiment systems, 13 malfunctioned or behaved anomalously in the course of the flight. Five malfunctions were recovered exclusively with onboard means and ground support, four were resolved by uploading new equipment with Progress, and four could not be fixed at all as neither the means for an in-depth failure analysis nor appropriate tools were available. The technical documentation provided for the maintenance and repair of experiment equipment was often inadequate. In most cases the off-nominal procedures provided in the flight data file were insufficient to recover system malfunctions.

Communications and telemetry
Communication and telemetry turned out to be a bottleneck during the mission. In general, only the UHF-1 channel was used and the available communication time had to be shared between the crew members. Parallel use of the UHF-2 channel had to be requested separately by the Euromir 95 project team. At times when the station did not pass directly over Russian territory during daytime, only two or three communications sessions were available early in the morning or late in the evening, and total communication time was limited to a few minutes. Exceptionally, a voice/video link via the geostationary satellite could be organised during these periods.

The transmission of data for the setting-up of experiment equipment via the teletype system was not always reliable. Because transmission errors appeared as wrong alphanumeric characters on the printout, this data always had to be confirmed using the voice channel.

The file transfers from the ground to the station via one of the voice channels (usually UHF-1) and the packet controller system were reliable most of the time due to the inherent transmission error detection and correction. In the course of the mission, however, there were a few periods, of up to 7 days, when no up/down file transfers were possible at all.

The possibility to download scientific data files from the MIPS-2 controller via the Mir telemetry system was very helpful throughout the mission, even though the transmission rate was very low (in the order of a few kbit/s). However, the transfer of files larger than a few kilobytes appeared to be very prone to transmission errors. On some occasions, files had to be put into the telemetry queue up to five times before the information was correctly received on the ground, a process that could take up to two weeks.

Onboard engineering tasks
During the Euromir 95 mission, as the European astronaut I was nevertheless involved in a variety of generic onboard engineering tasks, including routine maintenance work on the thermal-control system, on life-support systems and on the preparation and conservation of all EVA equipment (space suits and onboard systems). Because not all onboard system parameters are displayed to the crew, the effects of certain steps during maintenance and repair activities had to be confirmed by the specialists in TsUP before the crew could continue their work.

A few non-nominal situations were encountered in the course of the Euromir mission, including a leak in the Kvant module's internal cooling loop, which required unplanned maintenance and repair work. These occurrences allowed experience to be acquired in the fields of overall system structure and functionality, system maintainability, man/machine interfaces and the decision-making process especially during non-nominal situations.

Conclusions
The scientific programme foreseen for the Euromir 95 mission was successfully completed during the 179-day flight. The flight extension beyond the originally planned 135 days, combined with the possibility to upload additional experiment hardware, spare parts and consumables with a Progress spacecraft, provided the scientific community with additional experiment time and allowed the Euromir 95 project team to gain additional operational experience.

Despite minor deficiencies in terms of stowage/working space, the bottlenecks in communications and data up/download capacity and the extra crew time required to maintain the onboard systems, the Mir station is without doubt a very good platform for conducting research in all of the different scientific disciplines. It is also an excellent environment in which to validate the experiment hardware and operational concepts for the forthcoming International Space Station Programme.

For future missions, however, the prevailing conditions onboard the station have to be taken into account more fully during the development of stand-alone experiment equipment. Given the increased risk of system malfunctions and non-nominal system performance during long-duration missions, the maintenance concept for scientific hardware needs to be improved to allow the crew to perform thorough failure analyses and repairs for even complex electronic systems.

Commercially available laptop computers and software were used extensively and very successfully by the crew for experiment control, data acquisition and storage during Euromir 95. Further developments in this direction, including the improvement of electronic procedures and certain onboard management tools, the provision of detailed technical reference documentation, computer-based (in-orbit) training, and the application of voice control, are therefore highly desirable in order to boost overall mission effectiveness in the future.

Early Results from the Euromir 95 Experiment Programme

T. Stevenson
Mare Crisium, Freshwater, Isle of Wight, UK

J. Ströde & C. Viberti
Microgravity and Space Station Utilisation Department,
ESA Directorate of Manned Spaceflight and Microgravity,
ESTEC, Noordwijk, The Netherlands

A total of 41 experiments were conducted in the context of the Euromir 95 mission, in the categories of life sciences, materials science, astrophysics and technology (Table 1). First results were presented recently at a post-flight Investigator Working Group Meeting at the European Astronauts Centre in Cologne, Germany. This article summarises all but those of the life-sciences experiments, which will be published separately at a later date.

The materials-science experiments

Eight materials-science experiments were developed for the Euromir 95 mission. They included investigations into directional solidification, crystal-growth, and undercooling effects in the TITUS furnace. The experiment sample containers (two or three cartridge assemblies per experiment) and the TITUS multi-user facility were developed in parallel and launched with the Russian supply vehicle 'Progress' in October 1995.

After successful installation and testing of the facility, the Euromir crew assisted the automatic sample processing in various respects. In particular, some essential and successful trouble-shooting once again proved the advantages of conducting such experiments in a manned spaceflight environment.

The extended duration of the Euromir 95 mission and the available upload capacities during it contributed to the successful repair of the Russian CSK-1 furnace. This furnace had completely failed during the Euromir 94 mission and the sample containers of the four ESA materials-science experiments for CSK-1 had been retained aboard Mir. During the Euromir 95 mission extension, all of these samples could finally be processed in CSK-1.

All of the experiment runs took advantage of the single-shift-working scheme operated on board Mir. By starting the runs shortly before the end of the crew's working day, the samples reached critical temperatures only once the crew was asleep. Consequently, sample processing mainly took place in a very calm environment (a few hundred μg's as measured by TITUS's built-in accelerometers). Processing was accomplished at temperatures of up to 950 and 1200°C for CSK-1 and TITUS, respectively, and the two furnaces were operated for more than 450 h during the mission.

The Euromir 95 mid-mission equipment download (Space Shuttle flight STS-74) allowed the early return of some processed TITUS samples (first runs of three experiments). Together with the available telemetry data from TITUS, their preliminary analysis supplied

Figure 1. The TITUS facility (mounted on the floor) and the CSK-1 furnace (the tube on the right) aboard Mir. The portable Crew Interface Computer used to control TITUS, to store all flight data, and to provide a link to Mir's telemetry system can be seen attached to the left-hand wall

information with which to improve the temperature profiles of remaining experiment runs. All of these favourable circumstances made Euromir 95 a unique opportunity for materials-science research.

Due to a TITUS failure that is not yet fully understood, runs near this furnace's maximum operating temperature were aborted. Fortunately, however, only one experiment's runs could not be completed because of this anomaly.

The evaluation of the experiment results is not yet complete, with ground-reference runs still to be conducted in some cases. Nevertheless, the initial analysis of flight samples and flight data has already demonstrated the in-orbit success of the experiments and facilities. Moreover, some experimenters have already reported novel and promising scientific results during the post-mission IWG meeting.

The astrophysics experiments

ESEF, the European Science Exposure Facility, is a multi-user, multi-purpose platform mounted on the exterior structure of the 'Spektr' module. Though originally intended for the later 'Priroda' module, it became clear in late 1994 that this would not be launched before the Euromir 95 mission, and the servicing could not then be carried out by the ESA crew member.

The ESEF's design is based on a prototype which was flown aboard Salyut-7. The intention, following that successful flight, was to have the facility mounted permanently on Mir at the earliest opportunity, and to conduct a continuing programme of experiments starting in 1986. Due to upheavals in the relationships between Western and Russian agencies at that time, KMP3 (as it was then known) was not flown. The developer, the Institut d'Astrophysique Spatiale at Orsay (F), then stored the flight and technological hardware, but some other development items, including the Hydrolaboratory Model, used for training, were 'lost' in Moscow.

In February 1994, a group of investigators agreed to utilise KMP3, renaming it ESEF, for the Euromir 95 external payload programme. Thus began the task of resurrecting the facility and modifying it for flight in new circumstances aboard Mir.

The original investigators were:

- J. Borg, Institut d'Astrophysique Spatiale, Orsay (F)
- C. Maag, T&M Engineering, Canaveral, Florida (USA)
- J.A.M. McDonnell, University of Kent, Canterbury (UK)
- J-C. Mandeville, ONERA, Toulouse (F), and
- L. d'Hendecourt, Institut d'Astrophysique Spatiale, Orsay (F).

Once the use of KMP3 had been confirmed, J-P. Bibring, Institut d'Astrophysique Spatiale, Orsay (F), was brought in as Facility Scientist. Subsequently, Dr. d'Hendecourt's team withdrew their experiment when it seemed that the accommodation on Spektr would not allow sufficient solar-ultraviolet exposure for their purposes. C. Maag was joined by ESTEC's M. van Eesbeek.

The final team made use of the unique features of the ESEF in the manner originally intended, in that they launched evacuated, ultraclean cassettes containing surfaces and structures designed to provide information on space impactors and perhaps capture some of them. These cassettes were opened and closed at various times in an attempt to obtain some resolution of time-variant phenomena, specifically meteor streams. In addition, C. Maag designed and built an in-situ measurement package which counted impactors and also sensed contamination, long-wavelength radiation, and the atomic-oxygen flux.

Spektr was launched to rendezvous with Mir in May 1995, carrying the ESEF platform and the control electronics for the cassette mechanisms and the active measurement package. ESA Astronaut Thomas Reiter and Russian Cosmonaut Sergei Avdeev successfully installed the remaining parts, the cassettes, their motor drives and the active package on the outside of the station during an EVA excursion on 20 October 1995. The measurement programme then commenced, with periodic downlinking of the environment data, and occasional cassette operations in response to the passage of meteor streams and potential contamination episodes such as vehicle movements.

The particle-capture period ended on 7 February 1996 when the cassettes were finally closed in readiness for the retrieval EVA the following day. On that occasion, Thomas Reiter was accompanied by Commander Yuri Gidzenko, and together they removed two cassettes and mounted a new one to be operated and retrieved at some later date. Much was learnt by ESA during this first EVA experience, both through the activity itself and about the design issues for astronaut-serviced exposed payload facilities.

The retrieved cassettes were opened back in the laboratory in Orsay on 11 March. Some fragmentation of one of the low-density capture materials was apparent, but with little or no loss of science. The observations that could be made so far on these retrieved surfaces and structures are summarised in the accompanying panel.

In summary, this first mission for the ESEF has already demonstrated the effectiveness of a serviced exposure facility on a space station. Much good science has clearly been obtained and a greater understanding of the near-station environment achieved. These, together with the logistic and crew-intervention aspects, provide a firm basis for a future facility of this kind as part of the International Space Station.

Early Results from Retrieved Surfaces and Structures

1. A small number of craters in solid targets have been analysed for morphology and elemental chemistry, yielding confidence that meteor-stream particles of low density, small size and high velocity can be discriminated. In these targets, 'chains' of craters have been observed, suggesting the oblique impact of very loose aggregates. Residues indicative of space debris have also been detected.

2. Although the attitude history of the station has yet to be reconstructed, the total number of impacts is generally in line with measurements previously made in similar circumstances. In some cases, high numbers of impacts have been attributed to secondary effects, namely craters of the products of nearby impacts in the line of sight.

3. Underdense capture materials (polymer and silica foams) contain a number of particles. The technology for fully exploiting these capture media is not yet mature, but in-situ optical imaging and X-ray fluorescence elemental chemistry has already been performed on some of these particles. It may be possible to identify the individual particles within a meteor stream with some confidence, which would satisfy a long-standing dream of astrophysicists and meteoriticists. The mineralogical content of largely intact and unshocked material may then also be amenable to recently developed micron-scale analytical techniques, thereby achieving a comprehensive cometary-sample analysis.

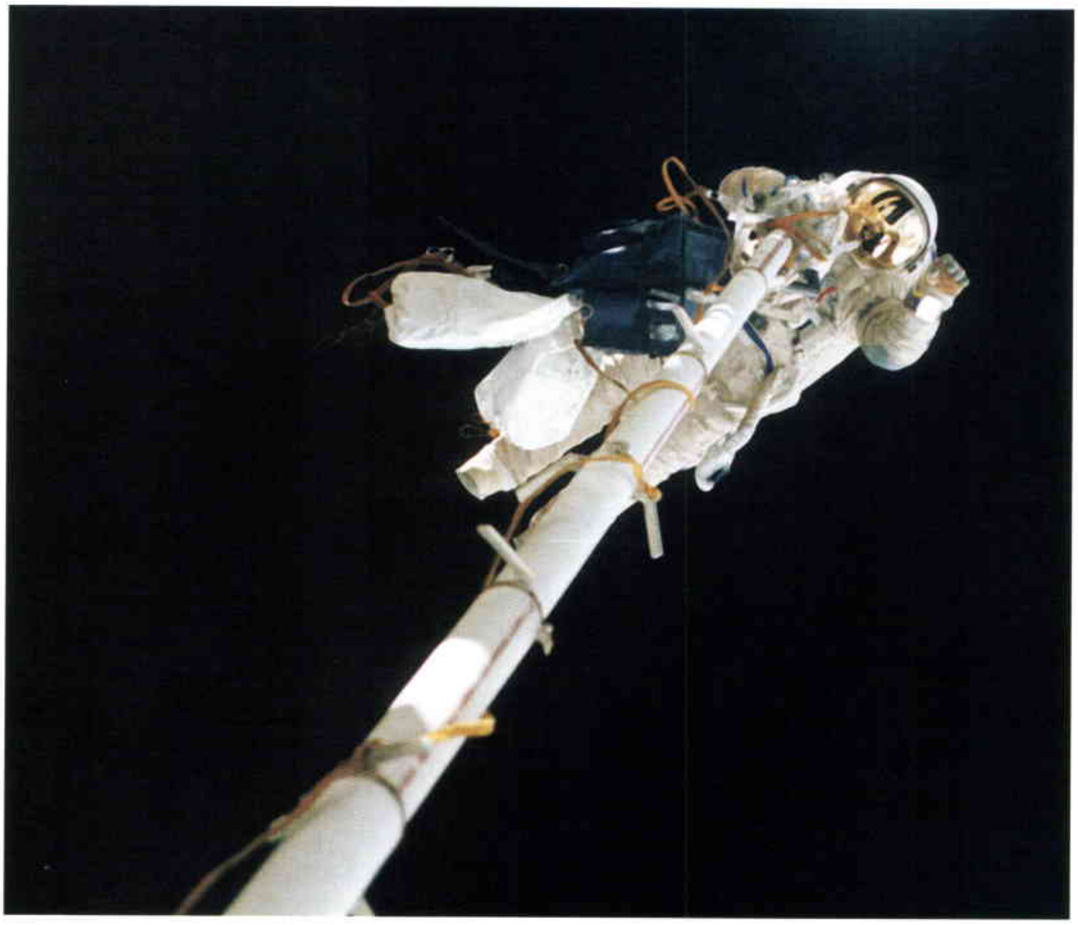
4. Thin-film structures, particularly good for the estimation of the original size of impactors, show a range of impact sizes which confirms previous measurements of the size distribution. Chemistry from these structures will also ultimately be possible.

5. Craters seen in various surfaces have been analysed for directionality. This is important for the decoding of other surfaces whose orientation is fixed in a reference frame, or both the orientation and epoch of impact is known (not the case for ESEF). This is particularly valuable where there is independent evidence of direction, as in the case of secondary impacts. In one notable case, several impact sites have been analysed and their morphologies have been attributed to secondary impactors from a single primary impact elsewhere on the cassette hardware. Thus the geometry is known, and very valuable information derived for similar morphology.

6. The active-measurement package has yielded several startling results. Firstly, the detection of large-scale space-debris structures ('clouds') has been confirmed. This manifests itself as the regular detection of bursts of impacts. The period between the bursts corresponds to the difference between the precession rates of the detector's orbit and that of the cloud, which should be imagined as being a ring of particles. The precession rate thus calculated then provides an indication of orbit inclination, and fine structure in the flux data can give an idea of the orbit phase of the parent body. The parent body of the cloud detected has not yet been identified.

   Secondly, the contamination environment, both volatile (at 80°C) and non-volatile, has been measured for an extended period. This shows episodes of very high deposition separated by relatively quiescent states when slow desorption takes place. Short-term deposition rates can be several hundred Angstroms per day, whereas the specification for the International Space Station is 30 Angstroms per year. Due to the total deposition, atomic-oxygen measurements proved to be impossible, as these depended upon the determination of a carbon-film erosion rate. Erosion was prevented, right from the start, by contamination overlaying the carbon.

Figure 2. ESA Astronaut Thomas Reiter at work during the second EVA, making use of the 'Strela' manipulator arm



The technology experiments

The technology-experiment package aboard Mir was characterised by an outstandingly large range of techno-scientific areas of investigation, ranging from new micro-biological monitoring techniques, gas-contaminant bio-filtering and gas-detection systems to space-to-ground multi-media interactive communications, passive magnetic levitation for fluid-dynamics research, Earth radiation-environment monitoring, robotics technology and human-factors engineering. The following brief overview of the preliminary results represents the status six months after landing.

The radiation-environment monitoring experiment 'REM'

The goal of this unmanned external payload was to monitor the low-Earth-orbit radiation environment at the high inclinations typical of Mir, in order to enhance and upgrade currently available models of the charged particles that surround our planet.

Two main radiation contributions are present: protons in the South Atlantic Anomaly (SAA), and electrons in the polar regions. As expected, the preliminary results from EuroMir show that the radiation dose is mainly accumulated in the SAA and at the times of Mir's closest approach to the Earth's magnetic poles. Large changes are observed in the daily absorbed doses in the polar regions, and a general increase in the SAA dose consistent with the approach of solar-minimum.

The on-going analysis of the REM experiment results is also providing valuable data on the proton- and electron-absorption capabilities of the detection shielding material, based on aluminum and tantalum. A comparison of the REM doses with the current NASA radiation models, which date back to the 1970s, has revealed major differences and confirmed the need to upgrade such models, since they are not yet compatible with contemporary geomagnetic field models and do not reflect well the solar-cycle dependence nor the directionalities that are known to exist.

The REM experiment has proved to be an extremely important one, addressing as it does both concerns affecting future crewed spaceflight in Earth orbit and fundamental environmental concerns for our planet.

The microbial contamination monitoring experiment 'MIRIAM-T2'

This experiment was aimed at analysing new techniques for microbial-contamination and fungine-growth monitoring onboard a long-term orbiting space station, by two simple and rapid measurement methods (described in more detail in ESA Bulletin No. 87, August 1996).

Twin samples were also taken for a-posteriori analysis back on the ground in order to both assess the above methods and identify the biological species sampled at various points on Mir's surfaces and in its air. A preliminary look at the data confirms that both the air and surfaces in Mir's basic block were reasonably clean, comparable in fact to a normal office environment.

Although the sample processing is still going on, the experiment has already demonstrated the flight crew's ability to use such methods to assess – quickly, simply and safely – the prevailing biomass level on board space stations.

The investigation of human posture and biomechanical motion: the 'Anbre' and Elite-S experiments

Both of these experiments, conceived, developed and performed independently employing totally different technologies (see ESA Bulletin No. 87), were aimed at analysing human-body postures in microgravity.

In a few words, T3 (see Table 1) was based on an ad-hoc-developed stretch garment to be worn as a self-contained measurement system by the crew member, equipped with dozens of elastomeric sensors placed in appropriate key positions, while Elite-S employs a space-qualified version of an infrared-based apparatus used on the ground to analyse motorial disorders and sports performances.

The vast amount of data collected with T4 (see Table 1) turned out to be very precise, recording offsets of just a few millimetres over large body limb movements. T3 also provided valuable data on human kinematics in microgravity.

Such results are going to be used to generate a detailed computerised three-dimensional dynamic model of real working postures in space in order both to verify and possibly upgrade human factors engineering requirements for the Columbus-Space Station Programme and for future crewed space missions.

The kinetics of biodegradation: 'Biokin'

Biokin allowed the concept of microbial decontamination of confined atmospheres in space to be validated and the microgravity kinetics of the process to be verified. It was based on one selected model bacterium, the Xanthobacter autotrophicus, within a simplified biofilter employing 1,2-dichloroethane as the target contaminant. The latter represents the class of organic solvents that evaporate from plastic hardware (e.g. laptop computers) and which typically support bacterial growth in a spacecraft.

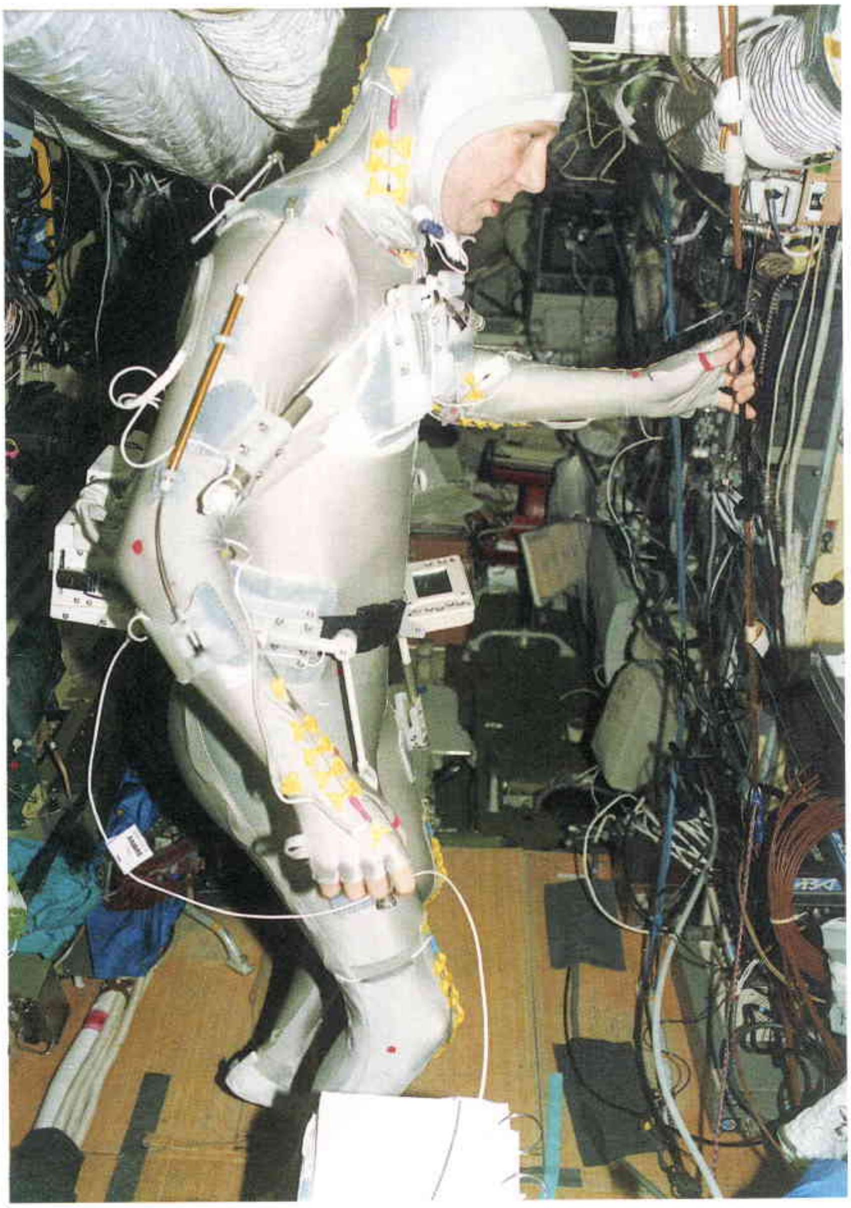


Figure 3. Thomas Reiter preparing to run the 'Anbre' experiment (T3)

Further details about the experiment's design and operational performance were provided in ESA Bulletin No. 87. The results show that biomass production is greater in microgravity than on the ground. They have also confirmed the suitability of such a bio-filter concept, which looks very promising not only for space environmental control and life-support systems (e.g. for the International Space Station Programme), but also for a new generation of air-filtration systems for ground-based use.

The smart gas sensor: 'SGS'

The purpose of the 'SGS' experimental

Table 1. The Euromir 95 experiments and facilities

LIFE-SCIENCE EXPERIMENTS

– RENAL FUNCTION AND DRUG METABOLISM	
01-DK P. Norsk	Influence of Microgravity on Renal Fluid Excretion in Humans.
15-D C. Drummer	Non-Invasive Monitoring of Drug Metabolism and Drug Effects during Prolonged Weightlessness.
– NEUROVESTIBULAR SYSTEM	
17-USA C. Markham	Correlation of Disconjugate Eye Torsion with the Time Course of Space Adaptation Syndrome
38-D M. Dieterich	Differential Effects of Otolith Input on Ocular Lateropulsion, Cyclorotation, Perceived Visual Vertical, Straight Ahead and Tonic Reflexes in Man.
– RADIATION EFFECTS AND DOSIMETRY	
25-D G. Obe	Chromosomal Aberrations in Peripheral Lymphocytes of Astronauts.
18.2-D G. Reitz	Radiation Health during Prolonged Spaceflight.
– MUSCLE PHYSIOLOGY AND MOTOR CONTROL	
33-CH D. Rüegg	Influence of Gravity on Preparation and Execution of Voluntary Movements.
34-I E. Di Prampero	Effect of Microgravity on the Bioenergetic Characteristics of Human Skeletal Muscle.
35-F F. Goubel	Changes in Mechanical Properties and Reflex Responses of Human Muscle as a Result of Spaceflight.
37-D J. Zange	Magnetic Resonance Spectroscopy and Imaging of Human Muscles before and after Spaceflight.
– CARDIOVASCULAR AND CARDIOPULMONARY SYSTEM	
19-S D. Linnarson	Effect of Short-term and Long-term Microgravity on the Pulmonary Gas Exchange, Respiratory Control and Cardiovascular Control during Rest and Exercise.
20-B M. Paiva	Pulmonary Function in Microgravity.
21-CH G. Ferretti	Regulation of Cardiovascular Responses to Exercise in Humans.
40-I D. Negrini	Interstitial Fluid Balance under Zero-G with Special Reference to Pulmonary Mechanics.
– BONE DENSITY	
16-NL C. Vermeer	Effect of Vitamin K Supplementation on Bone Mass during Microgravity Conditions.
45-F C. Alexandre	Bone Mass and Structure Measurement during Long-term Space Flights using an Ultrasound Bone Densitometer 'Bonus' and Bone Stiffness Measurement Device 'Swing'.
43-UK I. McCarthy	The Effect of Venous Pressure on Bone Mineral Density in Weightless Conditions.
48-UK A. Goodship	The Application of Mechanical Stimulation to Prevent Loss of Bone Mass in Long-Term Space Flight using Heel Strike Transients.
– MULTI-USER FACILITIES	
RMS-II F. Pedersen T. Stevenson	19-S, 20-B, 21-CH, 40-I
BDM Ch. Schmidt-Harms	43-UK, 48-UK, 45-F
BSU-Kit B. Elmann-Larsen	01-DK, 15-D, 16-NL, 45-F
Euromir 95 Freezer P. Genzel	

MATERIAL-SCIENCE EXPERIMENTS

A-462 D. Camel	Exquiaxed Solidifications of Al Alloys.
380 L. Froyen K.U. Leuven	Reaction and Solidification Behaviour in Metal Matrix Composites.
301 R. Willnecker	Specific Heat of Undercooled Melts.
B-1-4 G. Krabbes	Investigation of Chemical Vapour Transport.
B-1-5 H. Reiss	Liquid – Liquid Phase Separation in Glasses.
B-1-6 B. Hilmann	Thermosolutal Convection in Ge-Si.
B-1-9 H.J. Fecht	Metallic Glass Research.
A-298 L. Ratke	Casting of Hypermonotectic Alloys.

– MULTI-USER FACILITIES

TITUS J. Ströde.	A–462, 380 301, B–1–4, B–1–5, B–1–6, B–1–9, A–298

ASTROPHYSICS EXPERIMENTS

ESEF Platform J-P. Bibring	
COMRAD-A C. Maag	Particulate Impact, Atomic Oxygen and Surface Contamination Measurement in Space.
COMRAD-P J-P. Bibring	Flux Measurement and Intact Capture of Micrometeoroid and Orbital Debris Particles Using Micropore Foams.
DUSTWATCH-P J.A.M. McDonnell	Flux Measurement and Intact Capture of Micrometeoroid and Orbital Debris Particles Using Aerogel.
ORGMAT-P L. d'Hendecourt	Understanding the Evolution of Organic Matter in Space.
MULTILAYER J.C. Mandeville	Flux Measurement of Micrometeoroid and Orbital Debris Particles in Space.

TECHNOLOGY EXPERIMENTS

T1 E. Daly	Radiation Environment Monitoring.
T2 V. Cotronei	Verification Approach for Microbiologic Contamination.
T3 F. Bagiana	Analogue Biomechanics Recorder (Anbre).
T4 V. Cotronei	Human Posture Experiment/ELITE-S.
T5 S. Keuning	Biokin.
T6 H. Wessels	Smart Gas Sensor.
T7 P. Mugnuolo	Robotics Joint Controller (RJC)
T8 B. Svensson	Crew Support Computer Assembly (CSCA).
T9 T. Roesgen	Magnetic Levitator (MAGLEV).
T10 M. Uggiano	Video Integrated Services Controller (VISC).

equipment was to validate a small and light gas sensor vis-a-vis the expensive and bulky gas-chromatograph/mass-spectrometer-like types of equipment that are typically required for gas detection and analysis. The equipment was operated extensively throughout the mission, and also at times when interesting gases could be expected to be released, such as during the extravehicular activities (EVA) and during the repair of the leak that occurred in one of the Mir thermal-control system circuits.

The SGS system was also briefly described in ESA Bulletin No. 87. At this point in time, it can be stated that the SGS is indeed capable of providing complete 'smell-patterns' for a space station. Inter alia, it also provided a cross-confirmation with the T2 experiment's results concerning the quality of the Mir environmental control system, and the ability to purify the on-board air very effectively.

The robotics joint controller: 'RJC'
The nominal objective in this case was to assess the microgravity disturbances induced by various velocity and acceleration profiles of a robotics joint as a part of a robotic arm.

The successful Euromir extension programme in 1996 enabled the science team to gather additional data, currently under analysis, about the possible influence of single-event effects, disturbances in transient phases, Mir background acceleration noise, and possible performance degradation due to long-term functioning.

Although data processing is still in progress, it is already clear that RJC performed properly, gathering important data with which to characterise disturbance sources, to assess the disturbance levels on the Mir station (e.g. the strong disturbance detected at 400 Hz frequency), and to identify design improvements aimed at enhancing robotics technology for the automation of microgravity laboratories, with particular application to the International Space Station.

The Crew Support Computer Assembly: CSCA
The use of the onboard laptop computer during the mission is summarised in the companion article titled 'Crew Support Tools for Euromir 95' in this issue of the Bulletin.

The magnetic levitation experiment: 'Maglev'
This experimental equipment was developed to demonstrate a simple and inexpensive technology for the generation of passive magnetic fluid levitation in microgravity, but also provided interesting data on thermally-induced Marangoni convection generated within the target levitation cell.

Maglev proved that a levitating central force field can be generated by means of an array of permanent magnets acting on the test cell, the latter being filled with transparent ferro-fluid and a non-magnetic levitation sample, in this case an air bubble.

The trapping system's stability was also demonstrated by analysing how such a passive magnetic field can keep the air bubble in the centre of the test cell, even when the bubble is 'disturbed' by Marangoni convection flows or by mechanical transient forces applied externally to the test cell.

This experiment can certainly be considered a complete success, despite its extremely low development and integration costs.

The video integrated services controller: 'VISC'
The idea of having a remotely controlled video switcher and mixer to handle real-time visual information in synchronisation with other main information formats from Space Station experiments (e.g. audio and alphanumeric data), led to the development of VISC.

Despite some technical problems with the space-to-ground link, the VISC features available on board functioned well. For instance, Mir-to-ground exchanges of graphical annotations on VISC screens were demonstrated, as well as onboard remote and ground control of Mir's TV cameras.

Although some shortcomings were apparent when operating the touch screen and when linking space and ground modems, VISC was proved to be capable of enhancing both telescience space operations and crew/ground interactions.

Conclusions
Although final results are not yet available in many cases, it is already evident that the Euromir 95 experiment programme has provided a wealth of valuable data, samples, and findings. With very few exceptions, all experiments were run successfully, much to the credit of ESA Astronaut Thomas Reiter and his Russian colleagues. The first results and conclusions drawn from this novel experiment programme are already influencing the on-going decision processes regarding the future utilisation of the International Space Station.

Medical and Ground Crew Support during Euromir 95

V. Damann, C. Fuglesang, S. Jaehn* & W. Peeters
European Astronauts Centre (EAC), ESA Directorate of Manned Spaceflight and Microgravity, Cologne, Germany

The longest manned mission previously supported by ESA was Euromir 94, which lasted just 30 days. The quantum leap to the originally planned 135 days of the Euromir 95 mission meant that a number of concepts needed to be rethought and adapted. One of the more obvious consequences was that the astronaut would be separated for a much longer period from his home environment, which meant that some of the ground-related support also had to be re-evaluated. Additional support associated with the 'psychological climate' onboard the station as a result of the longer mission duration was also necessary. Post-flight analysis has shown that all support elements functioned satisfactorily, but a number of potential improvements have also been identified.

Introduction

The Euromir 95 flight represented an important increment in ESA's experience with long-term manned spaceflights. Whereas the 30 days of the earlier Euromir 94 flight were not considered critical in terms of the isolation involved, a number of lessons were learnt which were important enough to be carefully considered for Euromir 95. Debriefings and feedback from other long-duration flights involving the presence of foreign astronauts on-board Mir also received attention.

The ground support provided during the Euromir 95 flight fell into two distinct categories:

- Medical support
  Differences in medical philosophy have led to the principle that the progress of all ESA astronauts throughout such missions should be followed by ESA-assigned medical staff, reporting to a Medical Board independent of the mission management structure. For long-duration missions, there is then the additional benefit of a long-standing relationship between the astronaut and the crew surgeons, providing the astronauts with the necessary degree of confidence in their medical support team that can be so important during such long and isolated stays.

- Ground support
  For long-duration missions like Euromir 95, proper support for the astronaut's family also has to be ensured, an important aspect here being regular contact between the astronaut in space and his/her family and other close friends back on the ground, in so far as the mission's technical constraints and short communications slots allow.

Medical operations support

The ESA/EAC Medical Operations team is responsible for the health and well-being of the the ESA astronauts during all phases of a space mission. The length of the Euromir 95 mission provided a unique opportunity to accumulate new experience, but also called for modifications to the medical support programme devised for earlier much shorter missions such as the Euromir 94 mission and Shuttle trips.

The decentralised mission support scenario for Euromir 95 required the setting up of reliable communications links and reporting chains. In addition, the European crew surgeons working at the Russian Control Centre at Kaliningrad (TsUP) had to be trained to operate within the Russian flight operations team, on the basis of bilateral agreements between the Russian and the ESA Medical Operations teams.

Medical operations setup for Euromir 95

Two flight surgeons, Dr. A. Putzka and Dr. K. Lohn, were provided by the contractor, DLR Medical Operations, and one, Dr. B. Comet, by the subcontractor MEDES. Their shift schedule was such that each surgeon was on duty at TsUP for a 2 – 3 week period, covering all onboard activities from the first morning space-to-ground contact until the last communication in the evening.

During Euromir 94, it was found to be important to establish a link between the TsUP

* Space Consultant

flight surgeons and the flight control team at the Payload Operations Centre (SCOPE). A dedicated crew-surgeon console was therefore installed at SCOPE in Oberpfaffenhofen (D) to enable the medical team to communicate via the digital intercom system (DICE). There was one public DICE line and one secure line, which was used to communicate confidential medical information, between the two centres.

The TsUP-based flight surgeons interfaced directly with their Russian counterparts and were responsible for all medical issues arising during the mission. All routine inflight medical checks and the countermeasure program were monitored and, in concurrence with the Russian crew surgeons, the appropriate recommendations were uplinked to the crew. In addition, the surgeons provided support to the timeline planners for all crew-schedule-related activities.

There was a private medical conference between the ESA astronaut and the ESA surgeon(s) approximately two to three times per week, on the understanding with the Russians that any information gathered that could have an impact on the mission's execution would be passed on to them. Information from these conferences was used to brief the Payload Operations Manager (EPOM) and the Mission Management on the ESA astronaut's health and workload, so that the daily activity plan for onboard tasks could be fine-tuned or adapted as necessary.

In addition, the Russian medical team issued an extensive daily medical report, which was translated and sent to the chief crew surgeon at SCOPE.

The SCOPE crew surgeon's role was to collect all medical information from the TsUP surgeons and to provide the SCOPE team and ESA Mission Management with a thorough understanding of the medical situation. A secondary task was to provide the link with the ESA Medical Board for decisions relating to the execution of the human life-sciences experiments. The Russian and the ESA Medical Boards had approved all of the life-sciences experiments, including the operational procedures to be followed, before the flight. Any changes to those agreed protocols had to be re-approved by the ESA Medical Board. The SCOPE surgeon was responsible for informing the Medical Board about any such changes, in addition to filing the nominal reports on the mission's progress. Thirdly, the SCOPE surgeon had to interface with the responsible safety officer in the event of apparently hazardous operations or equipment malfunctions that might affect the crew's health.

Figure 1 shows the links and interactions between the various teams, but does not reflect the hierarchical structures.

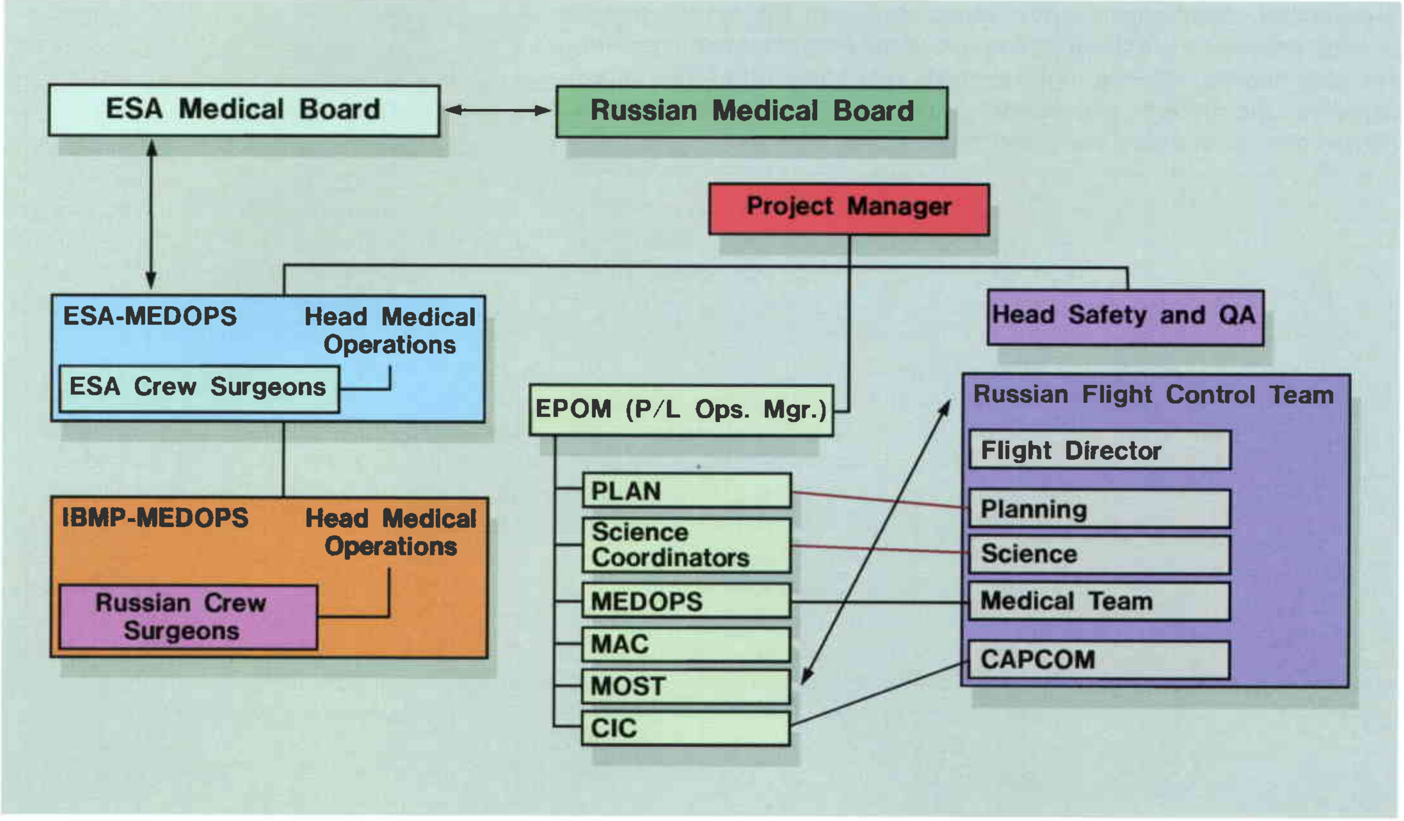


Figure 1. In-flight medical-operations setup

Figure 2. Medical countermeasures taken onboard before landing - the LBNP suit

Medical-operations documentation

In order to define clearly the roles and responsibilities of the medical-operations personnel and to make those roles more transparent to the Euromir 95 mission management, several documents were created.

The first document to be finalised and approved was the 'Euromir 95 Medical Flight Rules'. This document describes in detail all rules governing the daily tasks of the medical team, the rationales behind those rules, and the structure of the decision-making processes during nominal inflight operations and in contingency situations.

The second document, on 'Medical Data Protection Policy', defines the rules for protecting the astronaut's private medical data from public release, and the underlying criteria for medical data exchange with, for example, the scientific community. Further documents, such as the 'Medical Checklist', were published to give other non-medical flight controllers a more detailed insight into possible medical situations that might be encountered during a long-duration mission like Euromir 95.

A 'Medical Console Handbook' was used by all flight surgeons as the main reference for their work at the medical consoles, either in TsUP or SCOPE. It covers the operation of all equipment, contains basic space-medicine chapters, and lists all contact personnel needed to cope with contingency or emergency situations.

A 'Handbook on the Russian Medical Programme' compiles all available information about the routine inflight medical examinations and the countermeasures programme. This handbook was also made available to the life-sciences team, for whom detailed knowledge of these medical routines was especially important in the setting up of their experiment programme.

As the TsUP-based ESA surgeons were to be integrated into the Russian medical system, a 'Joint Medical Support Requirements' agreement was established with their Russian counterparts. This document describes the training needed by a foreign flight surgeon in order to be certified to work in the Control Centre. Fortunately, the ESA flight surgeons selected for EuroMir 95 had previously provided mission support in Russia and therefore required no further training. More importantly, it spells out the interactions and responsibilities of both medical teams, includes western-European medical data-protection guidelines, and formalises the Russian agreement to the routinely scheduled private medical conferences.

Lessons learnt

The Euromir 95 mission as a whole was a great success from the medical and ground-support points of view especially, in that it served to prove that the current medical-operations structure is well able to support long-duration missions. It also demonstrated that an open and transparent mode of working, whilst still protecting the astronaut's medical privacy to the greatest degree possible, enhances the relationship between the medical operations, the mission management and the other ground personnel to the benefit of all concerned.

Nevertheless, there are still some elements that can be improved for future missions, particularly in the context of the broadening of multinational cooperation in the International Space Station era:

(i) Although there was a dedicated secure voice link between SCOPE and TsUP, it could not always be used as expected because there was only one DICE console available at TsUP, which was shared by all personnel. It is mandatory to have a dedicated crew-surgeon console in each control centre in future.

(ii) As one might expect, engineering knowledge is limited in the true medical community. To improve the interfacing between the medical staff and the engineers (e.g. safety officers) and in order to incorporate new technologies such as telemedicine, a biomedical engineer should become a permanent part of the European medical team, as is already the case in the American and Russian systems.

(iii) The chief crew surgeon at SCOPE for Euromir 95 served in parallel as the executive secretary of the ESA Medical Board. This double function sometimes led to misunderstandings within the ground team. In the future, those functions should either be separated during a mission or both tasks should be made more transparent to the other ground controllers.

(iv) Negotiations with the Russian side were sometimes somewhat cumbersome, despite the excellent translational support. It is advisable for the future to have available a native Russian translator intimately familiar with medical terminology. This becomes even more important in the framework of ever wider international co-operation.

Family and ground support

For such long-duration missions, one can only expect an astronaut to concentrate fully on his/her tasks if he/she knows that their family is being well taken care of, and that they can have regular contact. Such support should not be over-institutionalised, but needs to be sufficient to instil a feeling of mutual confidence between the astronaut and his/her family and the crew surgeon and EAC support staff.

As far as the contact aspect is concerned, one really needs more location-independent communication possibilities. The Russian system provides a videolink from TsUP once every two weeks, as well as allowing regular short phone calls from private locations (via the installation of a specific system). This, however, requires that the astronaut's family be present in Russia. A video link provided via the DICE system proved to be a valuable addition, especially when the families were on the move or further afield. Audio contact could also be made by linking the space-to-ground loop to the public telephone network, which not only provided a good backup system but also provided contact with other more remote family members from time to time.

As a result of conflicting feedback from earlier flights, various aspects of the Euromir 94 flight were analysed with the help of a psychologist trainee at EAC. As a result, a number of recommendations for improvement were implemented for Euromir 95. A typical example was the news summaries, which were collected and condensed at EAC, and then transmitted in the astronaut's mother tongue to the station at regular intervals.

In fact, the cultural isolation problems cited after earlier Russian cooperative missions were not reported at all during Euromir 95. The well-balanced composition of the crew certainly played a very important role in this respect, but a number of small support activities undoubtly contributed also (e.g. presents and video tapes sent up at Christmas).

The two Euromir 95 Crew Interface Coordinators (CICs) were based, together with the two Experiment Coordinators, at the main Control Centre (TsUP) in Kaliningrad, near Moscow. They worked in two shifts, from one afternoon to the next, with a one-hour overlap for handover purposes. From the fourth week of the mission onwards, one of the four persons was always free for relaxation.

There were several systems available for communications between TsUP and SCOPE, serving complementary as well as back-up functions. These included the DICE system and a dedicated audiosystem, called VIS, in addition to the classical communication tools of telephone, fax and e-mail. An Internet link that became available near the end of the flight also proved to be very useful.

When communicating with the Mir station, there are typically 10 passes per day/night,

Figure 3. A rare social event – visitors in space

each affording only between 10 and 20 mins of link time (because only ground stations on Russian territory are used). Given the predominant system-related communications needs, this strongly limits the ground contact time available for the ESA astronaut. A good understanding prior to the flight of the activities to be performed onboard is therefore a must, as well as a good command of Russian as the station's working language.

The amount of written information that could be sent up was also rather limited, relying on so-called 'radiograms'. In practice, sending small 'electronic packages' to the onboard laptop computer proved more effective.

The use of Russian as the principal language of communication allowed the Russian crew members to feel more involved in the ESA scientific programme, and it also allowed the ground controllers to give advice as they were able to listen in. This was a 'lesson learnt' from Euromir 94, where the ESA astronaut communicated with the ground mainly in English.

Conclusion

The Euromir 95 support concept proved to be a viable setup that worked very satisfactorily. The more harmonious cooperation with the Russian medical infrastructure was clearly beneficial and merits further development and follow up.

A major conclusion, however, is that in the International Space Station scenario ESA needs to provide its astronauts, and their families, with carefully structured support before, during and after their flights. This support needs to address not only the technical demands of the particular mission, but also the cultural factors that begin to play an ever-increasing role as the durations of our astronauts' stays in space become ever longer.

Regular communication with the crew is considered a must for long-duration missions, not least for psychological reasons. Internet connections to TsUP and electronic-mail possibilities need to be further investigated and improved.

Crew Support Tools for Euromir 95

L. Bessone, F. de Jong & P. Nespoli
European Astronauts Centre (EAC), ESA Directorate of Manned Spaceflight and Microgravity, Cologne, Germany

The Euromir 95 long-duration mission raised many new crew-support issues for ESA. Previous mission experience indicated the need for increased emphasis on generic tools for astronaut Thomas Reiter. In addition, some possible solutions could be demonstrated to combat Mir's onboard stowage problem.

Overall, the mission considerably increased ESA's operational experience, while the experimental introduction of certain items generated a vast number of 'lessons learned' in the crew-support domain. Further experience in this area would enhance Europe's role in the International Space Station's operational phase.

Introduction

Euromir 95's planned duration of 135 days far exceeded the experience of any ESA Astronaut. The 30-day Euromir 94 mission had already indicated the need for new tools, unavailable in the Russian system, to help run the onboard programme. Further important feedback from the Euromir 94 debriefings highlighted the problems with stowage aboard the station.

Based on these requirements, we can categorise the support tools provided for Euromir 95 as:

a. Generic off-the-shelf tools
These were taken up by the astronaut, independently of the experiment programme, to make life on board more comfortable at the same time as assisting him with his work.

b. Specific operational support tools
Based upon feedback from earlier missions regarding stowage and handling constraints, a number of items were flown on an experimental basis. These were aimed primarily at supporting operational activities, whilst at the same time contributing to 'lessons learnt' for future missions.

c. A Payload and Crew Support Computer (PCSC)
A commercial laptop has been selected as a standard tool for the International Space Station era and flew as part of Euromir 95. It was specifically equipped to meet the experiment data-handling needs and to provide the astronaut with a suitable support tool.

Generic off-the-shelf tools

On the basis of lessons learnt from Euromir 94 and the inputs from both Euromir 95 astronauts, a number of off-the-shelf items were purchased for operational onboard support. The following table lists the items, describes their operational usage and suggests improvements where necessary:

Item	A	B	Cn	D
Stopwatch	x		C1	
Sunglasses (standard NASA issue)	x		C2	
Swiss Army Knife	x	x		
0.9 Mechanical pencils + refills and tip eraser	x	x		
Waterproof marker	x	x		
Space Pen				x
Ear plugs (disposable foam type)	x	x		
Eye mask		x		x
Mini Maglite (AAA-batt.)	x	x		
Portable MD Player-Recorder + power adapter + folding headphone (lightweight)	x			
NASA grey duct tape	x	x		
Dictaphone		x		x
Sailing rope (diam. 3 mm)	x			

A = used frequently during the flight
B = design excellent, no improvements necessary
C = design good, room for operational optimisation
C1 = have the display show simultaneously the actual time (in large digits) and stopwatch time
C2 = use denser sunglasses, for greater protection against UV radiation
D = rarely or not used during the flight.

Specific operational support tools

A fundamental problem faced by any astronaut on Mir is the absence of a proper stowage system. After more than a decade in orbit, Mir's interior could be described as organised chaos. Combined with the usual difficulties of working in microgravity (everything silently floats away if not properly fixed or stored), this constitutes a major operational problem for the astronaut (Fig. 1). This subject was specifically addressed at the Euromir 94 debriefings, with the main drawbacks being identified as:

- difficulty in setting up experiments
- difficulty in temporarily stowing products
- risk of losing smaller items such as the important data carriers (PCMCIA cards, floppy disks, etc.)
- loss of valuable time during operations.

Two new operational support tools were designed and developed to help remedy this operational problem: the Mission Stowage Bag and the Crew Vest.

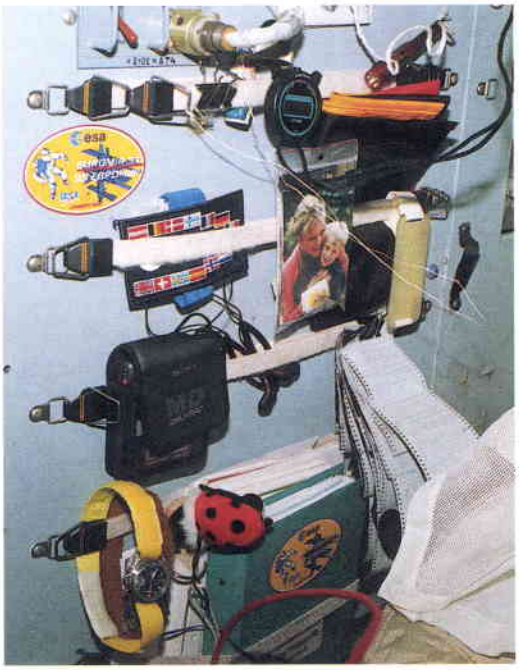


Figure 1. Some of Thomas Reiter's personal items 'tied down' aboard Mir

Mission Stowage Bag

The Mission Stowage Bag (MSB) was developed with two main objectives in mind:

- provision of a central, readily accessible storage place for most of the science data carriers and some other regularly used items
- allowing the astronaut to gather up the science data carriers quickly in the event of an emergency evacuation.

More than 40 experiments were conducted during Euromir 95, filling a whole series of data carriers. Several of them were not planned to be placed in the MSB, either because they were constantly in use within the station or were to be used only once.

Only a portion of the items present in relatively large quantities (60 dictaphone cassettes, 20 35 mm films, 30 Betacam cassettes) were placed in the MSB at any given time:

- 12 PCMCIA cards
- 15 Betacam cassettes
- 8 Hi8 cassettes
- 32 dictaphone cassettes
- DI8 bag (DAT tapes, memory cards, floppy disks)
- 6 memory cards
- 2 audio tapes
- 10 35 mm films
- Flight Data File (FDF)
- laptop + power cable
- one string of batteries.

Specific MSB features included (Fig. 2):

- All pockets containing mission data carriers were white and attached with velcro to baseplates. The astronaut could thus rip off the pockets quickly and collect them in the emergency bag (a large bag used as MSB upload packaging).
- Materials used: Nomex fabric (90 g and 180 g), Nomex Velcro, FR4-plates (fibreglass-reinforced material, type Hgw 2372.1 DIN 7735), Nomex cord and four metal rings.
- Foldable design, allowing compact upload dimensions (385x225x115 mm^3); installed dimensions in Mir were 840x740 mm^2. The FR4-plates, sewn permanently into the MSB baseplate, gave it the requisite stiffness in orbit.
- Rear of the MSB had four large pouches for general stowage (personal items, temporary stowage, etc).

Figure 2. The Mission Stowage Bag (MSB)

The MSB was anchored in Mir's Spektr module and used on a daily basis by Thomas Reiter, to store his private possessions, photographic and computer equipment, consumables such as earplugs and batteries, most of the Betacam cassettes and a few PCMCIA cards. Most of the data carriers were stowed next to their corresponding hardware for operational convenience. Reiter had decided to rescue only the magnetic-optical disk (the central backup medium) in the event of an emergency evacuation. The emergency bag was used as a temporary store for Betacam cassettes and T2 samples.

Figure 3. Cosmonauts Sergei Avdeev and Yuri Gidzenko and ESA Astronaut Thomas Reiter wearing their Crew Vests

MSB lessons learnt

- The MSB concept is extremely useful.
- The MSB should allow the stowage of:
  - most of the astronaut's personal items
  - photo and computer equipment, multi-purpose tools
  - consumables (earplugs, batteries, bolts, velcro, duct tape, ziplock bags, etc.)
  - non-specific experiment data carriers such as tapes, cassettes and films
  - experiment-specific data carriers such as PCMCIA cards and floppies (astronaut decides on orbit if it is operationally useful to store them there)
  - general stowage for items unforeseen by ground planners.
- Introduce an Emergency Bag with a mission-dependent design for carrying the central backup medium (magneto-optical disk during Euromir 95) and those items planned for return aboard Soyuz.
- Standardise the packaging of up/download items, and have someone co-ordinate this and their operational use onboard.
- Provide a few simple General Stowage Bags for the astronaut to stow items and data carriers no longer needed.
- The foldable design is very practical; there is no need to switch to stowage lockers. Retain the FR4-plates for stiffness and keep the simple cords for attachment.

Crew Vest

This multi-purpose vest was developed to allow its wearer to carry around a wide range of items and to provide temporary storage during experiment work and onboard engineering.

Two lists of requirements were compiled for it in consultation with ESA Astronauts Thomas Reiter and Christer Fuglesang. List 1 specified items with permanent and dedicated positions, whilst list 2 covered all the other items the vest should be able to accommodate.

List 1	List 2
– Pocket calculator	– PCMCIA cards
– Dictaphone	– Sunglasses
– Swiss army knife	– Floppy disks
– Maglite	– Betacam cassette
– Yellow stickers	– Hi8-cassette
– Blood/saliva/urine sample holders	– Flight Data File
– Pen & pencil	– Small items, such as bolts

Specific features of the Vest included (Fig. 3):

- Material used: jeans fabric as basis, Nomex (90 g & 180 g) for the pockets, synthetic zip fastener, Nomex velcro and two synthetic whalebones for stiffness.
- The vest was sleeveless, body-hugging and had three large ventilation holes at shoulder-blade height.
- A large pocket on the lower back, accessible from the left, provided a place for the Flight Data File. A second pocket on top, accessed from the right, held large items such as the duct tape and Betacam cassettes.

The three Crew Vests were not delivered to Mir until 20 December 1995 aboard Progress-M 30, by which time Thomas Reiter had been working in space for more than three months. This was a great pity as the astronauts organise themselves and their experiments during the first two weeks of a mission, and it is during this phase, and subsequent periods of Progress unloading, that the Crew Vest would be of greatest use.

Astronaut feedback was notable on the apparently extremely impractical nature of the standard onboard overall: pockets were small and few, with no pockets suitable for items such as pencils and screwdrivers; the short sleeves made them too cold when in the Spektr module, whilst they were too warm when in Mir's core module.

Crew Vest lessons learnt

- In general, standard daily clothing should be a practical, light overall with long sleeves and dedicated pockets for at least a pen/pencil, Swiss army knife, Maglite, screwdriver, dictaphone, small notebook, sunglasses and tissues.
- There should also be a supplementary belt/harness to help move equipment around, providing temporary storage for several items, both large and small.

Payload and Crew Support Computer (PCSC)

Along with other similar equipment already aboard Mir, the PCSC laptop computer and accessories (including four hard disks with two configurations) were used by the ESA Astronaut under an ESA/NASA agreement covering the sharing of technology resources for research purposes. By exchanging the main hard disk, the PCSC could be configured either to supporting the experiment programme or to serve as a personal computer for the crew. It could also be attached to NASA's Mir Interface to Payload Systems (MIPS), whereby the MIPS MO disk could be used to make an additional copy of the collected experiment data, which could then be sent back to the ground via Mir's telemetry system.

The PCSC was essentially a commercial IBM 750C ThinkPad laptop, with an 80486 SL Intel processor running at 33 MHz, 12 Mbytes of Random Access Memory (RAM), an exchangeable 340 Mbyte hard disk, a 1.44/2.88 Mbyte disk drive, a 26.7 cm active-matrix display, a Type-III PCMCIA slot, and an integrated TrackPoint pointing device.

Figure 4. The Payload and Crew Support Computer (PSCS), accessories and peripherals with the onboard stowage bag

The main modifications to the off-the-shelf laptop were the addition of a DC/DC converter, so that it could be powered by Mir's standard 28 VDC supply, and the coating of the various internal boards with a non-conductive film to trap escaping gases and protect the various components against short circuiting by any metallic particles floating in weightlessness.

The basic computer was complemented with several accessories: four exchangeable hard disks, two PCMCIA 260 Mbyte hard disks, four floppy disks, five MO disks of 1.2 Gbyte capacity each, power cable, serial and parallel loopback connectors (for testing the computer) and other small spare parts.

Everything was labelled and each item was packed into labelled Nomex pouches, which had exterior Velcro strips. The pouches were then placed in an aluminium/Nomex stowage container, providing easy access to the computer and the accessories which would remain fixed inside even when the lid was open. The stowage container with all the PCSC items weighed 7 kg and was delivered by Progress-M 28, launched on 20 July 1995.

A pre-mission agreement with NASA allowed the three additional MIPS laptops (also IBM ThinkPad 750C's) already onboard Mir to be configured as part of the PCSC facility. At least two PCSC-configured computers were thus available at all times.

Three PCMCIA hard disks carrying upgrade software and three PCMCIA SRAM cards containing MIPS software were delivered in September 1995 by Soyuz-TM 22. Two more PCMCIA SRAM cards were delivered by Space Shuttle mission STS-74 in November 1995. An additional PCMCIA hard disk with upgrade software and three fresh PCMCIA SRAM cards were uploaded with the Progress flight in December 1995.

STS-74 returned with an MO disk containing all the experiment data collected thus far. A second MO disk and a PCMCIA hard disk were brought back by the crew aboard Soyuz in February 1996. All other exchangeable hard disks and PCMCIA hard disks were returned by STS-76 in March 1996, the ESA laptop remaining behind on Mir for future use.

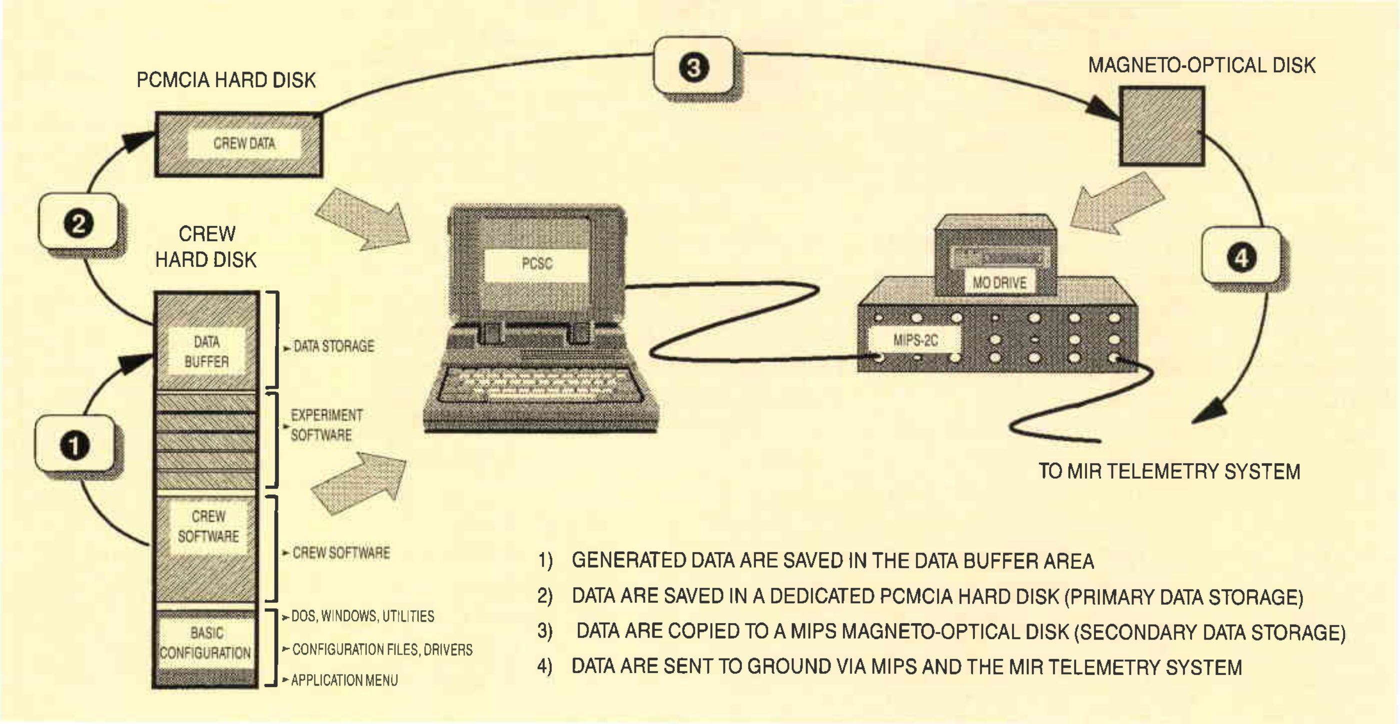
Software configuration and data handling

The 'payload hard disk' was installed in the PCSC, carrying mostly software for supporting the experiments programme. Twelve Life Sciences and Technology experiments used the computer for experiment hardware command and control, data acquisition and data handling. The 'crew hard disk' was installed in a MIPS computer, making it the 'PCSC crew computer', typically used in standalone mode as a personal computer, but it could also be interfaced to MIPS for data downloading and telemetry. This hard disk was notionally divided into three areas: basic configuration; crew software; data buffer.

The basic configuration area essentially contained the Operating System (DOS, Windows), configuration files, software drivers and software utilities. It also contained a simple shell DOS program, provided by NASA, that ran at the end of the booting sequence. This program provided a selectable menu to start Windows 3.1 or to access NASA's software for handling MIPS. While the basic utilities contained tools and batch programs that automated all the tedious and repetitive operations, extreme care was taken to ensure that the astronaut was always aware of the work being performed in background mode by the computer so that he could intervene and correct any problem manually.

The crew software area contained all the software used exclusively by the crew. This was mostly commercial software that could be run under Windows 3.1. In parallel, some experimental software was also run from the

Figure 5. Computer hardware and software configuration, with a schematic indication of the data flow



crew computer, notably experiment T8, which would record and notify the operator of possible system anomalies due to radiation hits corrupting RAM data.

The data buffer area contained both experiment-generated and personal data. These were also copied into a specific PCMCIA hard disk that was considered to be the Primary Data Storage medium. At the end of the mission, the data buffer area was copied onto a MIPS MO disk as the Secondary Data Storage medium. Both were returned to Earth.

Software packages
The software installed in the crew hard disk was selected by the crew and basically contained the same software tools used by the astronauts in their offices or at home: word processor, electronic spreadsheet, database and drawing package. They were used mainly for taking notes, writing reports or letters, reviewing online documentation and making lists for tracking equipment. Several of these documents (normally containing up to four or five pages of text) were exchanged between Mir and the control centre in Kaliningrad. In addition, an orbital tracking program provided the crew with real-time information on the ground areas visible from Mir's observation windows. This was used mainly for photographic purposes and for supporting public-relations activities.

A simple time-line program called the Crew Activity Organiser System was also provided. This tool, built by the European Astronaut Centre and normally used for displaying training time-lines, was tested in orbit for receiving and displaying the daily activity time-line.

Finally, a graphics package that displayed digitised images allowed the crew members to select their favourites from the 'Ars ad Astra' art collection of original drawings expressly created by artists from all over the world. This package was also used to view family photographs provided by the wives for inclusion on the hard disk without the crew's prior knowledge.

Data telemetry
Despite several glitches, a high proportion of the experiment data was successfully dispatched to the ground via MIPS and Mir's telemetry system. This allowed the experimenters to view their data relatively soon after its generation (typically 2 – 3 days) and, when necessary, to take corrective actions. While the majority of the two-way traffic concerned the experiments, the ESA Astronaut regularly sent and received text files (typically in ASCII format). In fact, he regularly generated reports and messages complementing the information transferred during the normally short audio and video connections with Mir. Once received on the ground, the Crew Interface Co-ordinator would forward the relevant items to the interested parties and collect and compile the replies to be sent to Mir. This worked very well and was invaluable in expediting operations.

Figure 6. Laptop connected to the Mir Interface Payloads System (MIPS) during telemetry transmission

Computer lessons learnt
The use of the laptop by the ESA Astronaut as a personal and mission-management support tool contributed to the mission's success. For this tool to be effective, however, an informatics environment must be built up for each astronaut as early as possible during mission preparation. This environment has to contain all of the software necessary for satisfying astronaut and mission requirements, plus all available experiment support documentation with ready access.

Conclusion
Euromir 95 served as a demonstration testbed for several elements that will be required for future International Space Station missions. From this point of view, it fully deserved its designation as a 'precursor mission'. Some of the innovations were immediately successful and can be further employed with only minor improvements. In a few cases, the initial designs proved to be less robust than expected under operational conditions and major redesigns will result from the 'lessons learnt'. Overall, however, a great deal of experience was gained that will be invaluable to the Agency in its preparations for future long-duration space missions.

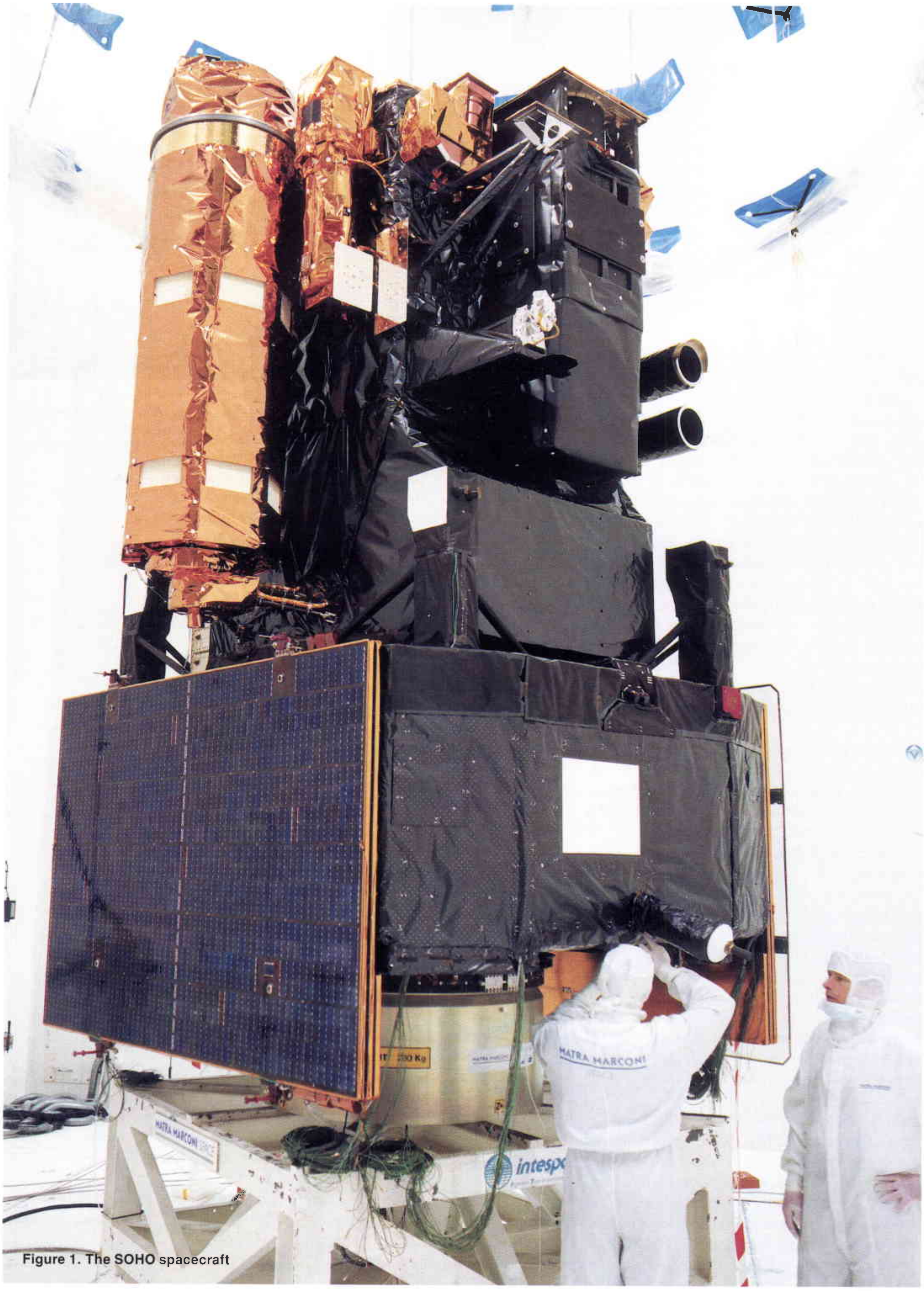


Figure 1. The SOHO spacecraft

SOHO – The Trip to the L1 Halo Orbit

F. C. Vandenbussche
SOHO Project Division, ESA Scientific Projects Department,
ESTEC, Noordwijk, The Netherlands

P. Temporelli
SOHO Project, Matra Marconi Space, Toulouse, France

The first four months of SOHO's life in orbit were devoted to the verification and commissioning of the spacecraft and its experiments, and to the manoeuvres needed to inject it into its final halo orbit around the L1 Lagrangian point. This article reviews the work that took place during this period to ensure that SOHO would be on station and fully operational as quickly as possible.

The scientific mission of the SOHO spacecraft was described in detail in ESA Bulletin 84 (November 1995), while the first scientific results were presented in the August 1996 issue (Bulletin No. 87).

The launch and early orbit phase

SOHO was launched from Cape Canaveral in Florida on 2 December 1995 at 03:08 Eastern Standard Time by a NASA-provided Atlas IIAS launcher (the launch window on this particular day was 51 min, closing at 03:25 EST). The spacecraft was separated from the launcher within 0.021 s of the predicted time and the attitude rates and errors were all within specification.

The Centaur upper stage initially achieved a 185 km x 175 km parking orbit. Following an 80 min coast period, the Centaur's second burn injected SOHO into a transfer trajectory towards the L1 Lagrangian point.

SOHO's first mid-course manoeuvre was performed during 3/4 December and its high accuracy allowed the second, which was actually an orbit-shaping manoeuvre, to be postponed until 4 January 1996. It was followed on 14 February by the halo-orbit injection manoeuvre, with a further small trim manoeuvre on 20 March.

SOHO's final operational orbit is a so-called Class II orbit, with an anticlockwise rotation (when looking at the Sun), at a distance of about 1.5 million kilometres from Earth. The period of this halo orbit around the L1 Lagrangian point is approximately 178 days.

The commissioning activities

The commissioning activities that took place during SOHO's journey to the halo orbit were part of an exhaustive, predefined scenario laid down in the Launch and Early Orbit, and Integrated Orbit Checkout Plans drawn up by ESA and NASA.

Immediately after launch, the performance of the spacecraft's subsystems was evaluated. Spacecraft commissioning then began and continued throughout the transfer phase to, and after SOHO's injection into, the final halo orbit. A total of 42 different commissioning tests were performed, some of which were repeated several times, to verify the overall health and performances of the various spacecraft subsystems. The commissioning testing also had to be carefully interleaved with the experiment switch-on and instrument-commissioning activities being conducted by the scientific investigators.

Figure 2. Launch of SOHO on 2 December 1995 from Cape Canaveral aboard an Atlas II-AS vehicle

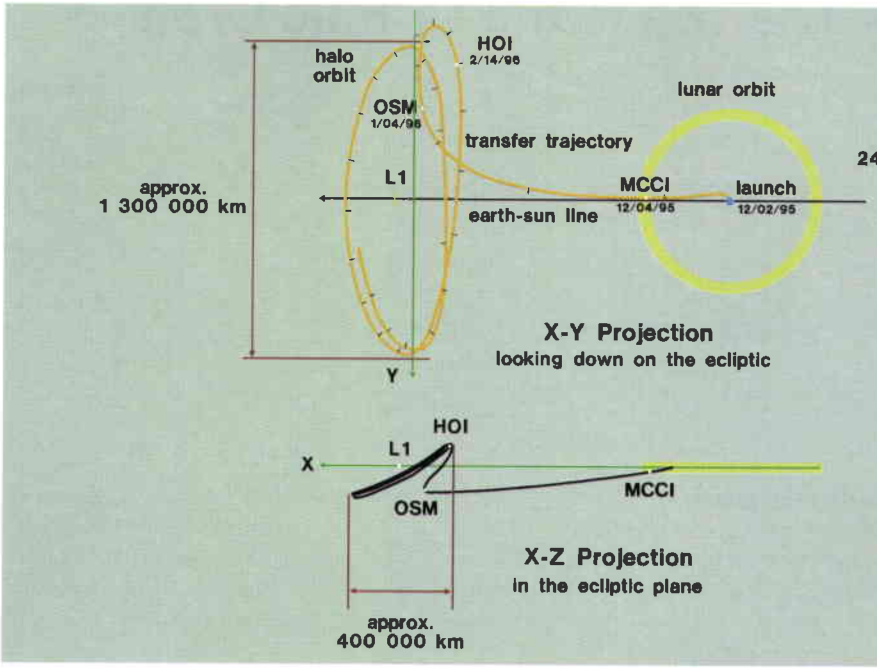


Figure 3. The SOHO transfer trajectory and final halo orbit around the first Lagrangian point (L1)

SOHO Commissioning and Early Operations

1. Launch and Early Orbit Phase: 2/21 December 1995
   - Service Module: switch-on and deployment activities; commissioning; power budget subsystems evaluation
   - First mid-course correction manoeuvre
   - Experiments: GOLF door closure verification, MDI start, CCD bakeout
2. Early Experiment Operations: 21 December 1995/2 January 1996
   - Service Module: subsystem evaluation; fuel budget
   - Experiments: GOLF 2, VIRGO 1, MDI 1 & 2 (partial), SUMER 1, CDS 1, LASCO-EIT 1, UVCS 1 & 2 (partial), SWAN 1 & 2, CELIAS 1 (partial), CEPAC 1-5
3. Second Mid-course Correction to Maximum Distance: 3/16 January 1996
   - Orbital shaping manoeuvres (2nd mid-course correction manoeuvre)
   - No experiment activity
   - Service Module: commissioning; subsystem evaluation; RF budget
4. Maximum Distance to Halo-Orbit Injection: 11/14 February 1996
   - Halo-orbit injection
   - Service Module: subsystems and thermoelastic evaluation, pointing and microvibration budget
   - Experiments: GOLF 3 & 4, VIRGO 2 & 3, MDI 1 & 2, SUMER 2, EIT 2, UVCS 2, SWAN 3-5, CELIAS 1 & 2, CDS & LASCO
   - Experiments: MDI, SUMER, CDS, LASCO, UVCS, joint calibrations, joint activities with Service Module
5. Halo Orbit: 13/29 March 1996
   - Service Module: subsystems evaluation and final budgets
   - Experiments: remaining commissioning activities; First Month of SOHO Science

SOHO declared fully commissioned on 16 April 1996.

The SOHO observatory was then formally transferred to the scientific community on 16 April 1996.

Power subsystem

SOHO's solar arrays were deployed flawlessly a few minutes after the spacecraft's separation from its Atlas launcher. The discharge from the batteries at the time of solar-array deployment was not more than 7 Ah per battery (each of 24 Ah capacity) and with a stable temperature of 23°C.

A full power-budget analyis was completed just after launch and repeated, including a trend analysis, at the end of the commissioning phase in March 1996. SOHO's power system proved to be working nominally and the estimated power margin after five years in orbit is predicted to be 7%.

Radio-frequency (RF) subsystem

The first RF signal from SOHO was acquired by the Madrid ground station after the spacecraft's separation from the launcher, 2 h 1 min 41 s after lift-off. The communications uplink was established immediately after this first signal acquisition for the main and redundant transponders.

The RF subsystem was then fully verified the day after launch, again at the beginning of January when SOHO was at almost maximum distance from the Earth (i.e. 1.5 million km), and once more at the end of March during the final commissioning phase. The design margins of 3 dB on the telemetry and telecommand links have been confirmed as being met.

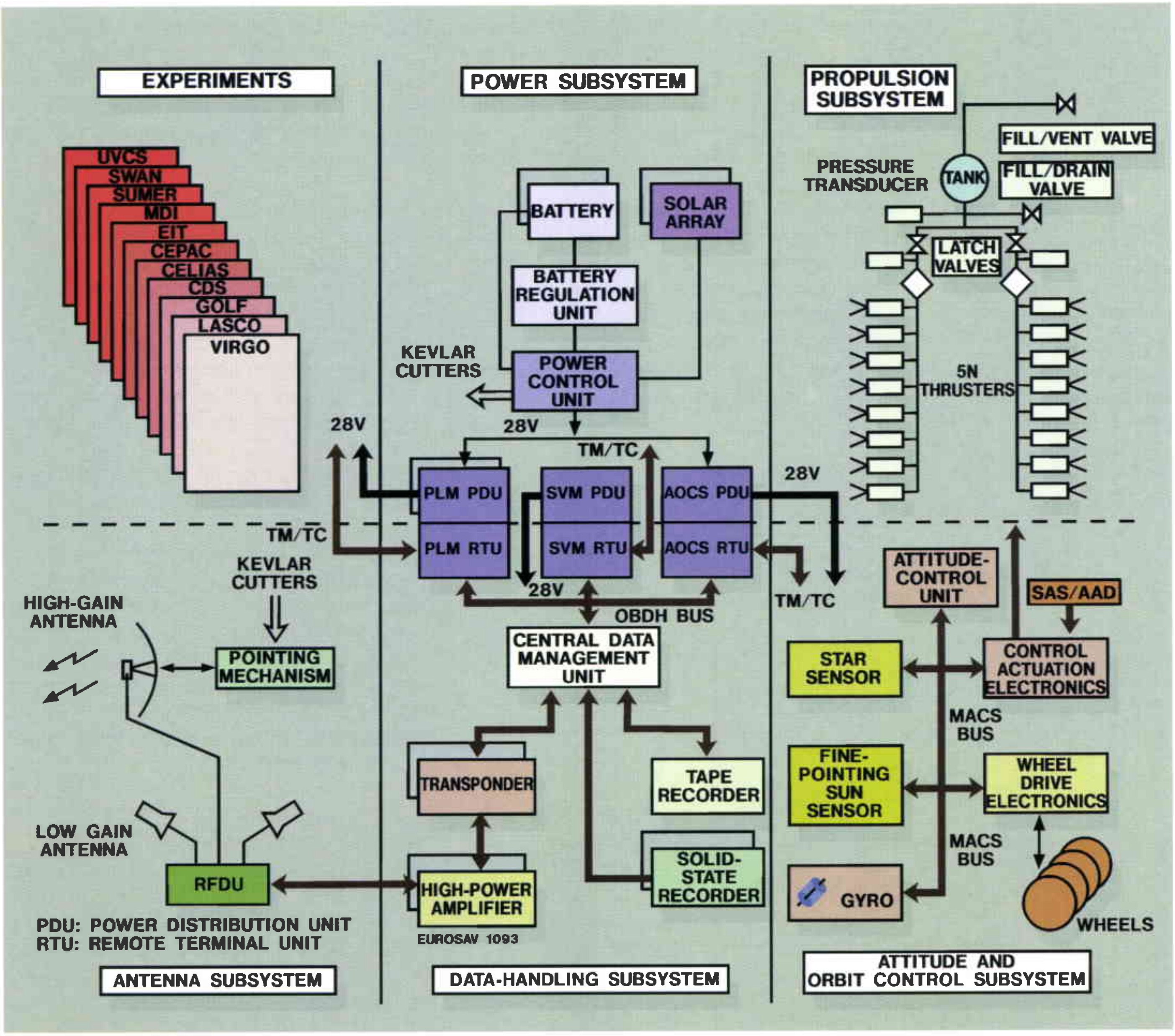


Figure 4. The electrical architecture of the SOHO spacecraft

The antenna pointing mechanism and the high-gain antenna performed nominally during a scheduled 360° roll of the spacecraft. The redundant transponder and high-power amplifier have also been exercised and behaved nominally, and the redundant receiver has been fully tested.

The RF system is therefore confirmed to be working nominally.

Data-handling subsystem

SOHO's data-handling subsystem has also been shown to be working correctly. The on-board time used to correlate all SOHO data is well within the design specification of ± 5 ms of drift over 2.5 days.

The solid-state recorder, with its full capacity of 2 Gbit, is being used every day to retrieve the data generated out of ground station visibility. Its automatic onboard error detection and correction functions have been exercised, with Single-Event Upsets (SEUs) being detected at an average rate of one per minute. All errors have been corrected, which results in a zero bit error rate. The onboard tape recorder has also been successfully commissioned.

All of the operational data-handling modes have been exercised and shown to be working correctly.

Attitude and orbit control subsystem

All the Attitude and Orbit Control subsystem modes have been tested, including the emergency Sun reacquisition mode, which was triggered on 3 December 1995. Both the nominal and redundant chains have been tested.

Reaction wheels 1,2 and 3 are used nominally, and number 4 has also been commissioned. The reaction-wheel capacity in combination with the spacecraft perturbation torques is such that wheel momentum management is necessary only once every eight weeks on average.

The sensitivity of the Star Sensor Unit (SSU) to Single Event Upsets (SEUs) has led to the attitude-control unit software triggering a change in AOCS operating mode from the normal star-tracker-based mode to a mode relying on gyroscopes on a number of occasions. A software patch to minimise this occurrence has therefore been defined and uploaded (after extensive validation using the ESTEC independent software validation facility).

Figure 5. Microvibration performance of the SOHO spacecraft's reaction wheels (RW1 and RW2) in pitch and yaw, as detected by the MDI experiment on 20 March 1996. It can be seen here that the Y-axis disturbance due to RW1 was 0.01 arcsec at 40.72 Hz

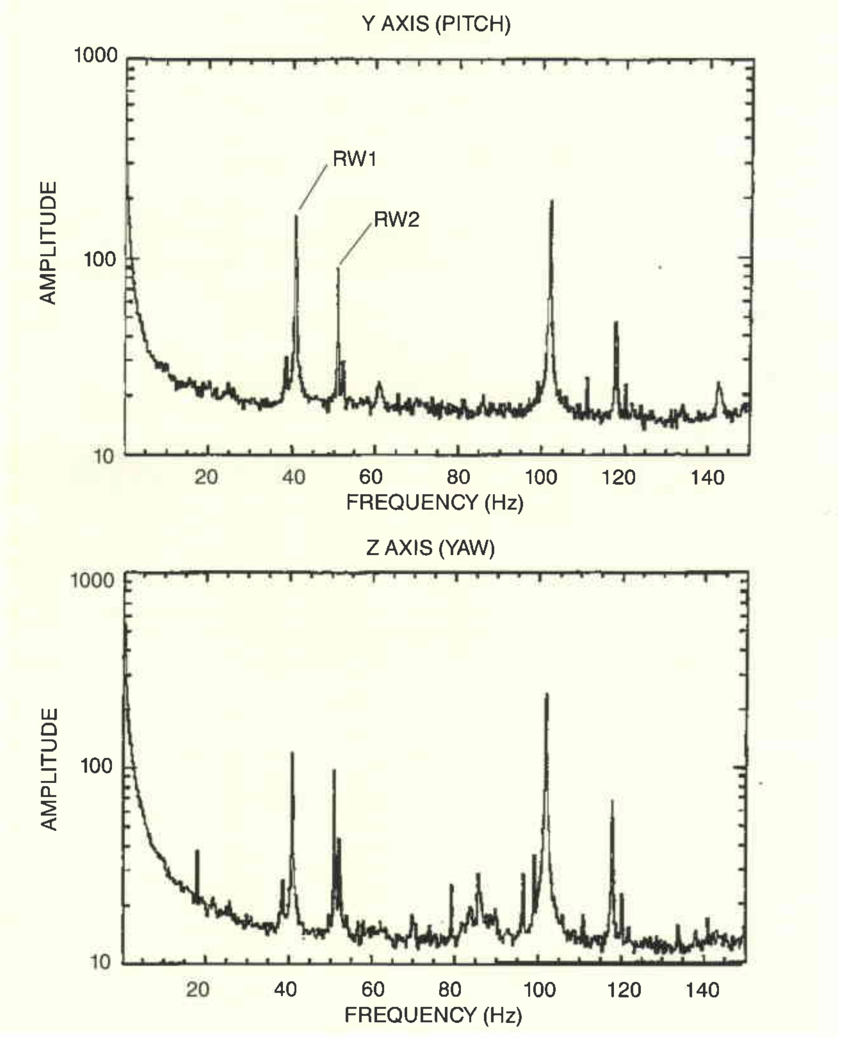


Table 1. SOHO's absolute pointing performance

	Expt. Axis	CDS	EIT	LASCO	MDI	SUMER	UVCS
In Orbit	Y	3'57"	3'20"	2'49"	2'34"	5'15"	3'20"
	Z	-24"	-12"	31"	+ 1'25"	45"	37
Before Launch	Y	44"	37"	-1'51"	1'12"	-58"	3'46"
	Z	-1'34"	-38"	-1'27"	45"	1'32"	2"

Microvibrations and pointing

A series of spacecraft commissioning tests and experiments were conducted in February/ March 1996 to evaluate the spacecraft's microvibration and pointing-stability performance, covering:

- experiment motions with Fine Pointing Sun Sensor, MDI (Michelson Doppler Imager) and SUMER (Solar Ultraviolet Measurement of Emitted Radiation) experiments monitoring
- MDI data to log microvibration from the reaction wheels and other disturbances. (The MDI experiment has its own image pointing control system to reject attitude disturbances. The measurement principle was calibrated during the ground spacecraft microvibration test).

The microvibrations generated by the UVCS (Ultraviolet Coronagraph Spectrometer) roll at 20 Hz and 10 Hz, the SUMER focussing mechanism, wheels 1,2,3 and 4 at various speeds and other instrument mechanisms were evaluated. The comparison between the test results and the analysis showed no major discrepancies, with most performance figures better than predicted.

Absolute pointing

The objective of this commissioning test was to verify SOHO's absolute pointing using data obtained from the CDS, EIT, LASCO, MDI, SUMER, UVCS and VIRGO scientific instruments. The results are summarised in Table 1. The in-orbit data are representative of the actual line-of-sight pointing of the instruments when the spacecraft is attitude-controlled using the fine-pointing Sun sensor, and therefore the end-to-end absolute pointing performance can be assessed. The ground-test data, by contrast, reflect only the pointing performances at the experiment interfaces (reference optical cubes).

The results of these tests showed the spacecraft's absolute pointing performance to be within specification. After the commissioning phase, SOHO spacecraft pointing has been readjusted to compensate for the small observed bias of the LASCO and EIT instruments towards the south pole of the Sun (about 3.5 arcmin). A number of other experiments, such as UCVS, SUMER, CDS and MDI, could realign their lines of sight individually.

Propulsion

SOHO's propulsion subsystem behaved nominally during the early-orbit, manoeuvring and wheel-management phases.

Thermal
Two full assessments of the spacecraft's thermal performance were conducted, during the early-orbit phase (8 December 1995) and late in the commissioning phase (27 March 1996) when the experiments were operational. Mathematical thermal models had been run using solar constant values provided by the VIRGO experiments in order to evaluate the ageing of the Sun shield.

All the spacecraft temperatures were found to be well within their design limits, and are expected to remain so until the end of the nominal mission lifetime.

Software
The SOHO software has performed flawlessly since launch, with more than 90% of the nominal processing having been exercised during the commissioning phase. However, several software patches have had to be uploaded into the Data-Handling Subsystem memory, including one to overcome the emergency Sun reacquisition problem mentioned above, and another to overcome a problem with the VIRGO experiment's cover, described below. Both patches were successfully loaded and have worked adequately. A patch was also loaded into the Attitude and Orbit Control Subsystem memory to improve the SEU filtering. Another software patch to reduce the number of mode switches caused by high-energy particle impacts on the SSU's Charge Coupled Devices (CCDs) has since been prepared and uploaded.

VIRGO's cover
The VIRGO experiment's sensors were commissioned during the first weeks in orbit. One of them, the Luminosity Oscillation Imager (LOI) sensor did not perform correctly. Subsequent investigations conducted by the Principal Investigator, with support from ESA, indicated that the problem was due to the LOI cover not staying open. A solution based on a software patch residing in the data-handling chain was devised based on a combination of mathematical simulation of the mechanism's behaviour and physical testing on a spare model of the VIRGO experiment in the laboratory.

The patch was uploaded on 26 March 1996 and the LOI cover was opened successfully on the second attempt.

Conclusion
On 29 March 1996 the spacecraft was judged as fulfilling all of the specified system requirements and SOHO was handed over to the solar-physics community to begin its scientific mission. The first scientific results were presented to the World at large at a Press Conference in Paris on 2 May 1996 and described in some detail in the previous issue of the ESA Bulletin (No. 87, pp. 7 – 24).

Acknowledgment
Many teams and individuals, too numerous to list here, contributed to make the SOHO launch operations and commissioning phase a resounding success, including key staff from Matra Marconi Space (France and UK), Saab (Sweden), Galileo (Italy), and NASA and its contractors, as well as the ESA Team. Their contributions are gratefully acknowledged.

Advanced Satellite Communications

– The Success of ESA's ASTP and ASTE Programmes

A. Mauroschat
ASTE Programme Office, ESA Directorate for Telecommunications Programmes, ESTEC, Noordwijk, The Netherlands

Satellite communications is both the largest and the fastest-growing sector of space applications. In the field of television broadcasting, for example, there are already more than 22 million analogue satellite TV receivers installed in Europe alone, and the advent of digital TV will greatly increase the number of people who will want satellite TV. The introduction of new services, such as hand-held communications via constellations of low-earth-orbiting satellites, is imminent, and high-speed multimedia communications as part of the Global Information Infrastructure will become a reality by the end of the century. To meet the rapidly growing demand of today's and tomorrow's services, satellite communications systems and applications must evolve just as quickly.

ESA's ASTP and successor ASTE programmes are providing many of the advanced technologies and equipment needed for today's and tomorrow's communications satellite systems. Like the ASTP, the ASTE programme not only covers satellite subsystem and equipment developments, but also addresses service developments and the demonstration of end-to-end user applications. For most of these activities inter-operability with the current terrestrial communications infrastructure is a key requirement, in order to ensure the optimum functionality for the Global Information Infrastructure.

Towards the next century: the ARTES programme

ESA is continuing to look towards the future and in 1994 it started the Advanced Research in Telecommunications Systems (ARTES) Programme, which has two primary objectives:
- to promote advanced applications and thereby assist with the development of new markets, and
- to place European industry in a position to play a significant role in the World market.

The ARTES programme has, at present, 12 elements, ranging from studies and investigations to the development and demonstration of new satellite payloads and associated services (see inset). Additional elements will be defined as the need for new developments or activities arises.

One of the most exciting areas within the ARTES Programme is the development of Advanced Systems and Telecommunications Equipment (ASTE). Within the ASTE Programme, i.e. ARTES Element 5, European and Canadian firms are designing and developing state-of-the-art hardware and software to meet the requirements of future communication satellites poised to enter the World market.

This article gives an overview of the ASTE Programme (and its predecessor, ASTP) and highlights some of its successful developments.

ESA's approach to satellite communications R&D

ESA's supporting satellite communications programmes actually have a long history: they began in the early 1970s when a Supporting Technology Programme (STP) was created to develop technology for the Orbital Test Satellite (OTS). The STP was then followed by a series of four-year Advanced Systems and Technology Programmes (ASTP) which provided the framework for the European Communications Satellites (ECS) and Maritime Communications Satellites (Marecs), and prepared industry for a number of non-ESA satellite procurements.

ASTP-4, the fourth programme in the series, was then followed in 1994 by ASTE, an on-going programme, which has received subscriptions to date of about 72 million ECU. The emphasis of the ASTE Programme is on new experimental missions and services, and novel systems and equipment. Since the start of the Programme, many areas have been investigated, including:

- Digital satellite broadcasting payloads: development of an experimental on-board programme multiplexer, known as 'Skyplex', scheduled for flight on Eutelsat Hot Bird 4.
- On-board processing and equipment for the next generation of mobile and fixed satellite services: development of high-performance on-board processing and RF front-ends.

- Improved user Earth stations and terminals, including communication control and networking techniques.
- Non-geostationary-orbit satellite communications: study and development of systems and equipment for satellite-based personal communication and audio broadcasting.
- Civil satellite navigation systems: terminal and applications development.
- Data relay: development of advanced equipment for optical and S- and Ka-band user terminals for inter-satellite communications.
- Satellite platform improvement: design of more cost-effective equipment and subsystems.
- Satellite operations: development of improved satellite control systems.

Many of the studies and developments undertaken under the ASTE Programme are on the verge of becoming commercial products or service offerings, ready for the World satellite communications market.

On-board antenna and beam-forming systems

On ESA's behalf, European industry has developed advanced on-board antenna systems for telecommunications and broadcasting satellites. The activities supported include the development of reflectors, feed systems and direct radiating arrays. A number of engineering/qualification models of new antenna systems have been built under the ASTP Programme. With that experience, industry in turn has been able to develop the expertise required to bid for contracts for operational satellite systems.

The 12 Elements of the ARTES Programme

1. Preliminary Studies and Investigations (on-going)
2. On-board Processing Payloads (on-going)
3. Multimedia Programme Initiative (in preparation)
4. ESA/Industry Telecommunications Partnership Programme (on-going)
5. Advanced Systems and Telecommunications Equipment (ASTE) (on-going)
6. Personal Communications (in preparation)
7. Experiment and Service Demonstration (on-going)
8. Multi-Orbit Small Satellite Programme (in preparation)
9. Global Navigation Satellite System (Step 1) (on-going)
10. Global Navigation Satellite System (Step 2) (to begin upon completion of Step 1)
11. Satellite Digital Broadcasting (in preparation)
12. Little-LEO Messaging System (on-going)

Figure 1. A Ku-band reconfigurable antenna system (Alenia Spazio)

Some of the highlights to date are:

- S-, X-, Ku- and Ka-band dichroic reflectors for the NASA Cassini project (Alenia)
- Shaped reflectors for Ku-band Orion and Eutelsat (Matra Marconi Space)
- Shaped reflector for the ESA Artemis Ka-band feeder link antenna (CASA/Alenia)
- Polarisation-sensitive C- and Ku-band reflectors for Chinese DFH-3, Orion, and Eutelsat (DASA/MMS)
- Steerable, rotatable, elliptical-beam reflector antenna for Eutelsat (Alenia)
- Ku-band feed systems for Italsat satellites (Alenia)
- Ku-band feed systems for Eutelsat/Hispasat (Alcatel/Alenia/CASA)
- C-band feed system for Intelsat-VIII and DFH-3 (DASA)
- L-band planar-array technology for Japan's MT-Sat satellite (Alcatel).
- Planar-array technology for ESA's Envisat (CASA).

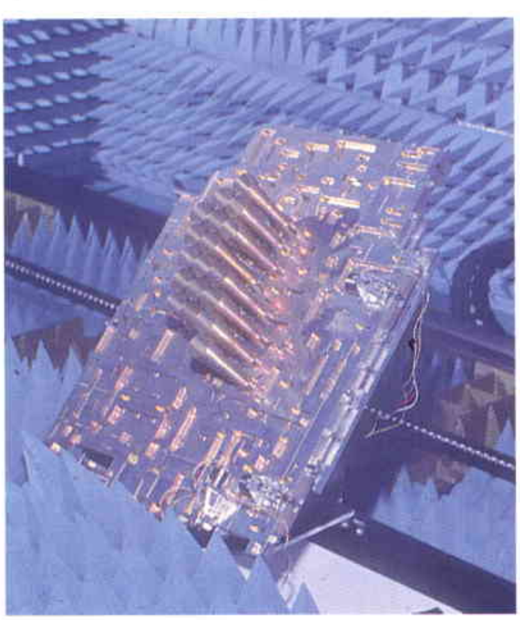


Figure 2. A Ku-band reconfigurable antenna system (CASA)

Shaped reflector systems are currently dominating the Ku-band fixed satellite service. Mobile and Intelsat C-band systems already use flexible beam-forming networks in the antenna feed system. The requirement for such systems is expected to grow and extend to other other frequencies, such as the Ku- and Ka-bands.

Under ASTP, key elements have been developed to respond to those specific requirements. They include high-power analogue and digital beam-forming networks. Two analogue high-power beam-forming systems are shown as examples. They were parallel developments, undertaken to engineering-model standard, of Ku-band beam-forming networks and the requisite variable power dividers and variable phase shifters. The multi-chip module developed within ASTP for digital beam-forming has recently been selected for flight on the EAST satellite proposed by Matra Marconi Space (UK).

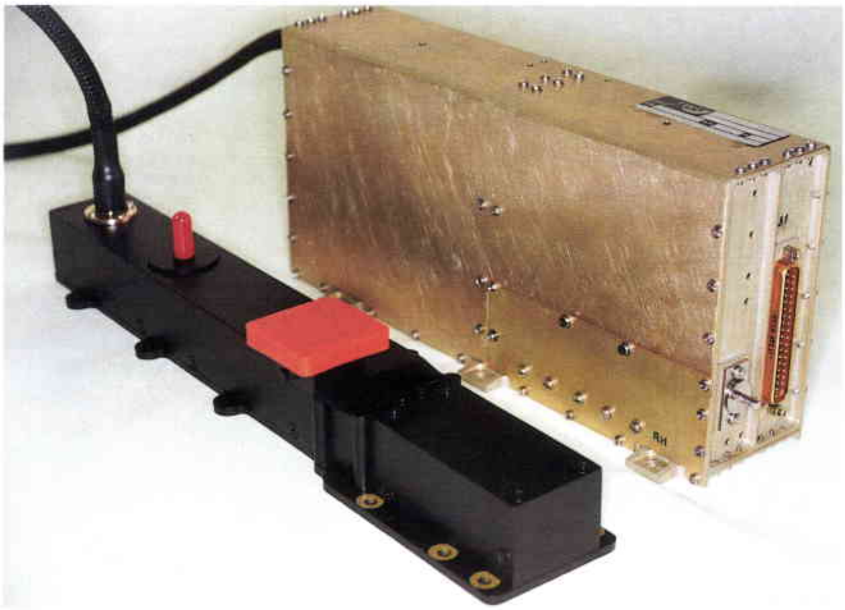


Figure 3. A Travelling-Wave-Tube Amplifier (FIAR)

On-board radio-frequency and baseband equipment

In support of the current and future satellites, ESA has expended great effort in the development and improvement of RF equipment for satellite payloads, including power amplifiers, low-noise amplifiers, up- and down-coverters, switch matrices, filters, multiplexers and local oscillators. Key goals for these developments are: improvement of electrical performances (e.g. efficiency of power amplifiers), improvement of reliability, miniaturisation, cost reduction, and reduced time-to-market.

Some of the highlights of the developments undertaken are:
- Skyplex, an on-board multiplexer to be flown on a Eutelsat in 1997, which allows up to six independent digital television signals to be broadcast on one satellite channel (Alenia Spazio and subcontractors are currently designing the unit)
- SAW filters (AME)
- Ku-band solid-state power amplifiers (MIER Comunicaciones)
- Frequency generation units (Alcatel Bell).

Important development work has been performed within the ASTP Programme in the area of travelling-wave-tube amplifiers (TWTAs). FIAR's 135 W TWTA is under manufacture and will be flown on the Eutelsat HotBird-4 satellite at the end of 1997. The development of a fully integrated microwave power module is planned in the current phase of the ASTE Programme.

Ground terminals

Eighty percent of the satellite communications market is in the ground segment – in other words, the sale of satellite terminal equipment and the provision of value-added services. The space segment itself – satellite production, launch and operations – accounts for the other 20 percent. In addition, the ground segment is the fastest-growing and most competitive sector.

Within the ASTP and ASTE Programmes, therefore, the focus has been on the development of satellite terminals, networks and associated applications for broadcasting, fixed and mobile satellite services.

In the broadcasting area, ESA has emphasised the development of digital transmission systems, based on digital satellite television and on future satellite audio broadcasting channels.

In the fixed satellite service area, novel ground-terminal systems and associated applications have been studied, designed and developed. The focus has been on addressing applications such as digital satellite newsgathering, video conferencing, portable personal communications, and low-data-rate data collection and remote control. High-speed satellite links for the backup of fibre-optic transmissions and the connection of terrestrial network nodes is another highlight of the ASTP and ASTE Programmes. Several of these developments are already at an advanced stage and about to reach the market.

For mobile satellite services, ground terminals and networks have been developed for operation with the new-generation regional European mobile satellite payloads: EMS (the European Land Mobile System) which was launched in August this year on the Italian satellite, Italsat-F2, and LLM (L-band Land

Mobile) which will fly on ESA's Artemis satellite. Small terminals – either vehicle-mounted or suitcase-style – have been developed for land-mobile communications.

Several of these developments have been extremely successful. Some examples of the new technologies are:

- Arcanet: a portable VSAT for telephone, fax and data communications (Indra Espacio)
- TSAT 2000: a low-cost VSAT system for low-data-rate applications (TSAT)
- Pico Terminal: a portable Ka-band terminal for remote data communications (MPR, IAS Graz)
- PRODAT: a vehicle-mounted L-band data terminal for security applications (FIAR)
- MSBN: a vehicle-mounted L-band voice terminal for closed user groups (FIAR).
- Digital 155 Mbit/s SDH Satellite Modem (Newtec).

Electrical power systems

Electrical power is one of the satellite's most fundamental requirements, given that loss of onboard power equates to the loss of the space mission.

The onboard power-system requirements have increased significantly for communication satellites as the payload power levels have been rising and satellite lifetimes have been increasing over the last three decades, reaching up to 15 years for today's commercial communications satellites.

To ensure that European industry is prepared for the changing requirements, ESA has

a

b

c

d

e

f

Figure 4.
a. Arcanet (Indra Espacio)
b. TSAT 2000 (TSAT)
c. Pico terminal (MPR, Joanneum Research)
d. PRODAT terminal (FIAR)
e. MSBN mobile terminal (FIAR, VTT, Ylinen)
f. Digital SDH satellite modem (Newtec)

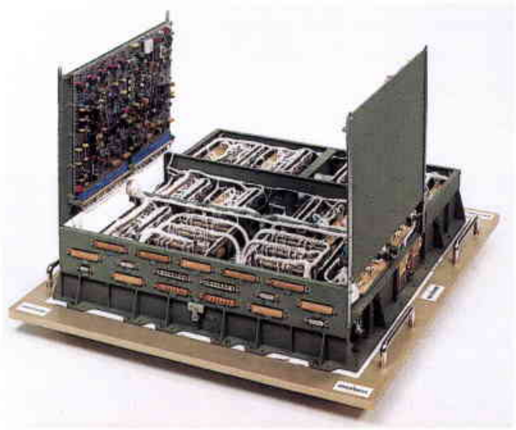


Figure 5. An integrated power conditioning unit (Alcatel ETCA)

undertaken work in all areas related to the satellite's electrical power system: solar arrays including solar cells, batteries, and power control and distribution.

Two of the most successful developments undertaken within ASTP and ASTE are the integrated power-conditioning unit and advanced rigid four- and five-panel solar arrays.

Attitude and orbit control systems

Until a few years ago, requirements for attitude and orbit control systems (AOCS) for communications satellites were focussed on geostationary satellites. Low, medium and high Earth orbits (LEO, MEO and HEO) have only recently been considered for communications satellite missions. ESA, for example, has been studying a HEO satellite concept, called Archimedes, which would primarily be used for digital audio broadcasting. Such missions impose different constraints to the traditional geostationary (GEO) mission, particularly where onboard autonomy and low-cost, low-complexity AOCS solutions are concerned.

Figure 6. Advanced rigid solar arrays (Fokker Space)

In support of communications satellite programmes in such new orbits, as well as those in the conventional GEO orbit, ESA has devoted considerable effort to AOCS-related areas, including the development of sensors, attitude and orbit actuators, and the associated onboard data processing.

Two highlights of such ASTP and ASTE developments are the improved infrared Earth sensor developed by Officine Galileo and the magnetic-bearing momentum wheel developed by Teldix Bosch Telecom.

Satellite operations

Satellite operations are a major driver of the overall cost of a satellite system mission. Traditionally, satellite integration and testing, in-orbit commissioning and normal operations have been very complex procedures performed by large teams supported by special high-performance computers. Within ASTP and ASTE, ESA has undertaken a number of activities to simplify these procedures and reduce costs. Because of the highly competitive nature of communications satellite services, the cost element is particularly important.

One focus of ESA's activities has been the development of a low-cost, stand-alone simulation, testing and operations tool based on the new worldwide CCSDS (Consultative Committee for Space Data Systems) telemetry and telecommand standard. It includes the development of a front-end work station that converts the packetised CCSDS space-to-ground link to baseband, a telemetry and telecommand graphic display unit, and a satellite simulator that interfaces with the CCSDS work station and simulates all basic satellite functions.

The application of artificial-intelligence-based systems to satellite operations has also been

Figure 7. A magnetic-bearing momentum wheel (Teldix Bosch Telecom)

studied. It could assist spacecraft operators in coping with the high complexity onboard the satellite and enhance their ability to detect and resolve anomalies.

Another example of a successful ASTP development is the low-cost satellite simulator for next-generation satellites, which is a very useful tool for satellite, subsystem and payload testing during satellite integration and operations.

Data-relay services for space users

A number of low-Earth-orbiting (LEO) satellites will be launched within the next decade, including Earth-observation, science, manned and military-reconnaissance missions. Conventionally, data generated by the LEO instruments is stored onboard the satellite – a far from failsafe method – and transferred in high-data-rate bursts to strategically placed ground stations during the short periods when the satellite is in view.

A more attractive alternative is to transmit the data in real time to the ground via a data-relay satellite in geostationary orbit. This offers the advantage of prompt data transfer to the users, eases RF downlink requirements, and considerably simplifies the ground segment by reducing the number of ground stations needed to service the system. Optical terminals offer potential advantages of lower mass and power consumption, and smaller antenna size and footprint compared to microwave alternatives for such inter-orbit links.

ESA has programmes underway to place data-relay satellites in GEO within the next decade. The first to fly will be Artemis in 1999/2000 an experimental satellite for testing and operating these new telecommunications services. It will carry a revolutionary laser data-relay payload called SILEX (Semiconductor Laser Inter-satellite Link Experiment). Using laser communications, SILEX will be able to receive data from LEO satellites (initially the French Spot-4 satellite) and relay it in the Ka-band feeder link to user ground stations at very high data rates. Being bi-directional, it will also relay commands from the Control Centre to a LEO spacecraft via Artemis.

Japan is also preparing a data-relay user spacecraft, OICETS, a LEO satellite that will carry a laser terminal for communicating with the SILEX terminal on Artemis.

ESA has also been looking further ahead than the SILEX programme, into the future of optical inter-satellite communications. Three directions have been taken within the ASTP and ASTE Programmes:

- The development of small LEO terminals for high-speed communications with SILEX, such as the Small Optical User Terminal.
- The development of very-high-speed communication LEO and GEO terminals based on high-performance solid-state lasers.
- The development of a very small optical terminal for short-range inter-satellite communication, for example to link constellations of satellites flying in LEO presently under development in ASTE.

In support of RF data-relay services, both S-band and Ka-band user terminals are being developed within the ASTP and ASTE Programmes for use onboard LEO satellites. An experimental S-band terminal will be flown on Spot-4 to transmit its telemetry data to ground using ESA's Artemis and the Japanese Comets data-relay satellites.

Figure 8. A Small Optical User Terminal (Matra Marconi Space, CAL, SPAR, Spacebel)

Satellite navigation

At present, satellite navigation is based on the US military Global Positioning System (GPS) infrastructure and its Russian counterpart GLONASS. Ultimately, a global navigation satellite system must come, at least partially, under civil institutional control. It is of strategic importance that Europe participate in such a system, as this will allow independent access for services such as air-traffic navigation and surveillance, and a variety of services for maritime and land applications, such as an Intelligent Highway System.

ESA, the European Union and EuroControl (the European air-traffic-control organisation) are cooperating in the deployment of an initial European overlay, the Global Navigation

Figure 9. A multistandard receiver for satellite navigation (Sextant Avionique, Thomson CSF, CIR, GMV, Univ. of Leeds)

Satellite System (GNSS-1), that will complement the GPS system. This system will be composed of a network of ground stations, and control and processing facilities as well as geostationary navigation transponders, in order to provide GNSS-1 users with enhanced satellite-navigation performance over the European region. To this end, additional ranging signals, integrity information and wide-area differential corrections will be broadcast to the users.

ESA has already started work on the GNSS-1 ground system within ASTP and ASTE. A multi-standard receiver demonstrator has been developed for use in field trials to support the definition phase of the system.

In addition, other activities are planned within the ASTE Programme which will include advanced applications of navigation receivers onboard satellites. One particularly promising application is the use of GNSS receivers for the attitude and orbit control of LEO satellites, which has tremendous market potential in view of the proposed LEO satellite constellations for future global personal and multimedia communications.

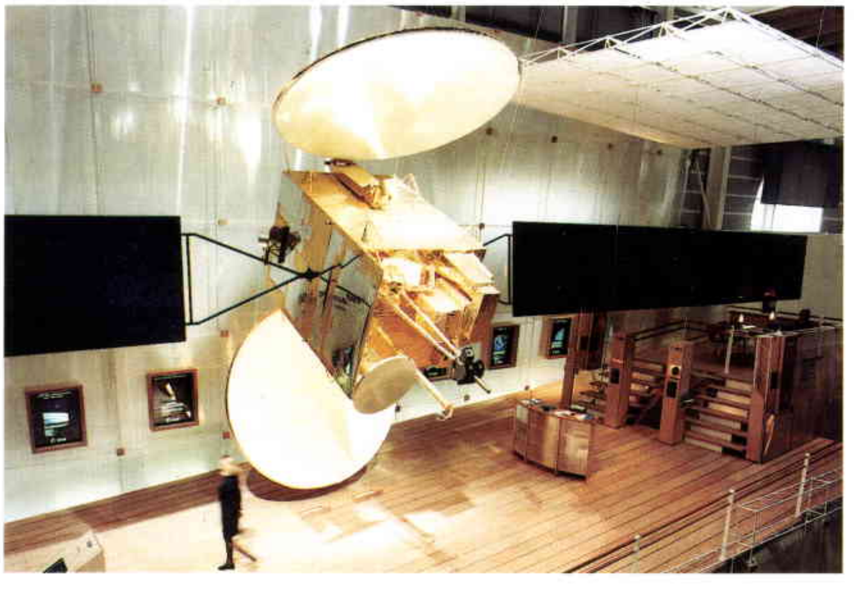


Figure 10. Full-scale model of the Artemis satellite on display at Telecom '95 in Geneva

Exhibitions

The achievements of the ASTP and ASTE Programmes have been displayed at various exhibitions, including the ESA stands at Telecom '95 in Geneva and at the AIAA 16th International Communications Satellite Systems Conference and Exhibition in Washington DC in February this year. A special brochure was produced for this event explaining ESA's satellite communications support programmes and giving a catalogue for the items exhibited (ESA BR-115, available from ESA Publications Division).

Programme management and information system

The ASTE Programme is managed by the ASTE Programme Office within the ESA Telecommunications Directorate. The present three-year phase of ASTE includes some 85 activities, with an average contract value of 700 kECU. For the administration and management of these ASTP-4 and ASTE activities, a modern information management tool has been developed. The system contains information on both proposed and approved activities, and on their administrative progress. It is being used for online consulting, as a reporting tool, and for project control of the ASTP-4 and ASTE activities.

Conclusion and future outlook

The first phase of the ASTE Programme has been extended to mid-1997. The second overlaps with the first, covering the period from early 1997 to 1999, and the work plan for 1997 has already been approved. The overall envelope of the ASTE Completion Phase is 100 MECU and the first subscriptions to the programme have already been received.

The ASTE Programme will continue to prepare European industry for the upcoming opportunities of advanced satellite communications. Emphasis will be put on the development of prototype systems in order to reduce the time-to-market and increase European industry's competitiveness in the fierce marketplace of satellite communications. The Programme will focus on the integration of satellite communications systems with advanced applications providing users with complete end-to-end solutions. Activities are grouped into the different satellite communications service areas: Fixed and Broadcast, Navigation and Advanced Mobile Satellite Services, and General Communications Services. In order to reflect the importance of support activities for the Global Information Infrastructure (GII), a new area of activities has been introduced focussing on this domain. Inter-satellite cross-links will be part of the GII and related activities will therefore be undertaken in support of the GII for the provision of future multi-media services via satellite.

The ASTE has continued the success of the long series of ASTP Programmes. This has been recognised by the industrial Telecommunications Advisory Groups and by Delegations through the approval of the second phase of ASTE and the early subscriptions that have already been received. It is an essential element in the successful development of future satellite communications services and applications in Europe and Canada.

Communicating with the Polar Platform/Envisat – The DRS Terminal

J. Mas-Albaiges
Polar Platform Project Division, ESTEC, Noordwijk, The Netherlands

L. Huertas
Envisat System Division, ESTEC, Noordwijk, The Netherlands

The Polar Platform carries a wideband communications system – the DRS Terminal – which will transmit the scientific data generated by Envisat's instruments to the ground via the Artemis data-relay satellite. The characteristics of this Ka-band link impose stringent requirements on both the Terminal's mechanical and electrical elements in order to preserve end-to-end data integrity during the communication sessions. A complex control system is needed to ensure that correct Artemis pointing and tracking is maintained by the DRS Terminal on the orbiting Polar Platform.

Envisat will be the first ESA mission to use Artemis as an integral part of its nominal operational service.

Introduction

For the Envisat mission, the Polar Platform (PPF) will carry a number of Earth-observation instruments that will generate extremely large volumes of scientific data. There will be two different systems available to communicate that data to the ground, one operating in X-band and the other in Ka-band. Like the X-band systems used on ERS-1 and 2, the Envisat X-band system will provide a direct ground link, but data can be downloaded only when the ground station is visible from the Polar Platform. Real-time transmission and a higher information transmission capacity are also needed to cope with the much greater volume of observational data that will be produced by the new generation of Envisat instruments, leading to the addition of the Ka-band system – known as the Data-Relay Satellite Terminal (DRST) – to operate in combination with Artemis.

This will be the first time that an ESA mission has used a DRS service during the routine operational phase. Some four years ago, an Inter-Orbit Communication experiment was sucessfully conducted using ESA's Olympus satellite as the relay between the Eureca retrievable carrier in orbit and the ground (from July 1992 to June 1993).

The Ka-band end-to-end system

Three main components – the PPF, Artemis and the User Earth Terminal – make up the end-to-end system. The Polar Platform's Envisat mission calls for a low-altitude polar orbit with a mean height of 800 km (orbital period approx. 100 min) and a 35-day repetition cycle, providing global Earth coverage for most of the onboard instruments within three days. The Polar Platform is designed to support a four-year Envisat mission lifetime.

Artemis will be located at the 16.4°E geostationary slot, with east-west and north-south accuracies of 0.14°. The greatest range to Envisat will be about 45 500 km, and this worst case has been used as the reference for link-budget computations.

The User Earth Terminal (UET) is the receiving station in the Envisat Payload Data Segment (PDS) responsible for the reception, demodulation and processing of the instrument data. It is a new, dedicated facility to be built at ESRIN, in Frascati near Rome (I). Figure 1 is a schematic of the complete system. The connections between the Envisat and Artemis Operation Control Facilities are also shown.

Ka-band transmission of the scientific data will occur in two stages. The signal will first be sent from the PPF DRS Terminal to Artemis via the Inter-Orbit Link (IOL), which has three 250 MHz channels centred at 26.850, 27.100 and 27.350 GHz. Two channels can be used simultaneously, and each active channel can transmit at 50 or 100 Mbit/s (rate selectable from the ground). Next, this signal is frequency-downconverted to 20 GHz, power-levelled by the Artemis SKDR payload (no further data processing is performed at this point)and relayed to the UET via the Artemis feeder link.

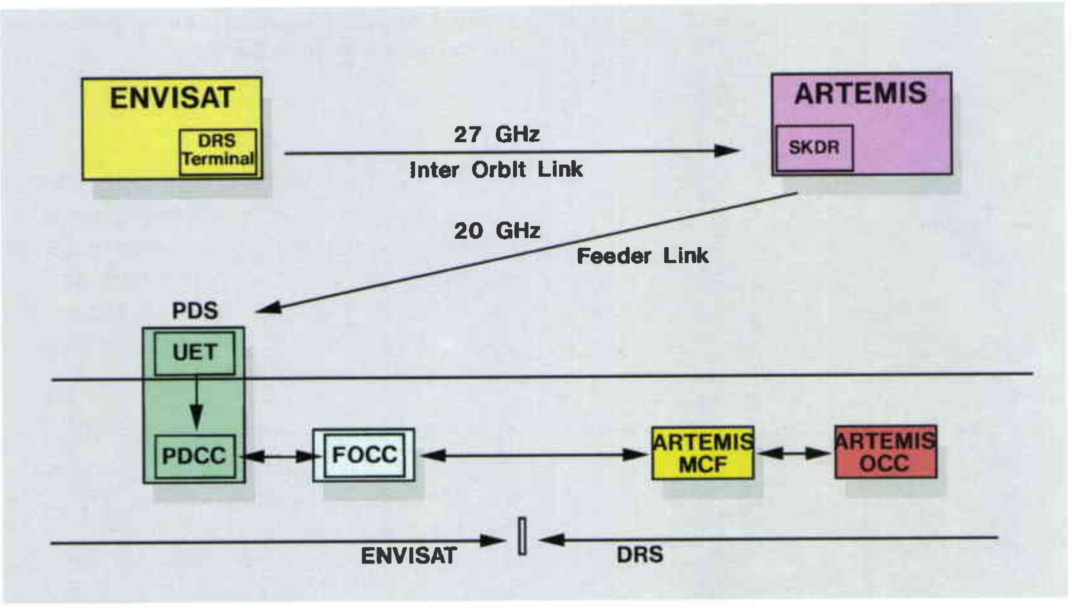


Figure 1. System overview

The Envisat mission planning envisages communication sessions through the DRS lasting an average of 30 min per orbit. The Earth coverage achieved with this baseline is depicted in Figure 2, where the shadowed zones represent areas for which the Ka-band link is not available. This coverage pattern has been computed taking into account the DRS Terminal's exact location on the Polar Platform, some occultation due to the latter's appendages (e.g. the solar array), and finally the Earth shadowing. Occultations observed in Europe, Central Asia or South America can occur in either an ascending or a descending orbit.

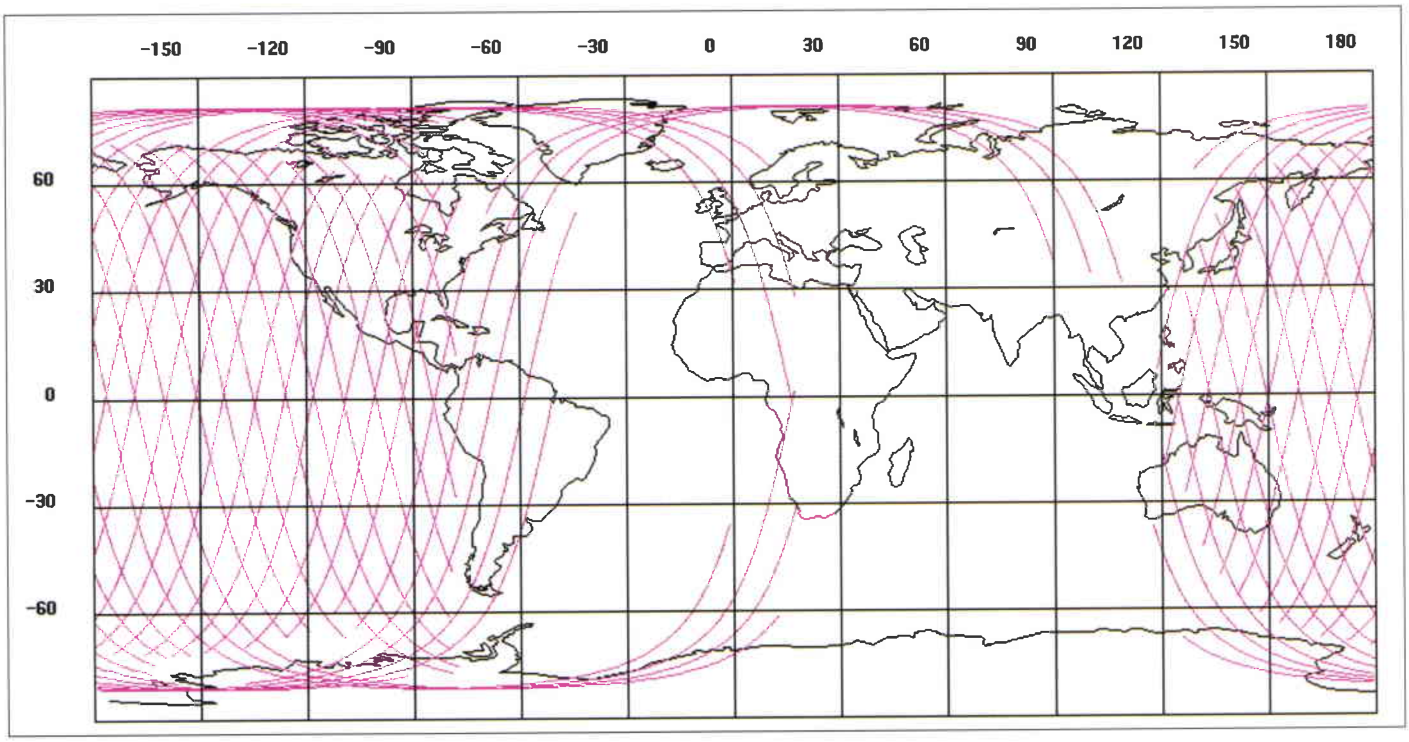
It is estimated that a total of 21 000 such communication sessions between the DRS Terminal and Artemis will take place during the four years of the Envisat mission.

Figure 3 shows the structural model of the Polar Platform in the ESTEC test facilities. The DRS Terminal's antenna is visible on the upper left-hand face of the spacecraft.

The DRS Terminal

The Terminal consists of two parts, the In-Board Assembly (IBA) mounted inside the Payload Equipment Bay (PEB), and the Out-Board Assembly (OBA) mounted externally on the zenith-pointing face of the Platform. The IBA contains all the electronic equipment responsible for RF carrier generation, modulation, signal amplification and filtering. There are three identical RF

Figure 2. Earth coverage with Artemis at 16.4°E



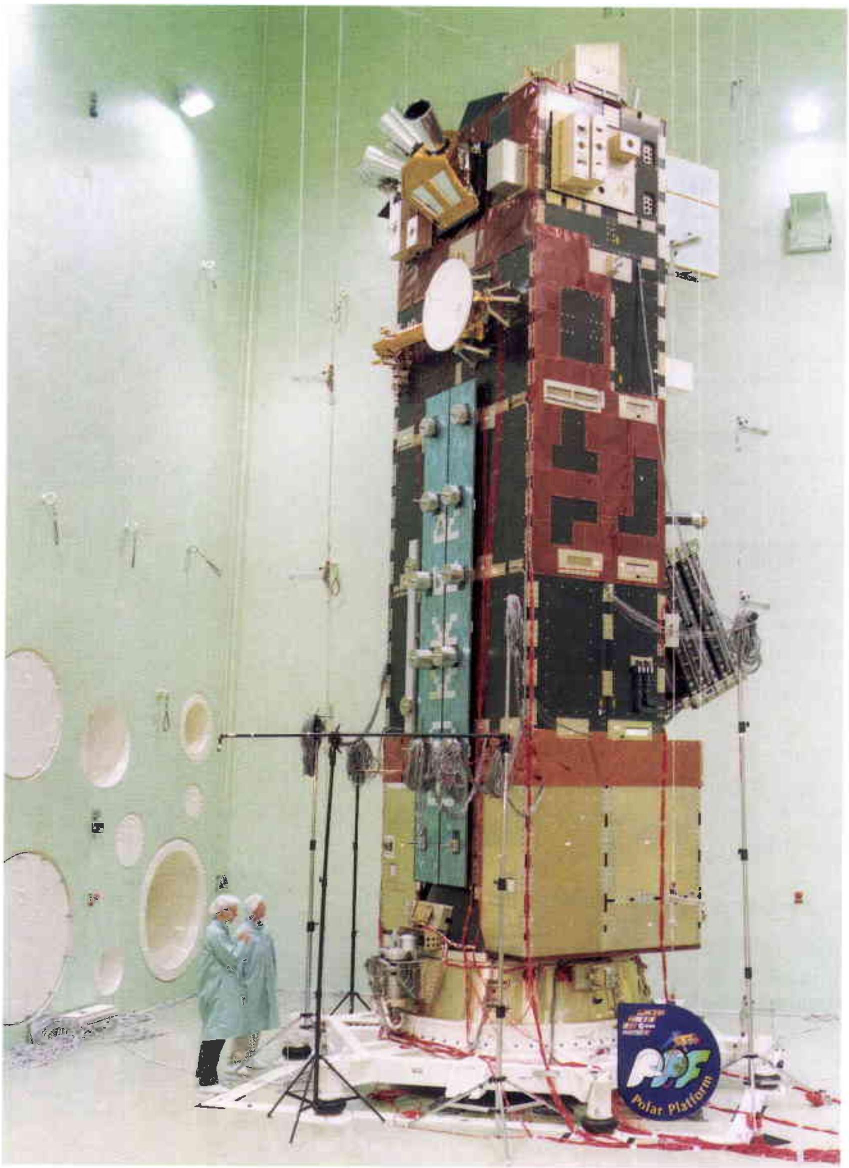


Figure 3. Structural model of the Polar Platform in the ESTEC test facilities (LEAF)

chains centred at the three transmission frequencies assigned to the Inter-Orbit Link. Following the mission requirements, up to two RF chains can be active simultaneously. The third one is a spare. Figure 4 shows the engineering model of the Ka-band Transmit Panel during the test phase.

The OBA contains the mechanical elements that sustain the Ka-Band Antenna and allow the tracking of Artemis during the DRS communication session. The OBA consists of a 2 m-long mast, the Antenna Pointing Mechanism (APM) and the Ka-Band Antenna. In launch configuration, the OBA is stowed as shown in Figure 5. To support this configuration and the subsequent deployment, the OBA includes a hold-down/release and a deployment mechanism. There are four hold-down points located below the Antenna and APM, and the deployment mechanism is at the base of the mast. Once in orbit, the OBA deployment begins after the sequential activation of four pyrotechnic devices housed in each hold-down point. The deployment manoeuvre, controlled by a damping device, lasts approximately 1 min, ending with the mast locked in deployed configuration.

The APM (Fig. 6) has two motor gears mounted on an L-shaped bracket. The motors provide independent rotation axes in azimuth (±165°) and elevation (range 90° to −30°). Both motor gears have optical encoders to record the actual antenna position.

The Ka-band Antenna is a high-gain (44 dB) Cassegrain design with a main reflector diameter of 0.9 m, radiating in right-hand circular polarisation. The RF connection between the IBA and the Antenna is via a waveguide and rotary joints. Thermal control is provided by heaters commanded by the Platform's thermal-control subsystem. The overall OBA is thermally protected by multi-layer insulation.

Functionally associated with the OBA, although physically located within the PEB, are the Antenna Pointing Controller (APC) and the Pointing Mechanism Drive (PMD). The

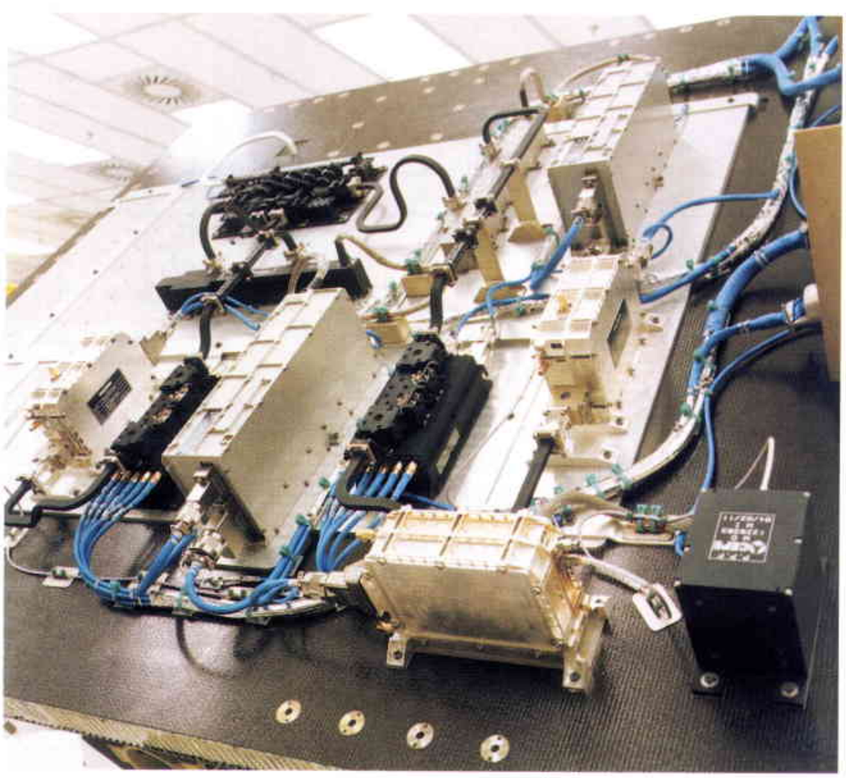
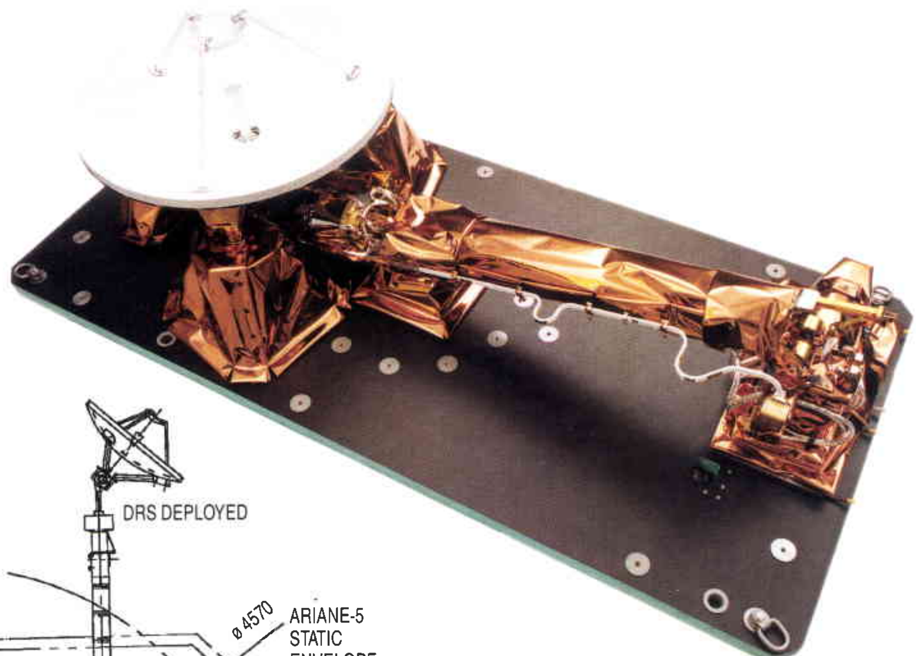


Figure 4. Engineering model of the Polar Platform's Ka-band Transmit Panel. (photo courtesy of Alcatel Telecom)

Figure 5. The OBA in launch configuration (right) and its stowage within the Ariane-5 fairing (below).



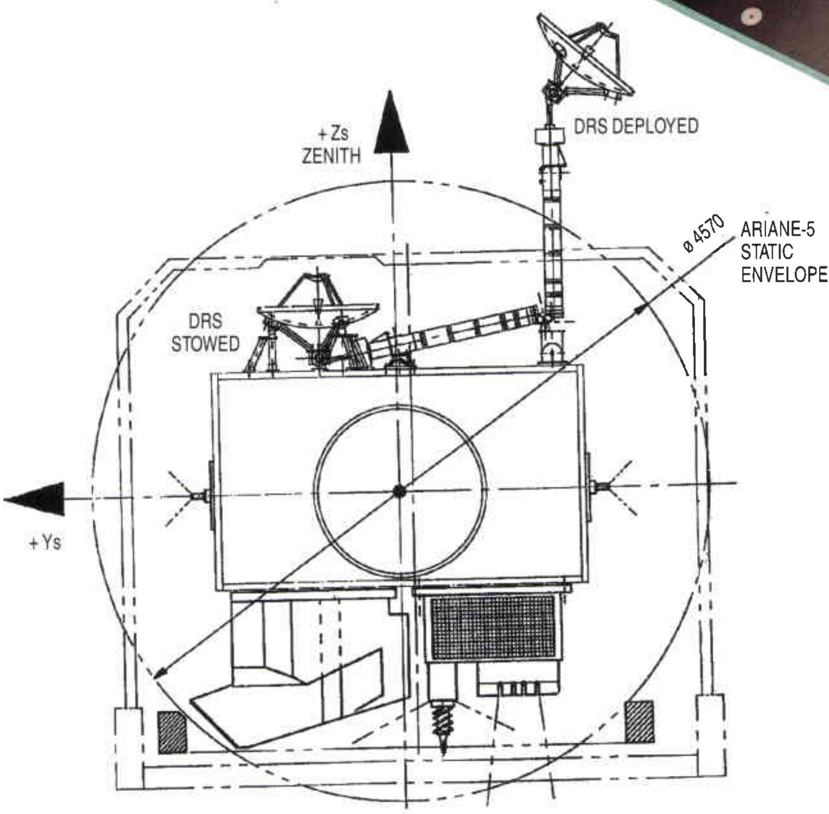
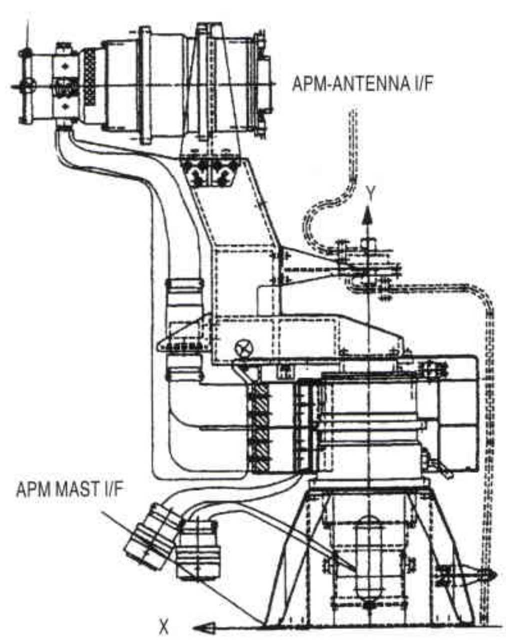


Figure 6a,b. Schematic of the APM (a), and its qualification model (b).
(photo courtesy of Alcatel Espacio/Inta)



a

b

APC controls the Antenna's movement during communication with Artemis. The APC provides two signals, for azimuth and elevation movements, to the PMD, which converts them into the required current levels for driving the APM's motor gears.

The Ka-band data path

Envisat's PEB (Fig. 7) accommodates the data-handling units that interface the scientific instruments with the communications systems. These units collect, format, record and code the instrument data before X- or Ka-band transmission.

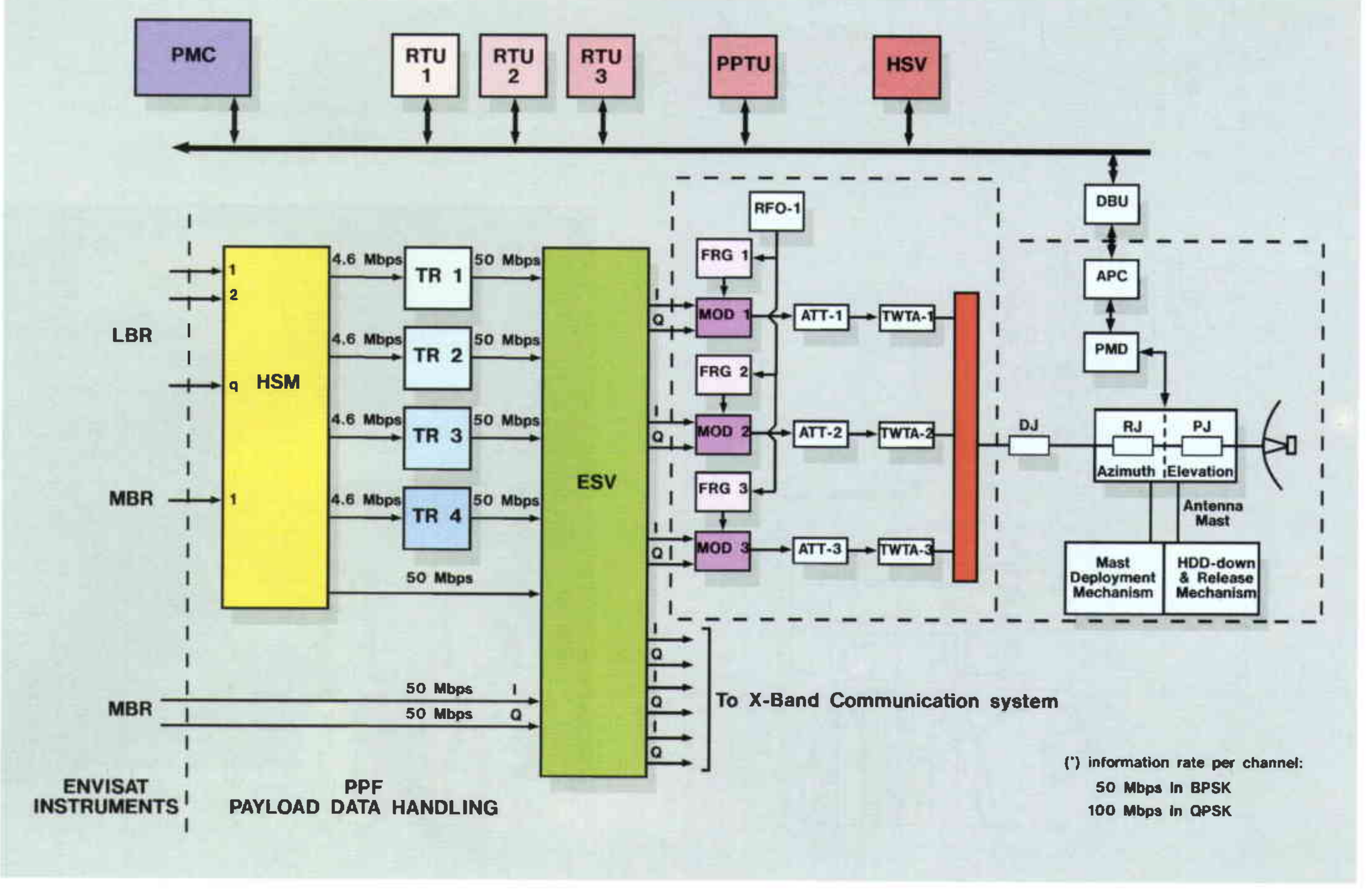
Units like the High-Speed Multiplexer (HSM), Tape Recorders (TRs) and the Encoding and Switching Unit (ESU) are part of the PEB's Payload Data Handling (PDH) system. Others such as the Remote Terminal Units (RTUs), Power Distribution Units (PPDUs) and Heaters Switching Unit (HSU) are peripheral elements to support the data handling and other functions.

The scientific instruments send their data in source-packet formats to the HSM. This unit can handle both Low Bite Rate (LBR) data, for instruments with transmission rates below 10 Mbit/s, and Medium Bit Rate (MBR) data, for instruments with rates below 32 Mbit/s. In both cases the interfaces are asynchronous and each instrument supplies its own clock signal. The HSM collects data from nine LBR instruments – ASAR and MERIS in LBR mode, GOMOS, MIPAS, RA-2, AATSR, DORIS, MWR and SCIAMACHY – and from MERIS in MBR mode. It formats these instrument data into Virtual Channel Data Units (VCDUs) with a Reed-Solomon (RS) protection code.

The HSM sends the LBR information to the four onboard 16-track Tape Recorders (at 4.6 Mbit/s) and an LBR and MBR composite to the Encoding and Switching Unit (at 50 Mbit/s). Each Tape Recorder has a capacity of 30 Gbit and allows data input at 4.6 Mbit/s and playback at 50 Mbit/s. This one order-of-magnitude ratio between the recording and playback speeds is the most challenging tape-recorder requirement.

Then, the Encoding and Switching Unit (ESU) receives data from three different sources: the Tape Recorders and the HSM both at 50 Mbit/s, and the ASAR in High Bit Rate (HBR) mode at 100 Mbit/s. The ESU's architecture provides the flexibility to route the input data from any of these sources to any of the three Ka-band modulator interfaces. Data are differentially encoded and, to increase immunity to noise, half-rate convolutionally encoded. Finally, the data are delivered in BPSK or QPSK format for RF modulation. This

Figure 7. Schematic of the Envisat PEB, showing the Ka-band data-transmission path



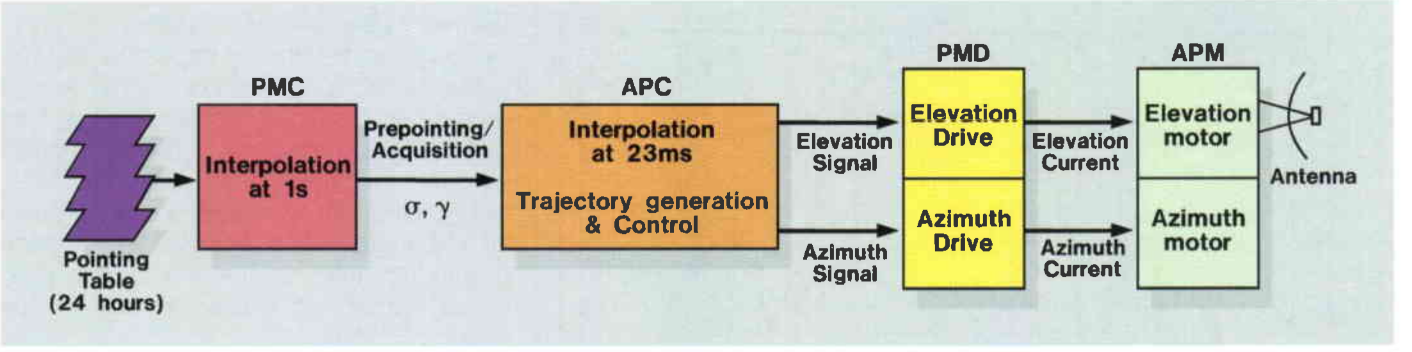


Figure 8. The pointing and tracking functions

unit's high-performance capability must ensure data-processing integrity with less than one bit error for each 50 000 million transmitted bits.

Pointing the DRS Terminal towards Artemis

The communication sessions via DRS will be conducted according to a predefined protocol. Artemis will point its IOL antenna towards the PPF. The Platform's Ka-band antenna boresight must point towards and track Artemis to cope with the relative motion of the two spacecraft during each session. The open-loop pointing approach adopted for the DRS Terminal requires complex algorithms, shared between the ground and space segments, which determine the correct orientation for the antenna and control its movement.

The Envisat mission-control scenario will define the start and end times of the DRS communication sessions during each orbit. With this information, orbitography computations will be performed to define the Ka-band Antenna trajectories needed to locate and track Artemis. From these trajectories, pointing tables containing the required antenna azimuth and elevation angles at 2 min intervals will be derived and uploaded to the PPF on a daily basis and stored by the Payload Module Computer (PMC). The PMC will then perform an interpolation to compute the pointing directions at 1 s intervals, sending two types of commands to the APC: a prepointing command at the beginning of the session to move the antenna from its current position to point towards Artemis and, once in tracking mode, a series of acquisition commands every second conveying the azimuth and elevation angles that the antenna must satisfy 2 s later. The APC will use this information and the actual antenna position supplied by the APM's optical encoders to further interpolate the antenna trajectory at approximately 23 ms intervals. Pulse trains modulated by elevation and azimuth velocities will be sent to the PMD with the same frequency. The PMD will then generate the driving currents for the APM motors to ensure that the antenna describes the desired trajectory (Fig. 8). The pointing accuracy achieved, thanks to the sophistication of the APM's design features, will be better than one thousandth of one degree (0.36 arcmin).

The Antenna Pointing Mechanism is a particularly critical element in the DRS Terminal's performance, not only because of the stringent pointing-accuracy requirements, but also because of the number of operating cycles that it will have to endure during Envisat's four-year mission lifetime. For this reason, the mechanism has been submitted to a 90 000 cycle life test based on a 211° angular excursion profile, with a velocity of 4.2°/s and an acceleration of 0.5°/s^2 (considerably higher that the maximum velocities and accelerations expected during flight). To verify the complete the rotational range, the origin of the angular movement was shifted by a few degrees every 100 cycles. The test showed that the mechanism's functional performance remained within specification and also allowed important design features such as the liquid lubrication to be tested (Fig. 9).

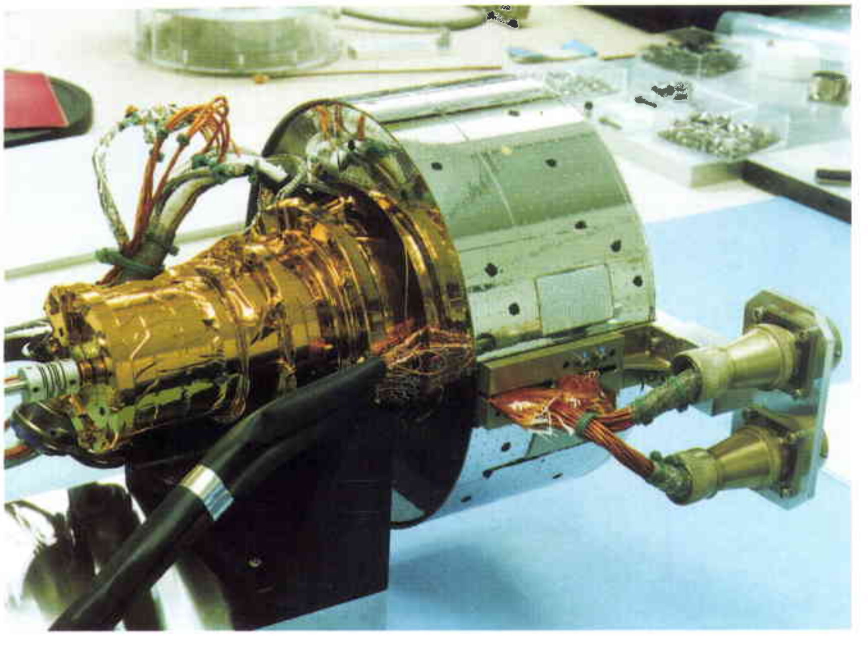


Figure 9. Qualification model of the APM's azimuth motor gear (photo courtesy of Alcatel Espacio/Inta)

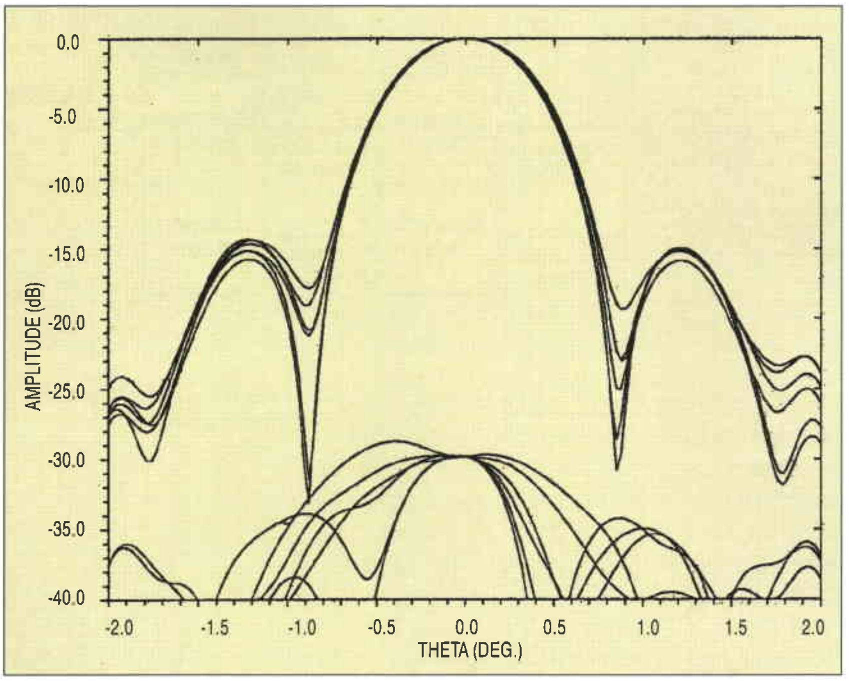


Figure 10. Flight model antenna's co- and cross-polar radiation patterns at 27.1 GHz (courtesy of Saab Ericsson)

Because of the open-loop pointing approach, it is important to consider the factors that can induce pointing instabilities. These factors, such as residual misalignment between the OBA elements, depointing due to thermal distortion, or random errors due to the APM, have been identified, analysed and budgeted for. The appropriate power level and radiation pattern (Fig. 108) from the DRS Terminal must ensure stability of the signal received by Artemis.

Link performance

The Ka-band link is designed to comply with the mission requirement of providing a bit error rate for payload data of better than 10^{-6}, with a link availability of 99%. Table 1 presents the link-budget summary for QPSK modulation, showing that the requisite BER figure is met.

Table 1. Link budget

Inter Orbit Link (IOL)

Link Characteristics		
Availability	99	%
Bit Error Rate	1E-06	
Modulation Type	QPSK	
Information Bit Rate	100	Mbit/s
Transmission Bit Rate	200	Mbit/s
Required E_b/N_0	10.5	dB
Coding	Diff - Conv 0.5	
Coding Gain	5.5	dB
Polarisation	RHCP	
Frequency	27.1	GHz
SKDR Noise BW	234	MHz
PPF Spacecraft		
Transmit Power	58.50	W
Transmit Power (dB)	17.67	dBW
IBA + OBA RF loss	−4.34	dB
Antenna Gain (EOC)	43.93	dBi
EIRP	57.26	dBW
Required EIRP	55.20	dBW
Margin	2.06	dB
Path		
Distance	45 400	km
Space Loss	−214.24	dB
PFD at Artemis	−106.87	dbW/m^2

Artemis Feeder Link

Link Characteristics		
Availability	99	%
Bit Error Rate	1E-06	
Modulation Type	QPSK	
Information Bit Rate	100	Mbit/s
Transmission Bit Rate	200	Mbit/s
Required E_b/N_0	10.5	dB
Coding	Diff - Conv 0.5	
Coding Gain	5.5	dB
Polarisation	Linear Vertical	
Frequency	20	GHz
SKDR Noise BW	234	MHz
Artemis Spacecraft		
Transmit Power	30.00	W
Transmit Power (dB)	14.77	dBW
Total SKDR RF loss	−4.86	dB
Antenna Gain (EOC)	36.8	dBi
EIRP	46.71	dBW
Path		
Distance to UET	40 500	km
Space Loss	−210.61	dB
PFD at UET	−116.43	dBW/m^2
Ground		
UET Receive G/T	37.20	dB/K
C/N_0	90.68	dB
E_b/N_0	10.68	dB
Channel Degradation	2.90	dB
Required E_b/N_0 (with coding gain)	5.00	dB
Margin	2.78	dB
Needed E_b/N_0 for VCDU 10^{-11}	7.75	dB
Needed Margin	0.03	dB

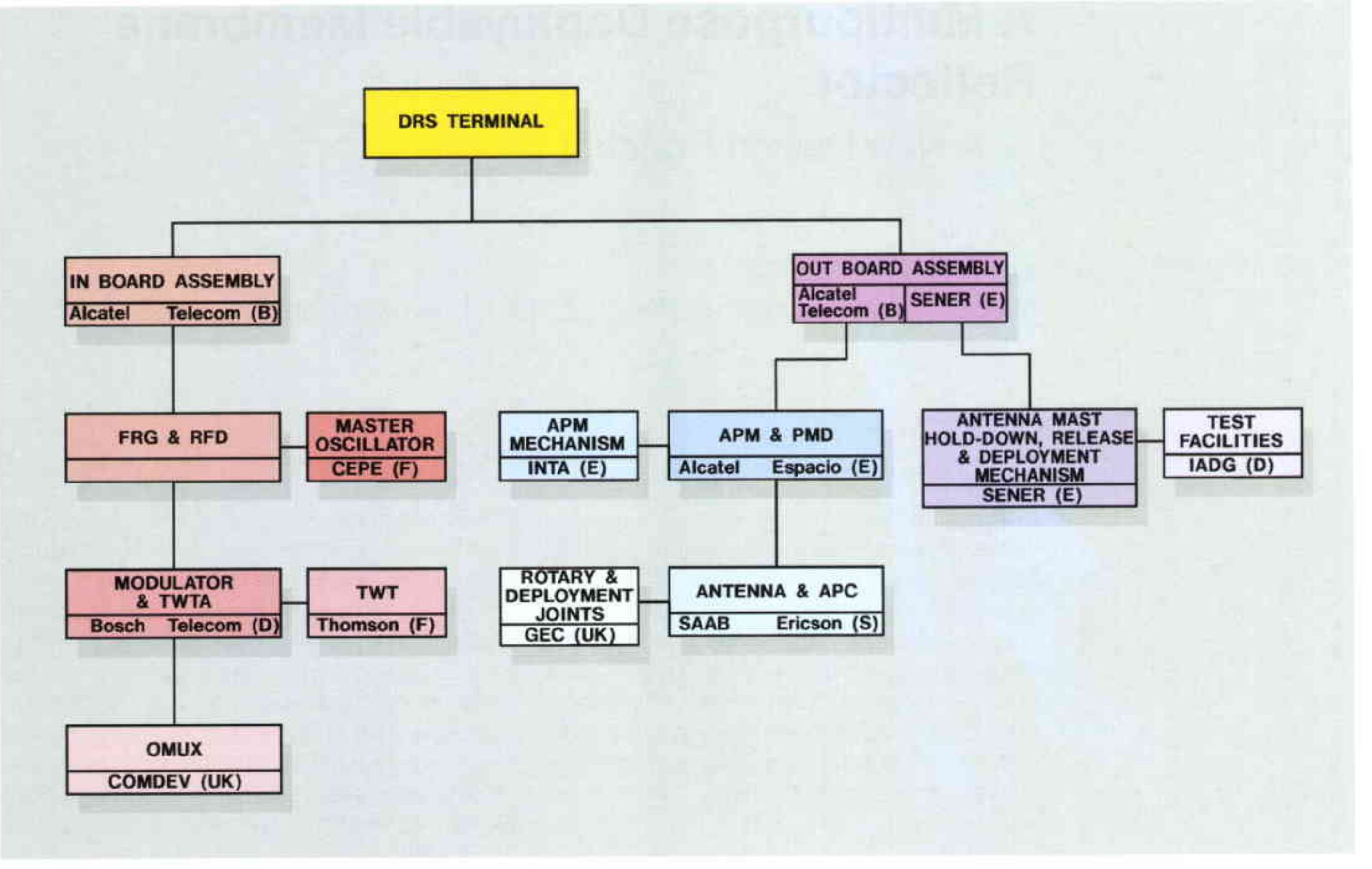


Figure 11. The industrial organisations building the DRS Terminal

On the ground, the signal, once demodulated, is sent to the Viberti and Reed-Solomon decoder. The impact of the coding and decoding sequence used in the Ka-band link has been the subject of a specific study under an ESA contract to analyse and simulate the end-to-end link in terms of the required bit-error and VCDU deletion rate figures. The results show that the required VCDU deletion rate of 10^{-11} is met with a signal-to-noise ratio of 7.5 dB in BPSK modulation, and 7.75 dB in QPSK. Given the current Ka-band link budget, and considering that the Envisat onboard noise does not exceed 10^{-6}, this requirement is marginally satisfied for the case of QPSK modulation, as shown in Table 1. Potential improvements in the data processing between the Viterbi and RS decoders have been investigated which, if required, can improve the current margin by 1 dB.

Current status

Two DRS Terminal models are envisaged in PPF programme, namely an engineering and a flight model.

The engineering model was completed before the end of 1995 and the Transmit Panel part has been integrated at higher level (PEB and PPF) for testing and validation at module and system level, respectively. The OBA part has been submitted to alignment checks and thermal-balance/thermal-vacuum and modal-survey tests. Later it was integrated into the PPF structural model for the modal-survey, acoustic and pyro-shock release tests in the LEAF and vibration testing in the new HYDRA facilities at ESTEC (NL).

Delivery of the various units for the flight-model DRS Terminal was completed in September 1996. Tests at overall Terminal level are scheduled until November 1996, followed by subsequent delivery and assembly, integration and test tasks at Payload Equipment Bay and Polar Platform level.

Industrial organisation

Matra Marconi Space (UK) is the Polar Platform Prime Contractor. Dornier GmbH (D) is the Payload Equipment Bay contractor, and within this module, responsible for the DRS Terminal. The industrial organisation charged with building the DRS Terminal is summarised in Figure 11. Alcatel Telecom (B) is responsible for the IBA and most of the OBA units, whilst Sener (E) has supplied the reminder of the OBA elements.

A Multipurpose Deployable Membrane Reflector

– A New Design Concept

W.J. Rits
Structures and Mechanisms Division, ESTEC, Noordwijk, The Netherlands

Large deployable reflectors are required when designing high-gain antenna systems for spacecraft, particularly for land-mobile telecommunications payloads. A novel deployable reflector concept is presented here which is based on the inherent properties of doubly curved surfaces. The new reflector consists of three basic elements: a parabolic membrane, a number of collapsible ribs, and an expandable hub. The membrane itself serves both as the structure and as the radio-frequency reflective surface, resulting in a highly versatile lightweight antenna with substantial applications potential.

Introduction

Large reflectors are a key element of high-gain antenna systems for spacecraft, particularly those carrying land-mobile telecommunications payloads, where there is a strong desire to keep the mobile ground terminals as small as possible. Such reflectors inevitably need to be foldable for launch and at the same time they have to fulfil a number of sometimes conflicting electrical and mechanical requirements.

In this field of large spacecraft antennas, one is constantly searching for reflector designs with improved specific mass (i.e. mass per unit aperture area), compact stowage volumes, and high deployment reliabilities. These requirements are driven both by the limited payload-accommodation envelopes of today's launchers and the high cost per kilogramme of placing payloads into orbit.

There are currently several designs of deployable reflector in various stages of development, ranging from outline concepts to fully qualified reflectors which have already been used on operational satellites. The vast majority of the well-developed concepts are based on a rigid deployable structure which, after it has attained its final shape, functions as a stable platform to which a reflective surface – such as an electrically conductive mesh – is attached. The key to the geometrical stability of this kind of reflector is therefore the stiffness and stability of this support structure.

Few concepts, however, make use of the inherent geometrical stability of a doubly curved, nonelastic membrane. A membrane of this type, properly shaped and tensioned, can function both as the structural element and as the reflecting surface, and as such has the potential of providing a truly lightweight reflector. This characteristic of doubly curved surfaces is exploited in the ESA-developed Collapsible Rib Tensioned Surface (CRTS) reflector presented here, which is the subject of ESA patents in France and the USA.

The CRTS concept

The CRTS reflector is based on the inherent geometrical stability of a doubly curved, non-elastic membrane which is maintained in a tensioned condition. A non-elastic membrane is one that behaves like a piece of cloth rather than, for example, a sheet of rubber. To achieve the required tensioned state, the reflector has three basic elements: the parabolic membrane itself, a series of thin-walled collapsible ribs with C-shaped cross-section, arranged radially and supported by an expandable hub.

The hub is contracted during folding and deployment, so that the ribs can deploy the membrane without having to pre-stress it at the same time. Once the membrane is fully deployed, the hub is expanded to apply a state of prestress to the membrane and thus to set it into its proper shape (Figs. 1 & 2).

The membrane itself consists of a set of flat gores, i.e. pie-shaped pieces of material, attached together at the seam. When the reflector is deployed, each gore takes the shape of what is called a 'parabolic cylinder'. This can be pictured as a tube with a parabolic cross-section. Hence, the overall shape of the reflector is not an exact paraboloid, but only an approximation to it whose accuracy improves as the number of gores is increased. Each rib is typically held in a pocket attached to the membrane at the seam between the two adjacent gores. It is positioned with the convex side facing upwards, i.e. towards the focus of the reflector. The ribs are firmly attached only to the outer rim of the membrane.

The reflector ribs

The radial ribs consist of thin slender metal blades of C-shaped cross-section, which are pre-formed to the nominal – usually parabolic – reflector profile. The ribs are therefore doubly curved structural members, with a high curvature (i.e. small radius) in the cross-section plane and a low curvature (i.e. large radius) in the plane of the rib itself. The ribs are firmly fixed to the membrane at the rim of the reflector, and are allowed to slide relative to the membrane at the intermediate positions. Near the vertex of the reflector, they are connected to the expandable hub.

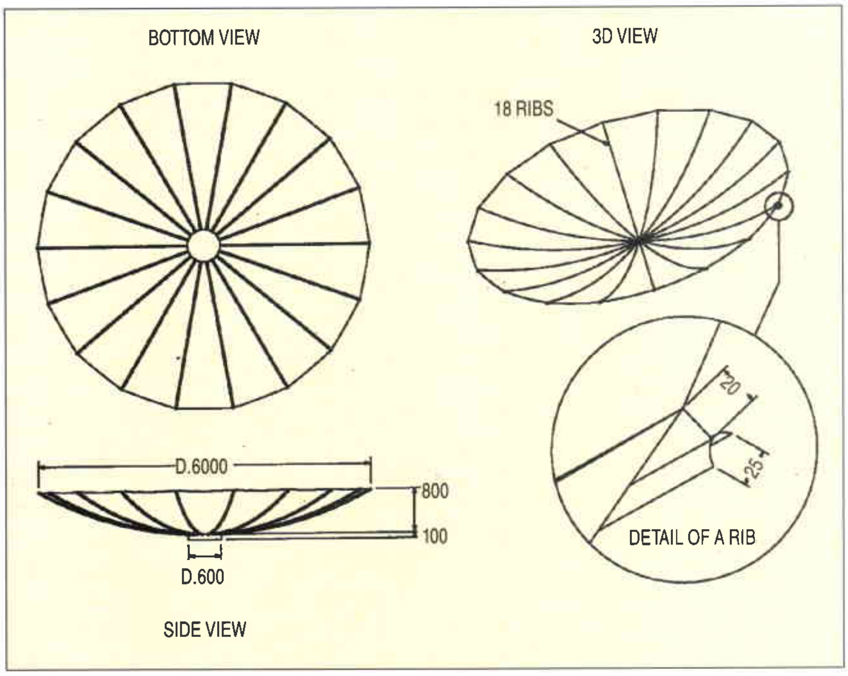
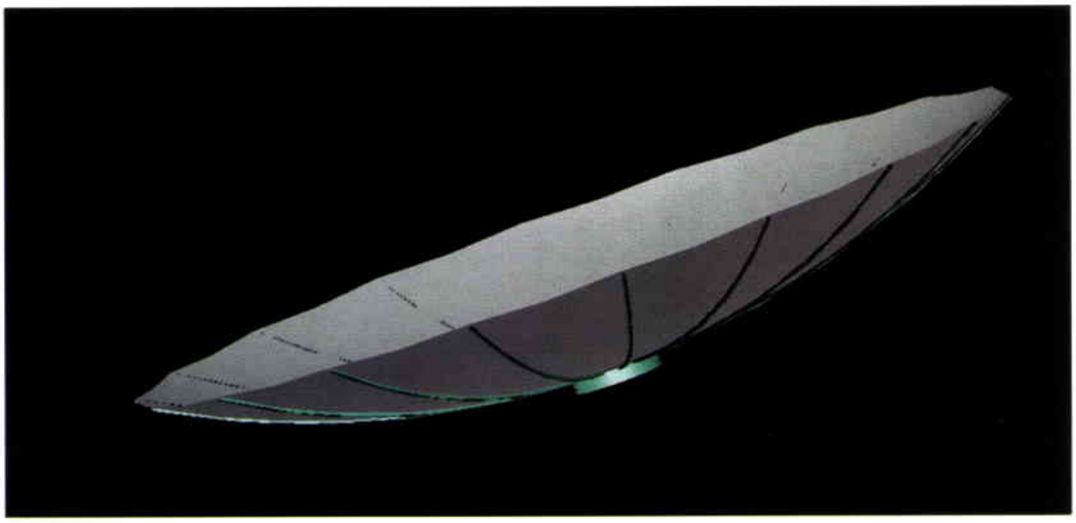


Figure 1. Schematic of a CRTS reflector



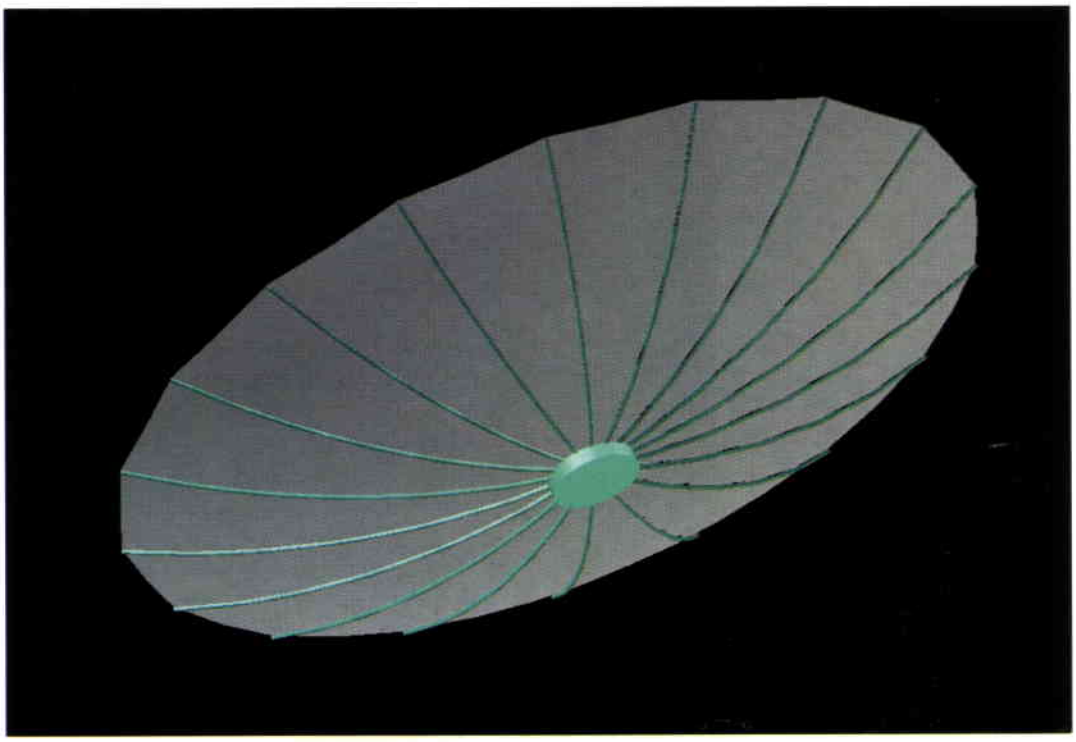


Figure 2. Three-dimensional view of the CRTS reflector

Owing to the curved cross-section of the ribs, they function as a beam up to a certain threshold bending moment. For bending moments higher than this threshold, the cross-section will snap into a flat shape, thereby reducing its local bending stiffness by a factor of up to 50. This basically creates an instant hinge line at any desired location along the rib. It is this feature that allows the reflector to be folded into a small volume for launch.

This unique behaviour of the C-shaped ribs has been investigated analytically, numerically and experimentally. The conclusion of this study is that the ribs' snap-through behaviour can be predicted reasonably well by finite-element analysis, but that all predictive techniques tend to underestimate the actual snap-through bending moment observed experimentally. Typical results from this work are presented in Figure 3.

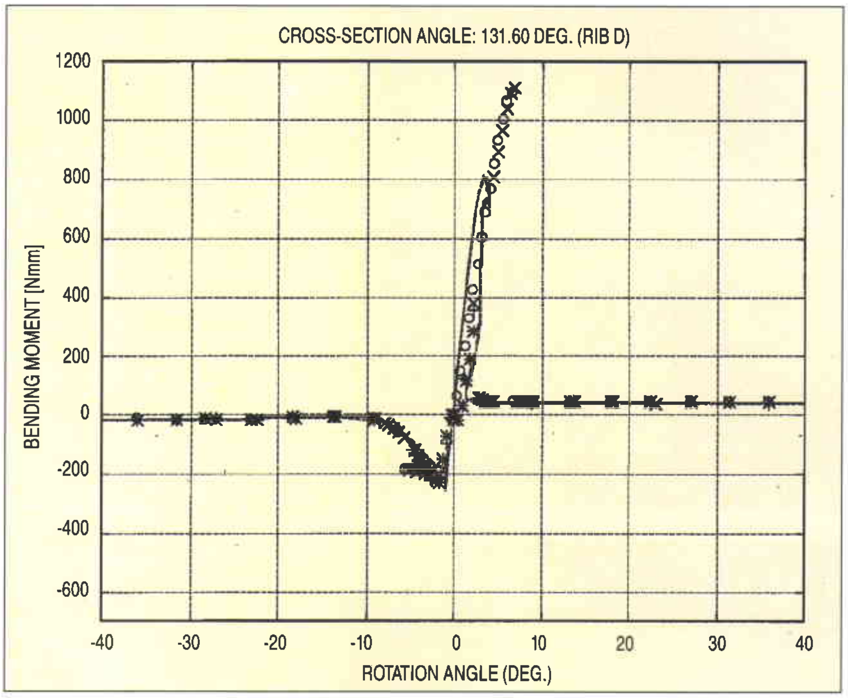


Figure 3. Typical snap-through behaviour of a rib with C-shaped cross-section
--- finite-element results
x, o Experimental results

The most suitable material for the ribs is copper-beryllium, mainly because of its low creep behaviour, its relatively low stiffness and its high elastic limit. In addition, it is easily formed when in an annealed condition, and can be hardened with a rather simple thermal process. The low-creep attribute is particularly important as the antenna may be stored for prolonged periods in a folded condition and there should be no plastic setting of the rib.

The three key parameters of the rib's design are its width, the enclosed cross-sectional angle and the thickness of the blade material. They need to be optimised as a function of antenna size, required accuracy (the main factor determining the number of ribs needed) and deployed natural frequency. The rib design is not necessarily limited to a single blade, a multi-blade rib probably resulting in an even more optimised design, since the bending moment along the rib increases towards the reflector vertex.

Expandable hub

The expandable hub is designed to provide the proper boundary conditions to the ribs at the vertex of the reflector, and to supply a radial force (and displacement) to these ribs for tensioning the membrane. It also provides the rigid mechanical interface for the whole reflector. Within the hub, the ribs are attached to sliding elements which can only move in a radial direction. All other possible motions are constrained. The force- and displacement-generating device, which in essence pushes outwards on the sliding elements and therefore on the ribs, can be based on a spring action or on a motor-driven mechanism.

Membrane

The reflector membrane is required to have a high in-plane stiffness, which provides a high and stable surface accuracy, in combination with a low bending stiffness, which facilitates folding. In addition to these essentially mechanical requirements, it needs to be radio-frequency (RF) reflective and exhibit low creep. A good candidate material that can fulfil these requirements is a fibre-reinforced metallised plastic foil. The membrane can be assembled from high-precision gore segments whose seams coincide with the locations of the ribs.

As the membrane of a CRTS reflector serves both as the prime structural element and as the RF-reflecting surface, it is important to note that the accuracy of the reflector is in principle determined by the accuracy of the membrane, with the ribs serving only as tensioning elements. This is fundamentally different from almost all other reflector designs, where the supporting structure controls the reflector accuracy to a large extent.

One additional desirable characteristic for the membrane is optical transparency. This stems from the fact that these kinds of reflectors will mainly be used for antennas that are large compared with the size of the host spacecraft. In this case, the solar radiation pressure becomes an important disturbing factor for the satellite's attitude control. Having a surface that is RF-reflective yet optically transparent minimises this effect, and would therefore be very desirable. One option for achieving this goal is to replace the metallised plastic foil with a nonelastic metallic mesh. Such a mesh would differ fundamentally from the knitted elastic type used on reflectors with a rigid support structure, and would most likely be a woven mesh with inherent high in-plane stiffness.

Auxiliary elements
Other elements required for a CRTS reflector are a stowage container and a (pyrotechnic) release system. The stowage container protects the folded antenna package during ground handling, testing and launch, and is released just before in-orbit deployment is initiated. The release system, which holds the ribs and the membrane in folded condition, initiates the actual deployment of the reflector by releasing the ribs to deploy due to their stored elastic energy. It is not inconceivable that both the functions of the stowage enclosure and the release system can be combined into a single device.

Functional aspects
A CRTS reflector is composed of a foldable membrane and continuous ribs with no built-in hinges at fixed locations. This means that the same reflector can be folded in different ways, and this unique characteristic can be used to good advantage to fit the reflector into different, externally imposed, payload envelopes. However, the folding scheme selected does have an influence on the deployment behaviour of the reflector. These aspects have been studied in some detail and the results of this work are summarised below.

Folding schemes
Three different folding scenarios are considered here:
- *Scheme 1* is based on a pseudo-inward-rolling of the ribs, with the membrane suitably folded in between them, as represented schematically in Figure 4.
- In *Scheme 2*, the ribs are folded in a zigzag fashion, i.e. with alternative convex and concave folds, and the membrane folds into a concertina (Fig. 5). This scheme has been tested on a simple 1 m-diameter model.
- *Scheme 3* is the most complex of the three and can best be described as a wrapping of the ribs around the expandable hub (Fig. 6).

A comparison of the three packaging methods, based on packaging efficiency, complexity of the folding process, and the possibility that the reflector might deploy into a non-nominal configuration, shows Scheme 2 to be the most promising.

In terms of packaging efficiency, Schemes 2 and 3 are the best because they minimise the volume of gaps in the package. Scheme 2 is

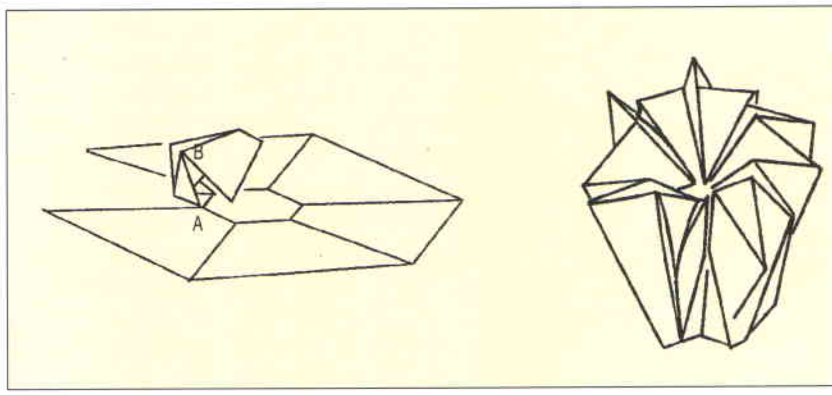


Figure 4. Folding scheme 1

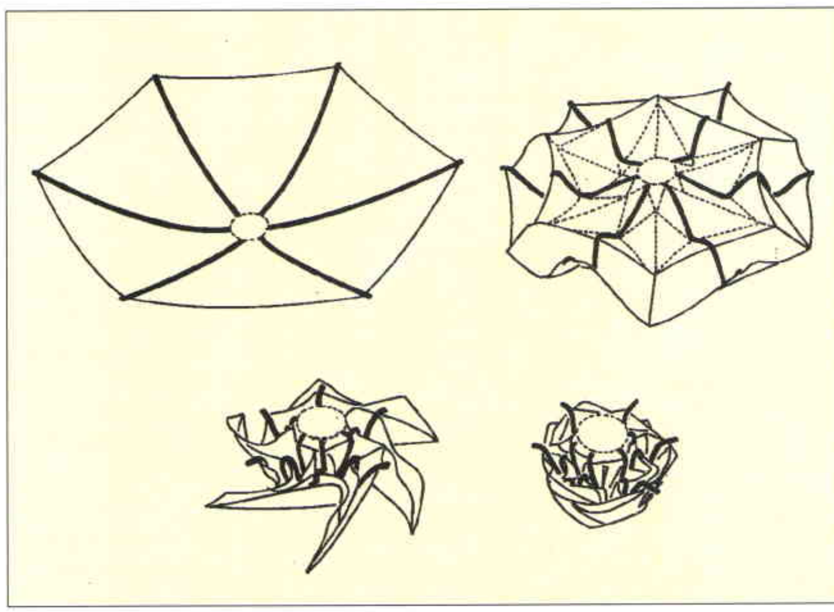


Figure 5. Folding scheme 2

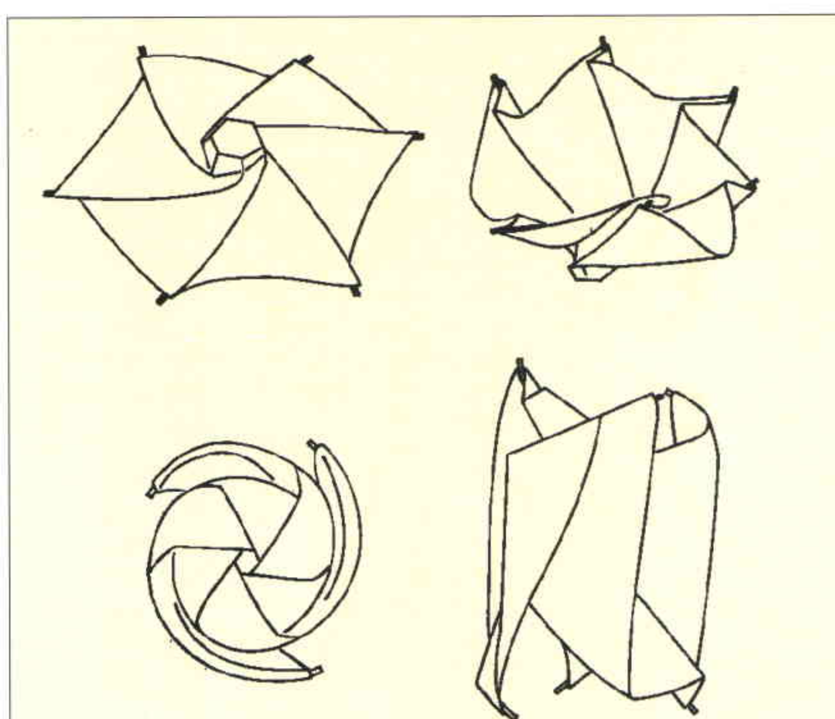


Figure 6. Folding scheme 3

more flexible, because the height and diameter of the package can be readily modified to suit mission requirements. In Scheme 3, some space is taken by the region where the ribs bend and twist near the hub, but from this point onward the ribs wrap nicely around the package. With this scheme, however, changing the size of the folded reflector requires a careful re-analysis of the whole packing scheme.

As far as the complexity of the folding process itself is concerned, Scheme 2 is clearly superior and its practical implementation has therefore been tested experimentally. Implementing Scheme 1 should also be relatively straightforward, even though it may be difficult to ensure that the rib folds remain in the required position after packaging, while the implementation of Scheme 3 appears to be rather complex.

Only preliminary assessments can be made so far regarding the possibility of the reflector deploying in a non-nominal configuration. With Scheme 1, there is the possibility that the tip segments of the ribs might become interlocked during deployment, because all ribs are bent towards the centre of the hub in the packaged configuration, and they tend to move over centre during deployment.

For Scheme 2, two aspects are important. Firstly, a rib with several up and down folds is not naturally stable and needs to be suitably restrained to prevent it from buckling out of plane within the volume of the package itself. This aspect has been investigated experimentally and was found to be of no major concern. Secondly, there is the possibility that the membrane might go past the hub during deployment and, having deployed too far outward, be unable to flip back to the front of the hub, remaining in a concave, rather than a convex shape. This is a potentially serious problem, and indeed some deployment tests have shown this kind of behaviour. The problem can, however, be eliminated by contracting the hub diameter further than strictly required by pre-stressing considerations.

Scheme 3 appears to have potentially the lowest risk in terms of non-nominal deployment. The fact that the ribs are wrapped around the central part is likely to induce a kind of natural synchronisation of the deployment, thereby reducing the risk of non-nominal conditions.

Deployment

As noted above, the deployment behaviour of a CRTS reflector has been studied both theoretically and experimentally with a 1 m-diameter model. The theoretical work concentrated on modelling the deployment of a single rib, initially with a simple two-degree-of-freedom model of a rib with a single fold, and finally with a finite-element model of a rib with multiple folds. Based on this work, it is possible to predict the global deployment behaviour of the reflector, and to make a first estimate of the time needed to deploy a full-sized reflector. One specific case analysed indicated that a 5 m-diameter CRTS reflector will deploy in approximately 5 seconds.

Following the theoretical investigations, a series of deployment tests were carried out on the 1-m model packaged according to Scheme 2. This model differs in two respects from an actual CRTS reflector. Firstly, it has straight, instead of parabolically curved ribs, and hence the gores become flat when the model is fully deployed. Secondly, the model does not have an automatic hub contraction/expansion mechanism, and therefore tensioning of the membrane is not possible. Due to these simplifications, the model has to be considered a deployment model rather than a fully functional scale model.

For the test, the model was folded with a dedicated folding device and suspended horizontally. Deployment was initiated by cutting the restraining string, and recorded with a video camera. Figure 7 shows the successful deployment sequence. The reflector was deployed pointing downward, otherwise gravity effects would have been too large for the root folds of the ribs to snap-in. The time interval between consecutive frames in Figure 7 is 0.12 s.

Performance

The anticipated performance advantages of a CRTS reflector compared to reflectors with a rigid support structure are:

- low overall mass, due to the very low mass per unit area of the membrane and ribs, in combination with the absence of a rigid support structure
- flexibility in terms of stowed dimensions, and in particular the fact that the same reflector can be folded in different geometries to suit application requirements
- good stowage efficiency
- simplicity of the concept, which is expected to result in a low recurrent cost and a high deployment reliability.

A less desirable attribute of the reflector is the rather uncontrolled deployment. The actual deployment progression, from initiation to fully open, is not kinematically controlled as in most

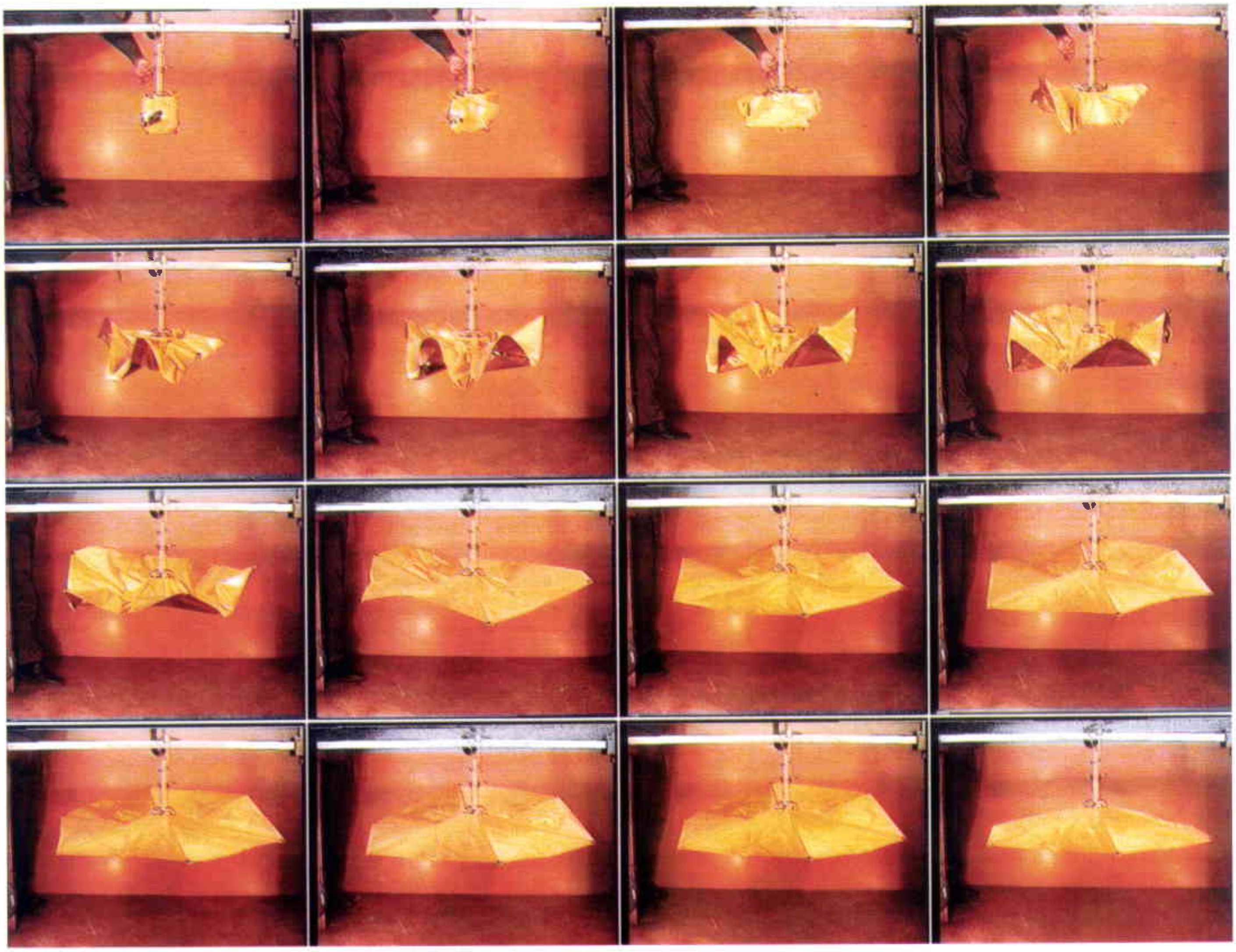


Figure 7. Deployment sequence of the 1-m model folded according to Scheme 2

– but certainly not all – other deployable reflectors. However, the division of the deployment into two distinctly separate phases, namely the actual deployment phase itself and the membrane tensioning phase, means that the ribs deploy without external constraint. They will therefore naturally return to their lowest energy state, which is their fully deployed position in a zero-gravity environment.

Other performance characteristics such as surface accuracy, deployed natural frequency, etc. have not been quantified so far but are currently being studied. They are not expected to differ substantially compared with other deployable reflector designs.

Concluding remarks

Whereas the primary application today for large deployable reflectors in general, and for the CRTS reflector in particular, is for land-mobile telecommunications payloads in geostationary orbit, other applications are also being considered, such as high-resolution radio telescopes based on Very Long Baseline Interferometric (VLBI) techniques, and Earth-observation weather radars.

An important aspect that is frequently overlooked is that deployable reflectors are not only required for large antennas, but are also beneficial for providing small to medium size antennas for small satellites. The low mass and the compact and flexible stowage characteristics of CRTS reflectors are strong assets that make them potentially very suitable for these kinds of applications also. In fact, it may very well be that this field of application will emerge as the more commercially appealing in the shorter term.

Acknowledgement

A special word of thanks is due to Dr. S. Pellegrino, Dr. Z. You and their co-workers in the Department of Engineering at Cambridge University (UK) for their substantial and enthusiastic contributions to the development of the CRTS reflector.

Improved Fidelity in ESTEC's Large European Acoustic Facility (LEAF)

G. Piret & W.A. Shickle
Testing Division, ESTEC, Noordwijk, The Netherlands

L. Grilk
Stork Comprimo, Amsterdam, The Netherlands

Some of the most demanding tests that a spacecraft undergoes during its proving cycle are the launch-environment simulations. ESTEC's LEAF, electrodynamic shaker facilities, and future Hydraulic Vibration Facility (HYDRA), are and will continue to be the established tools for simulating this environment. The LEAF simulates the airborne noise produced after engine ignition and during the atmospheric flight phase of the launcher. The launcher's structure-borne vibrations are simulated using the electrodynamic and/or the hydraulic facilities.

Introduction

The LEAF acoustic facility, which was commissioned in 1990, was designed for the noise levels specified by the launcher authorities at that time for existing and future users. Since then the test levels demanded have decreased below those at which LEAF could produce accurate noise spectra. Deficiencies of up to 10 dBL were observed at frequencies above 2000 Hz, caused by the reduction in levels at lower frequencies giving insufficient noise spill-over to the higher frequencies. To eradicate this deficiency, additional high-frequency noise generators have been installed.

The Large European Acoustic Facility

The main features of the LEAF are shown in the cutaway view in Figure 1. The chamber, which is 11 m x 9 m x 16.4 m high, with an internal volume of 1670 m^3, has walls made of steel-reinforced concrete. They are 0.5 m thick to withstand the acoustic loads and to attenuate noise levels outside the facility. A thick coating of epoxy resin has been applied to the chamber's inside walls to reduce noise absorption and thus increase the reverberation time.

The chamber is supported on rubber bearing pads to isolate it from the surrounding vibration-sensitive facilities and residential areas in the environs. A full-height, concrete-filled steel door seals off the chamber during the acoustic test. When open, it permits the insertion of Ariane-5 sized spacecraft.

A gaseous-nitrogen subsystem provides up to 11 kg/s of clean dry gas to drive the noise generators. It consists primarily of:
- a 25 m^3 liquid-nitrogen tank
- a 40 m^3 water tank maintained at 75°C
- a vaporiser and superheater, working on the principle of a counterflow heat exchanger
- a 5 m filter
- pressure control valves
- instrumentation and control equipment.

During operation, the liquid nitrogen is driven from the tank under a pressure of 10 bar and through the heat exchangers. These produce gas at 5 $\pm$ 0.5 bar and 20 $\pm$ 2°C. It takes 80 sec at maximum flow to achieve this gas pressure and temperature, during which time the unconditioned gas is vented to the atmosphere. Valves in the pipelines to the noise generators control the gas pressure within the 0.2 – 2.0 bar range.

Noise generation

The LEAF was originally specified to achieve an acoustic noise level of 154.5 dBL with a dynamic range of – 10 dBL, i.e. a low level of 144.5 dBL. A future extension to 158.5 dBL was also foreseen. Today, the levels being specified are in the range 135 to 147 dBL. Details of the 1/3-octave spectrum required to achieve these levels are shown in Figure 2. Also worthy of note is the lower drop-off of the noise in the high-frequency range compared with the original specification.

To achieve the original specification, acoustic powers of 120 kW for the 154.5 dBL and 180 kW for the 158.5 dBL levels were required. To eliminate the danger of contaminating the spacecraft with oil, it was decided to use electrodynamic rather than hydraulic flow modulators. These can also deliver more acoustic power than the hydraulic type. Four 30 kW WAS 3000 noise generators (Fig. 3) supplied by Wyle (Huntsville, USA) were therefore used. These were installed onto

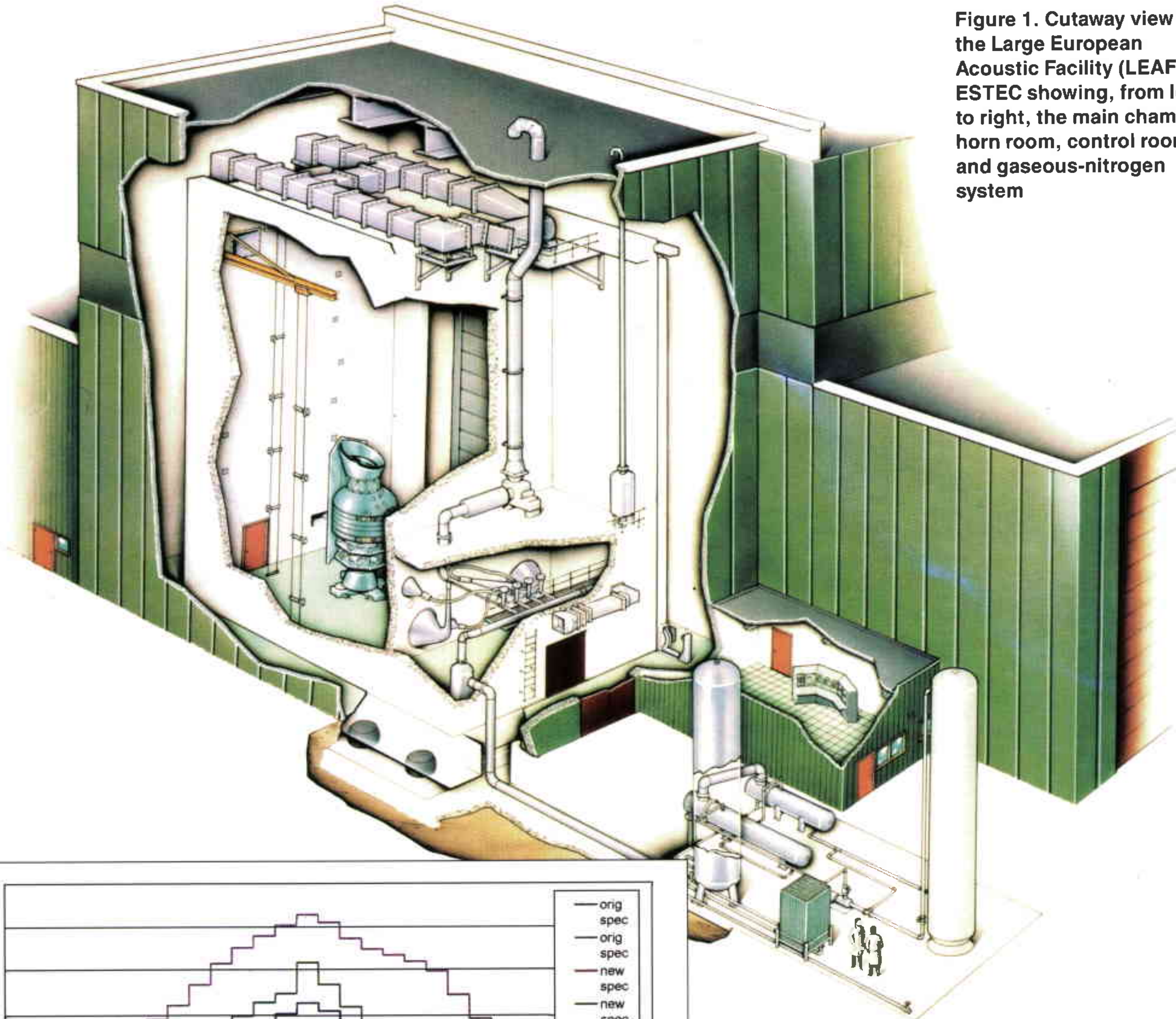


Figure 1. Cutaway view of the Large European Acoustic Facility (LEAF) at ESTEC showing, from left to right, the main chamber, horn room, control room, and gaseous-nitrogen system

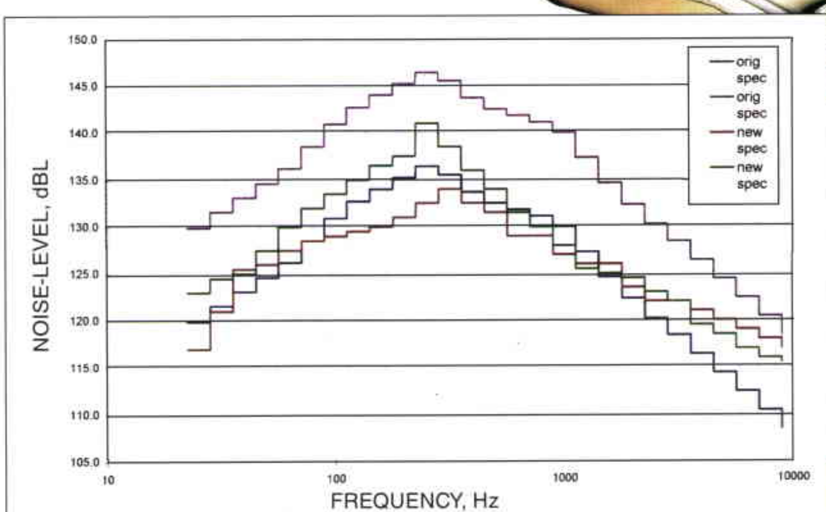


Figure 2. Comparison of the new and the original performance specifications for the LEAF

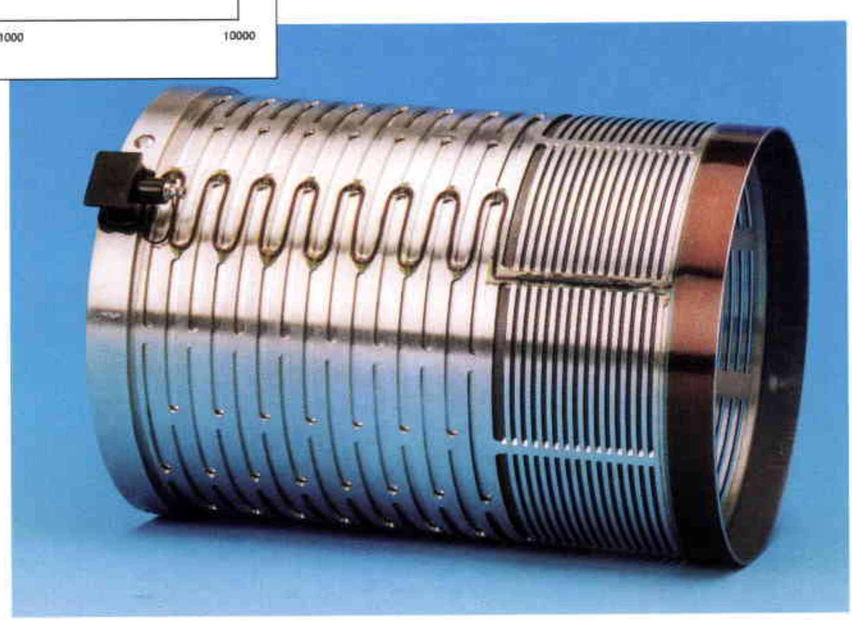


Figure 3. The Wyle MU110 modulator, showing the spring, slots and coil

horns of 25, 35, 80 and 160 Hz lower cut-off frequencies in the chamber/horn room wall. Additional apertures were foreseen to install two further horns and noise generators to meet the 158.5 dBL requirements. The number of apertures was later increased to eight to allow a level of 162 dBL to be achieved in a reduced chamber volume for the testing of Ariane-5's engines.

When operating these noise generator/horn combinations, deficits of up to 10 dBL were observed in the 2 to 4 kHz frequency range (Fig. 4), due to the low noise spectrum in the lower frequencies reducing the noise spill-over to the higher frequencies. It became essential,

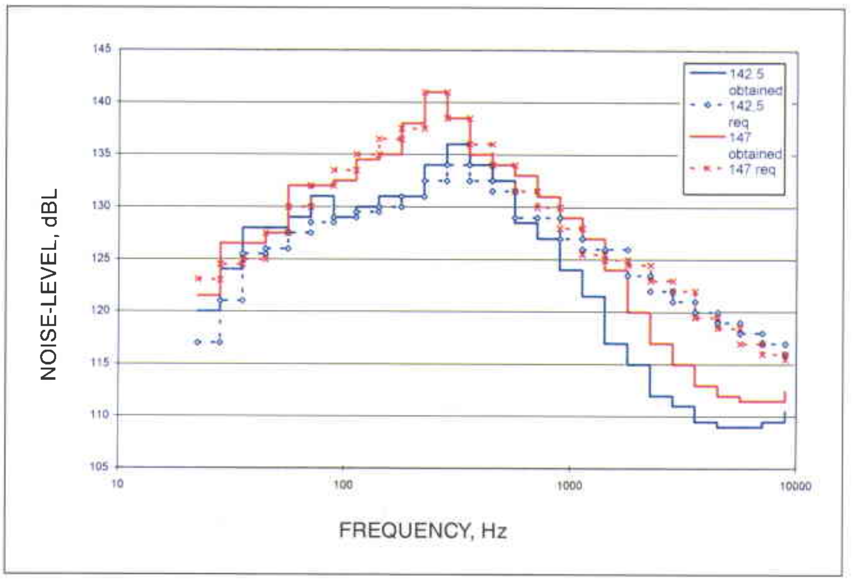


Figure 4. The LEAF noise spectrum without the NAE generators (cf. Fig. 8)

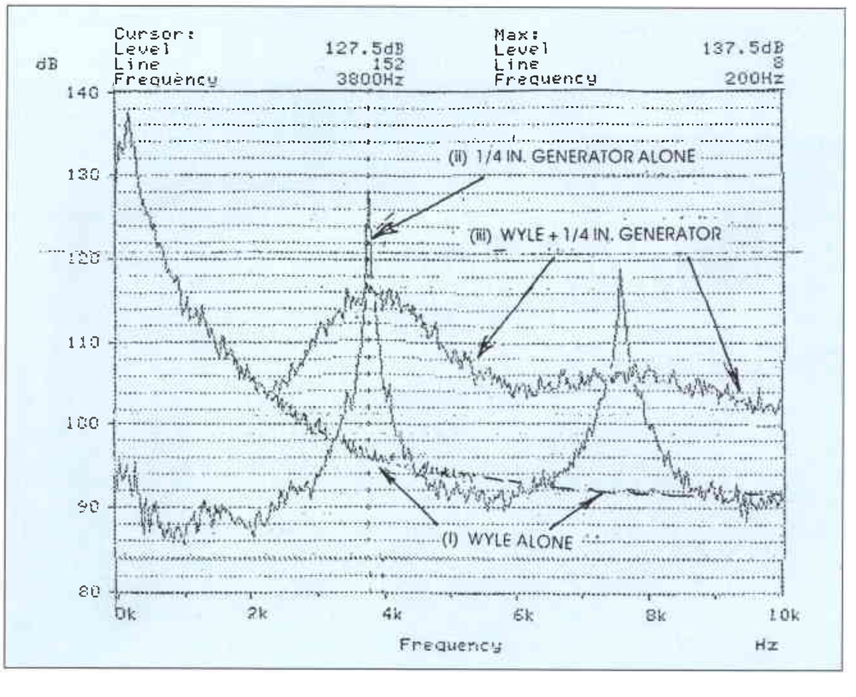
broadband contribution of noise that is added in the frequency range above that of the cut-off of the Wyle generator (Fig. 5).

Until last year, however, the NAE generators did not have the high-frequency performance now required for the LEAF application. They covered a frequency range of 500 – 1250 Hz, whereas the LEAF required additional energy from 1000 to 4000 Hz. A conceptual design for a generator to cover this extended frequency range was therefore developed for ESA by Aiolos Engineering Corp. of Canada. A prototype was subsequently tested in the IAR chamber to validate the design. The tests also confirmed that direct control of the sound levels, with sufficient power, could be achieved.

therefore, to install additional high-frequency noise generators. No suitable systems were commercially available, but a novel solution has been developed, tested and patented by, among others, the staff of the NAE Aeroacoustics Facility (recently renamed IAR) in Ottawa, Canada.

The NAE high-frequency generator is an aerodynamic device that generates intense tonal noise. A wall jet of gas flows through a rectangular nozzle and impinges on a resonant cavity. The depth of the cavity can be adjusted to give a range of fundamental frequencies for the given generator geometry. By itself, the NAE generator creates tonal noise at the fundamental frequency plus harmonics. The low-frequency noise emitted by the Wyle generators is used to modulate the high-frequency tones produced by the NAE generator. This results in a supplementary

Figure 5. The narrow-band effects of adding a 1/4-inch generator



To cover the exact LEAF frequency-range requirements, generators with 2-inch wide and 1/4, 1/2 and 1-inch high cavities were installed in the LEAF's 25 Hz horn (Figs. 6 & 7).

The results of commissioning tests completed in 1995, illustrated in Figure 8, confirmed that a wide range of spectral shapes can be obtained by various combinations of these modulators and generators.

The acoustic testing of the Italian national satellite SAX in September 1995 (Fig.9) and of the Structural Model (STM) of ESA's large Polar Platform/Envisat spacecraft in July 1996 have conclusively demonstrated the improved fidelity of the upgraded LEAF facility.

Future developments

The appropriate acoustic spectrum for a given test is currently set up manually by the facility operator, prior to the introduction of the test specimen into the chamber. This process can take several days and consumes large amounts of liquid nitrogen. In addition, significant differences in the spectrum can occur due to absorption by the spacecraft when it is introduced into the chamber, calling for further manual fine tuning. This has to be done within 10 seconds of starting the test or the latter may have to be aborted to avoid over-/undertesting.

The implementation of an automatic PC-based spectrum control system is therefore under investigation, the advantages of which include:
- reduced test-spectrum setup time
- direct and rapid adjustment when the spacecraft is introduced
- simplified operation and control.

This will provide the LEAF with the ability to conduct more accurate test simulations of launcher-specific environments more quickly and at reduced cost.

Conclusion

The NAE generators have significantly improved the noise levels in the LEAF in the high-frequency range, and the versatility of the facility in terms of the spectra achievable has been greatly enhanced with the Aiolos upgrade.

Any future work will be directed at further extending the capabilities of the LEAF as and when necessary to keep it in the forefront of environmental testing technology.

Acknowledgement

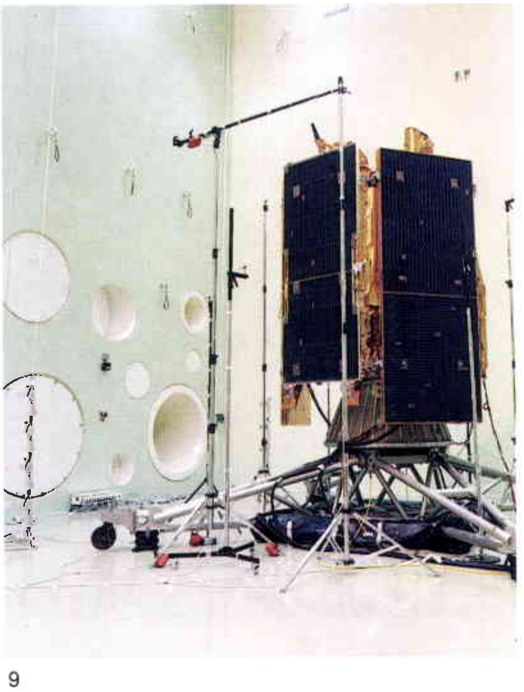
The authors would like to thank the staff of Aiolos Engineering Corp., especially G. Elfstrom and B. Clark, and IAR for their cooperation and hard work in this project. They would also like to thank B. Westley, formerly with NAE, for sharing his vast experience with them.

Figure 6. The NAE high-frequency generator assembly

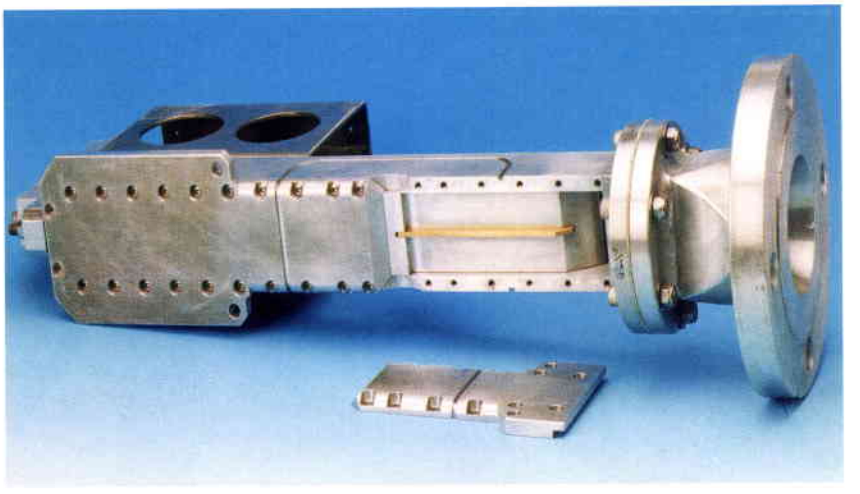
Figure 7. The NAE generators installed, with their motor drives, in a section of the 25 Hz horn. They are connected to the gaseous nitrogen supply via reinforced flexible pipes (centre left). The Wyle noise generator is the brass-coloured cylinder in the upper left of the photograph

Figure 8. The LEAF noise spectrum with the NAE generators (cf. Fig. 4)

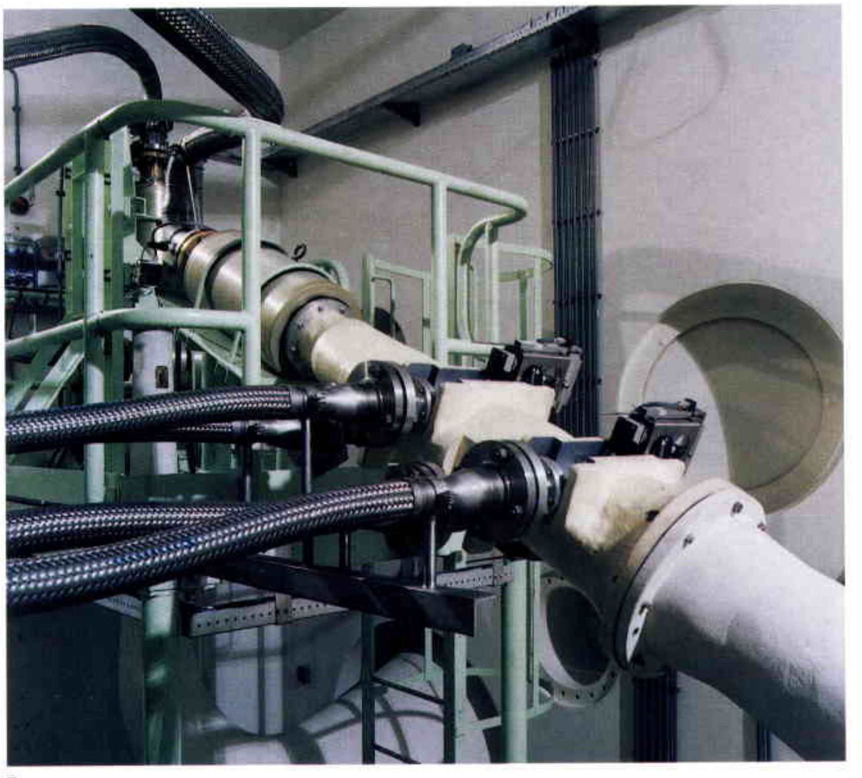
Figure 9. The Italian SAX spacecraft being prepared for testing in the LEAF



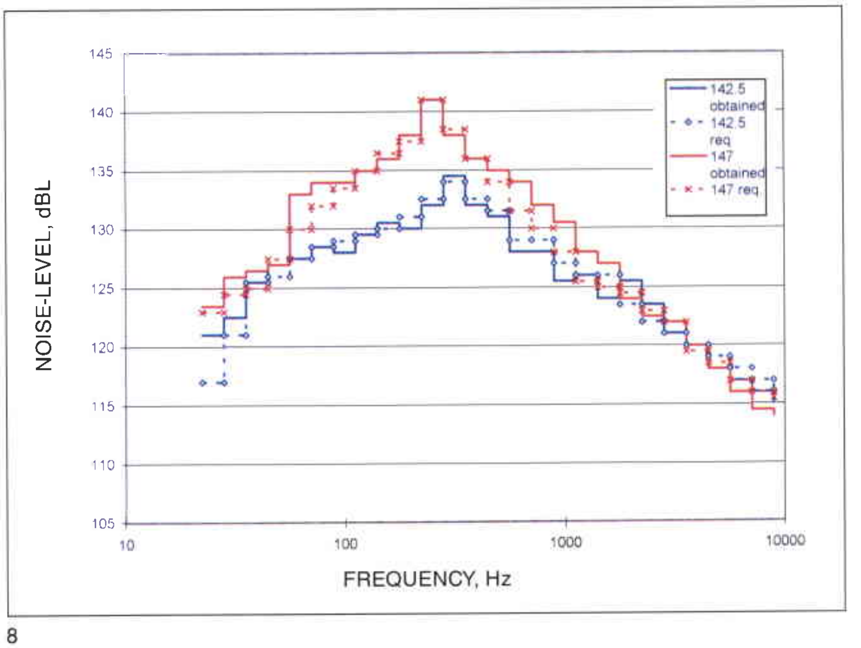
9



6



7



8

Future Space Missions and Services

– A Road Map for Future Technology Development

A. Atzei, N.E. Jensen & W. de Peuter
Systems Engineering & Programmatics Department,
ESTEC, Noordwijk, The Netherlands

Thanks to the unique global capabilities that it brings, space technology will be a major strategic tool in the next century. In addition to their broad economic potential, space technology will help society overcome several threats to the quality of life on Earth or even to human life itself. In that sense, space technology is fundamental to sustaining security in all its forms – political, economic, military and ecological – in a truly global approach.

At the current time, however, space initiatives are going through a transition period and are gradually settling into a mature industrial and commercial sector where the basic technologies exist, where market forces determine major developments (which are influenced by many global and regional players), and where public budgets remain constant or are even diminishing. Private investment is therefore becoming increasingly more important for financing application-oriented and commercially-driven space activities.

Introduction

The role of space agencies is changing. As a result of the relentless reduction in public funding in recent years, space agencies are tending towards serving more as a catalyst to industry rather than directly financing commercially-driven space activities. Scientific and exploratory activities and space research and technology programmes will increasingly be undertaken and managed most effectively through cooperating national and supra-national space agencies. New relationships will evolve between space agencies and industry, with the agencies providing technical and financial support and sharing the risks for the pre-competitive research and development phase and actively promoting emerging and potential applications. Furthermore, synergy between military and civilian developments as well as between terrestrial and civilian space systems may very well contribute to the future strength and structure of the space industry.

Forecasting the technological preparation needs for the future is not an easy task today because many trends established in the past are no longer valid or are changing rapidly. The economic, cultural, institutional and technical environment of space activities is adapting to the realities of the worldwide commercial, and highly competitive, market-place on the one hand, and to the public cooperative projects for peace-keeping, environmental protection, ecological and space exploration and manned programmes on the other.

Programmatic aspects and technology drivers

This article outlines a road map for space-technology development by presenting a global overview of major future space activities of major relevance for Europe, together with their associated technology fields. A synthesis of their major programmatic aspects and technical drivers is presented in Table 1.

The missions are structured in accordance with their programmatic background and according to the following service domains:

- The *public-service domain*, covering those satellite-based services where a governmental obligation has to be expected, and which are based on scientific results or technical achievements.
- The *commercial-services domain*, covering those satellite-based business activities where free market forces determine the developments. Governmental rules are only necessary at the level of regulatory issues rather than specifying ways and means.
- The *scientific domain*, covering those satellite-based activities, including microgravity, where the public interest fosters the search for basic knowledge. A competition in prioritisation exists in this domain vis-a-vis other scientific fields of public interest, whereby space science, for example, must compete with the Earth sciences and microgravity for resources.

Future missions and services

A selection (from Dossier 0) of medium-term plans for satellite-based missions and services, together with a synthesis of their technical requirements, is presented in Tables 2 – 5. As far as their expected market potential is concerned, it should be borne in mind that:

- The commercial services are primarily concerned with the communication and navigation markets, which are expected to continue to grow for at least the next 5 to 10 years. The opportunities appear best for broadband communications satellites to provide the means to link anyone, anywhere, quickly and cheaply to the information superhighway. The projected market growth is as high as 300 – 400 billion ECU late in the next decade.
- The Earth-observation market is still small and relatively immature compared with that in satellite communications. Its growth to mass-market status requires efficient ground infrastructures and services, very high revisit frequency for regular imaging, and synergy with communications and navigation. It will primarily involve high-spatial-resolution data, geographical information systems, and in-car navigation.
- In order to become viable, other possible future space-based services, such as materials processing, need drastically cheaper access to and from space (cost reduction by a factor of 10 – 100).

Finally, it can be expected that the future of the space sector will be characterised by the increasing role of commercial services on the one hand (especially for multimedia applications), and by several international cooperative programmes addressing global interests on the other (especially Space Station utilisation, space exploration, and risk/disaster management). The space sector has to adapt to the rapidly evolving opportunities, both in terms of industrial efficiency and R&D strategies.

Major features that will characterise space development in the medium term include the opportunity for mass production of low-cost spacecraft for telecommunications services based on satellite constellations, and the need for high-resolution Earth-observation payloads and related ground-processing techniques.

Table 1. Programmatic Aspects of the Space Sector and the Major Technology R&D Drivers

Space Sector	Timing, Mission and Budget Type	Drivers for Technology R&D
Public and Application Services — Weather — Navigation — Disaster management	— 'Long-term service guaranteed' approach (>30 years) necessary — Public infrastructure financing with delegated exploitation	— Satellite constellations — Advanced ground computation and simulation features — Often, available services have to be tied together by appropriate 'merging technologies'
Commercial Services — Mobile telecommunications — Multi-media — Broadcasting — Navigation services and traffic management — Global, regional and local applications of Earth observation	— Global financial and insurance arrangements dictate schedule for early return on investment — Public guarantees expected — Typically 3 – 4 years from kick-off to launch — Constellation build-up over several years — Constellations from a few to several tens of satellites	— End-to-end turn-key approach — Commercial services will go 'fully digital' — Interface with terrestrial means and standards crucial — On-board processing for comms./nav. & Earth obs. needed for simpler user end — Use of higher frequencies (>30 GHz) — Continuous services — Ground stations for constellation control
Science and Exploration — Astrophysics — Planetology — Moon/Mars exploration — Earth observation — Microgravity	— 10 year cycle typical for large missions — Public funding from R&D budgets — International programme setup	— Usually one-of-a-kind — Very demanding developments in all technical fields — Technology-push approach — Mission success oriented — Direct man/machine interactivity
Space Transportation — Future re-usable systems — Small expendable launchers	— 10 – 20 years of development — Operational flexibility — Guaranteed availability	— Improved cryo-propulsion — Re-usability — Low cost
Man in Space — Space infrastructure — Crew transportation — Logistics, payload support	— 20 year development time — Public funding for development and operation — Indefinite system lifetime	— Design update during lifetime — Maintenance and reconfiguration of elements — Habitability — Very high reliability

Table 2. Examples of Application-oriented Missions for Specific Meteorological, Environmental or Ecological Services

Service	Other Missions (Applications)	Technology/Operational Drivers
— 4-D traffic weather service (« 300 m) — Volcanic-ash warning — Ozone measurements — Pollution reduction	Weather data and 'nowcasting' (GEO, four satellites) 1000 kg 400 W 50 kbps	— All-day/night instrument in the 0.3 to 12 µm band — 2.5 MFLOPS on board — Near-real-time (15 min)
— Snow cover, water equivalent — Soil moisture — Inland-water surveillance	HYDROSAT (hydrological satellite) SSO, 555 km variable coverage 1700 kg 1100 W up to 75 Mbps	— P + C-band SAR, 500 m resol. — On-board data processing — Local low-cost receiving and processing stations
— Ecological mapping: change-detection maps (vegetation cover), biomass estimates — Algae bloom — Oil-spill detection: localisation and extent of potential oil/chemical spills — Forest-damage assessment and planning — Coastal erosion	COSMO/SKYMED (LEO small-satellite constellation of three optical and four microwave payloads in a 600 km polar orbit)	— Imaging spectrometers, high-resolution TM-like sensors, geometric resolution of ⩽3 m — Visible and infrared radiometers and spectrometers — High-resolution imaging spectrometers and interferometers — Improved (multi-channel) SAR, polarimetric SAR — LIDARs — High-resolution data for near-infrared (NIR), middle infrared (MIR) and red; — Improved classification algorithms and better interface to GII

Table 3. Telecommunications Services and Related Features after 2000

Service	Mission under Study	Technology Fields
Multi-media services		
Interactive Multimedia	1. Geostationary Satellites — EUROSKYWAY — SPACEWAY — CYBERSTAR High-capacity, high-mass satellites	Traffic-agile, multibeam antennas — (a) miniaturised, highly integrated radio-frequency (Ka-band) transceive front-ends — (b) extensive use of VLSI for modems/baseband switches (on-board processing) — (c) intelligent communication control techniques (earth/ground segment) Low-cost user earth stations (suitcase)
	2. Lower Earth Orbit Satellites — SATIVOD — TELEDESIC	— mass produced satellites — as (a) and (b) above — briefcase user earth station
HDTV (digital and high-definition TV)	Various from commercial entities	N/A
Mobility Services		
2nd Generation Satellite Personal Communication Services (S-PCS)	Low/medium Earth orbits	— high-gain multiple spot-beam onboard antennas — digital on-board signal processing (routing techniques) — inter-satellite linking techniques — intelligent communication control techniques (levelling)
Sound Broadcast — audio, data for traffic, weather, safety, games, etc.	MEDIASTAR — 8 h HEO, six satellites — Three service areas: Europe, N. America, E. Asia	— digital audio and data — new consumer products (radio CD quality)
Data-Relay Services		
— for space applications — others (security)	Follow-on to ARTEMIS (geostationary)	— massive-data-transfer inter-satellite link — same as above

Table 4. Navigation Services, Long-term Improvements and Technology Fields

Typical Advanced Services	Long-Term GNSS Improvements	Technological-Development Sectors
— Sole means for aeronautical navigation — Agriculture (e.g. precision farming) — Civil engineering — Security and tracking of goods — Waterborne operations — Fishing-vessel monitoring — Coastal engineering — Public transport, rail, road — In-land waterway services (e.g. channel dredging) — Added-value combined navigation/ communication services — Private road traffic monitoring and control	Improved Signal In Space (SIS) stand-alone performance	— Very Precise Orbit Determination (VPOD) techniques — Inter-satellite ranging — New signal design
	Avoidance of external intrusion in the system	— On-board regenerative payloads — On-board clock technology
	Minimisation of ionospheric delay errors	— Development of dual-frequency receivers — Use of high-frequency technologies (i.e. medium-gain active multibeam user antennas)
	Improved system integrity	— Satellite Autonomous Integrity Monitoring (SAIM) techniques, i.e. via ISL

Table 5. Future ESA Scientific Missions and Their Major Technical Characteristics

Discipline	Mission Objective	Project	Technology Driver
Space Exploration	— Phased Moon exploration and utilisation — Deployment and operation of rover/robotic payload on lunar surface; in-situ measurements	MORO (lunar orbiter) 1200 kg, 500 W, spinner	— Lightweight subsystems (cameras, optical sensors, batteries)
		LEDA — Lander — Rover 3000 kg (1000 kg dry)	— Throttlable bi-propellant engines (> 3 kN) — Night-time survival — Lightweight long-term energy storage — Autonom. guidance for landing — Wheeled-rover locomotion — Tele-operations/tele-presence techniques — Robotic manipulators
	Support of Mars science and exploration missions	Intermarsnet: four small 70 kg landers	— Entry thermal protection — Landing system — Non-photovoltaic power source
Horizon 2000	Comet remote-sensing and in-situ measurements	ROSETTA 3000 kg orbiter releasing two small 45 kg probes	— Autonomous advanced navigation techniques — Very large solar array (50 m^2) — Comet-approach camera — Small-sample acquisition/distribution
	Infrared astronomy	FIRST 1 000x71 000 km; 3600 kg; 1 kW; 50 kbps	— Large telescope antenna with micron accuracy — Cryo-coolers — Heterodyne detectors
	Investigation of the Equivalence Principle	STEP (M3) SSO; 400 km; 1000 kg; 400 W; 700 kbps	— Very high sensitivity accelerometers — Very low gravitational noise spacecraft — Proportional helium thrusters
	Astro-seismology to measure fluctuations in the light of stars	STARS (M3) L5 point; 1200 kg; 550 W; 6 kbps	— Triple Reflecting Telescope (TRT) in Silicon Carbide (SiC)
	Observatory to map fluctuations in cosmic background	COBRAS/SAMBA(M3) L5 point; 1200 kg; 550 W; 6 kbps	— Cryo-cooler — 0.1 K open circuit delusion system — Multi-frequency mm wave antennas
Horizon 2000 Plus	Investigation of gravity waves	LISA four spacecraft; 4000 kg total; 850 W	— Ultra-sensitive electrostatic accelerometers — Extremely low noise spacecraft — Low-thrust propulsion (e.g. Field Emission Electric Propulsion) for drag-free control — Ultra-stable oscillators
	Astrometry, cosmology, detection of new planets	GAIA L5 point; 2700 kg; 1 kW;	— Picometer ranging system — Time-phase integration CCDs — Advanced optical detectors — High mirror alignment stability
		Long-baseline interferometer	— Proportional thrusters (e.g. FEEP) — Solid-state gyroscopes — Laser ranging system 1 μm at 5 km
	Science of planetary systems	Mission to Mercury	— Thermal control for high heat fluxes — High-temperature mechanisms — High-temperature GaAs solar cells — Low-power Stirling coolers

Major R&D effort will be devoted to the investigation and demonstration of low-cost (reusable?) launchers, whilst the ambitions of the scientific missions will require major advances in a broad range of challenging technologies, particularly for the application of interferometry techniques. The emerging space exploration programmes will also serve as a driver by providing substantial opportunities for more sophisticated applications of robotics and artificial intelligence. Small satellites and micro-technologies are expected to enable improved exploitation of space applications, by reducing the financial risk associated with the related business opportunities.

A new approach to technology R&D

The new operating environment and the limitations in funding necessitate a strongly focussed, goal-oriented Technology R&D (TRD) programme. To this end, the process of defining and selecting TRD activities has been thoroughly reviewed, balancing 'technology push' with 'application pull' in the proper way (Fig. 1).

Firstly, the problems and technical challenges of, and the capabilities required for expected space applications are been synthesized into a concise document known as 'Dossier 0'. The latter compiles foreseeable needs, both within and outside ESA programmes, and will form the top-down road map for technology development. By nature, its structure is application-driven.

Secondly, emerging technologies and opportunities and the need to maintain industrial momentum in certain key technology areas constitute the bottom-up counter-force. It has been concluded that a disciplinary approach is best for describing a technical vision for this bottom-up process.

Thirdly, the intelligent merging of top-down needs and bottom-up technical trends has led to the establishment of a set of concrete goals for technology R&D, known as the 'Frame Programme'. The latter is meant to be a Master Plan, a high-level technology R&D work plan, necessary and sufficient to cover the technology needs of the space missions and applications referred to in Dossier 0.

Fourthly, this Frame Programme must be implemented within the technology R&D schemes available. Apart from the ESA TRD Programme(s), national agencies' and non-space TRD Programmes will also be used to cover parts of the overall Frame Programme. The last step before execution is the elaboration of the Frame Programme into a detailed work plan, and the latter's implementation via a set of contract actions.

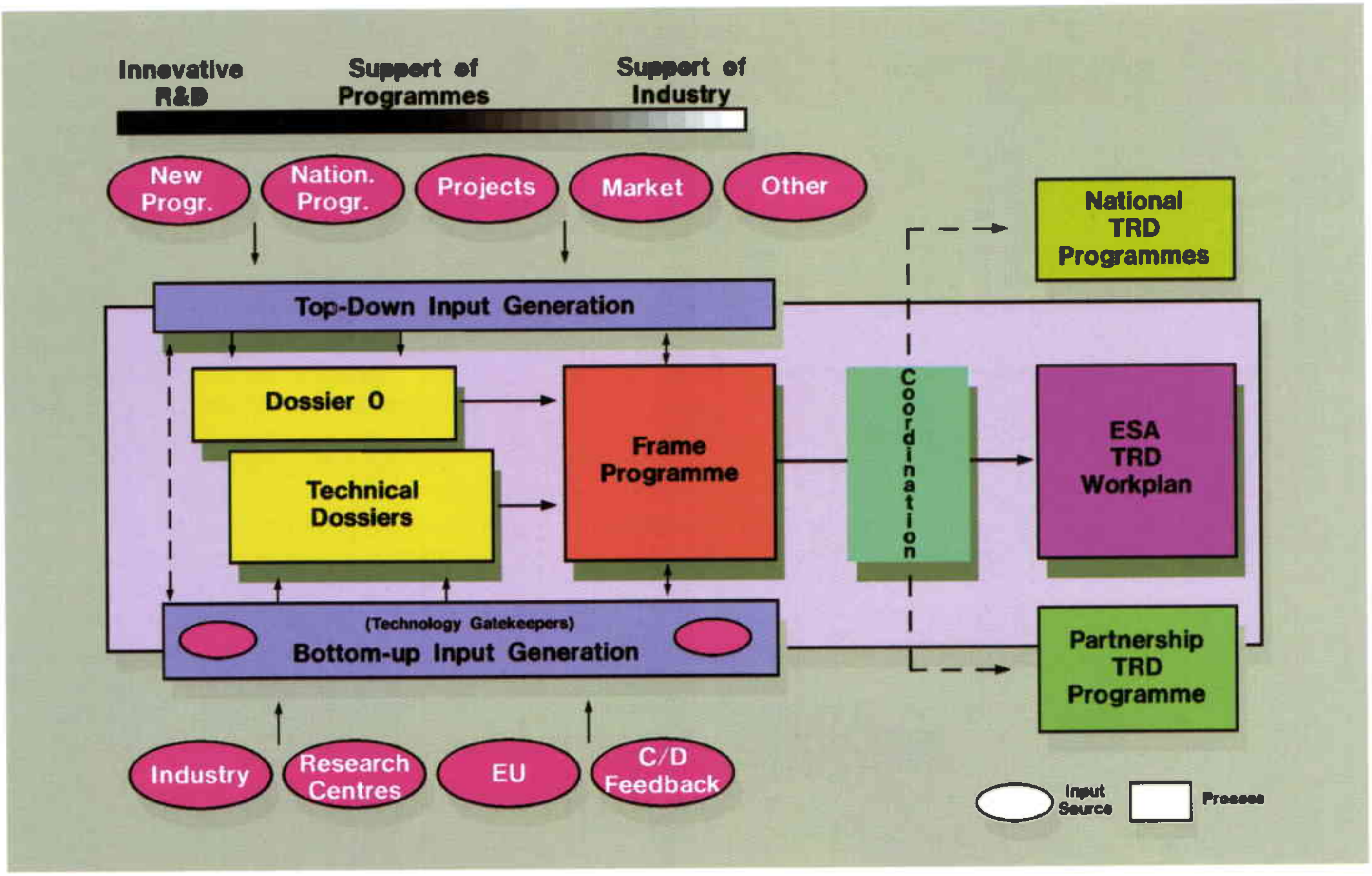


Figure 1. Improved ESA Technology R&D (TRD) definition process

Technology axes

The basic structure of the Frame Programme is formed by a set of so-called 'Technology Axes' representing the core disciplines relevant for spaceflight. Some are identified as 'Major Axes', where their relevance is judged particularly high from both the strategic (core-competence) and tactical points of view (market-opportunity).

The funding needs for space Technology Research and Development (TRD) are growing exponentially due to two phenomena:
- the number of applied technologies continually increases as new applications emerge, and
- the depth of the TRD effort also increases, which implies a larger critical mass to maintain all sub-disciplines.

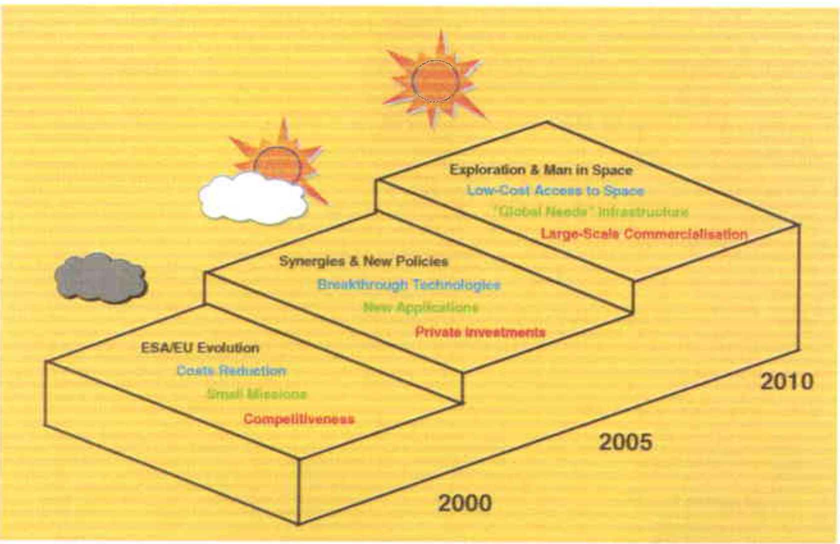


Figure 2. Major characteristics of future European space activities

For ESA, therefore, it has become clear that the availability of funding will never keep pace with this trend and it must be decided which technical activities are vital to the European space community and thereby deserve priority.

13 Major Axes have been identified:

1. Components
   The availability of advanced components must be assured to enable European equipment and systems manufacturers to compete on the World market.

2. Solar Cells
   Advanced solar cells are crucial for the satellite solar arrays of the future: for high-power telecommunications satellites (10 – 20 kW), for commercial applications in MEO (Medium Earth Orbit) and ICO (Intermediate Circular Orbit), and for future science and small-satellite programmes.

3. Spacecraft Data Systems
   Hardware and software building blocks for control and data systems (fault-tolerant computers, support ASICs, standard interface controllers, etc.) will be a critical resource for future European missions, including the next generation of commercial spacecraft.

4. Payload Data Processing
   Digital processing chains are a key element in imager/spectrometer data reduction for Earth Observation instrument data processing.
   Data Processing Units, integrated analogue chains and application software and support circuits for functions such as data compression, vision and navigation sensing for science missions and robotics also require attention.

5. Antennas
   These are a key mission-specific subsystem for all future ESA and international missions and represent a strategic technology for commercial telecommunication applications. Advanced reflectors provide a large collecting/transmitting area with a much lighter, simpler and less costly structure than an active-array antenna with its thousand of complex elements.

6. Digital Telecommunications Payloads
   Dramatic progress in digital technology makes it a suitable candidate for replacing many current analogue payload implementations, thereby increasing flexibility, capacity and cost-effectiveness, whilst reducing assembly, integration and testing effort.

7. Software Engineering
   The objective here is to introduce the concept of 'best practices' into the application of software-engineering methods and tools within space projects, with an emphasis on space-specific onboard-software aspects.

8. Space Environment
   Modern space components are more and more sensitive to space-environment effects (radiation, electrical discharges, etc.) and improved prediction capabilities for both the space environment itself and its effects are critical for the successful application of the latest components.

9. Radar Technology
   The excellent experience with the ERS satellites has demonstrated a clear role

for microwave instruments for Earth observation. The need to fly cheaper missions, with the trend towards more operational/commercial applications, calls for future radars to be designed to consume a minimum of spacecraft resources.

10. **Thermal Control**
On highly dissipative spacecraft such as telecommunications satellites, heat-rejection requirements are already pushing the performance limits of fixed radiators, and deployable types will soon have to be used. The next generation of antennas will require specialised thermal control to remove the heat dissipated at the back of the Earth-viewing reflector.

11. **High-Accuracy Pointing**
Advanced sensor and actuator technologies and signal-processing algorithms are needed for the implementation of very-high-precision pointing and stabilisation systems (sub-arcsecond range). Their inaugural application will be on ESA's FIRST scientific satellite.

12. **Electric Propulsion**
Electric-propulsion systems can enhance existing space missions (e.g. station-keeping for commercial geostationary telecommunications spacecraft), as well as enabling completely new missions.

13. **Micro-/Nano-Technologies**
Micro-/nano-technologies and the resulting microsystems are of strategic importance to European space industry, potentially impacting all areas of activity. Micro-miniaturisation can play an essential role for Europe in designing new generations of satellites and preparing industry for the challenges of the global competitive marketplace.

Concluding remarks

Space is expected to drive the transition towards a 'service-on-demand' type of business, emphasising the early transformation of scientific results into practical applications. A new approach is needed in terms of the pace of technology development, including imaginative multi-source financing agreements between industrial, public and venture-capital sponsors, as well as new legal ground rules.

ESA can support this process very effectively with its technology R&D activities, particularly by:
- promoting greater specialisation both in large companies (e.g. prime contractors) and small and medium-sized enterprises, through improved networking
- promoting broader involvement of small and medium-sized enterprises in space R&D and accommodating their specific needs within ESA's planning methods and formal rules
- pursuing a stronger market and application orientation for its technology R&D activities wherever possible, leading to a clear set of 'priority technologies'.

The strategy for improving the competitiveness of the European space sector should include the introduction of innovative elements into:
- product-oriented R&D
- service-oriented partnership programmes
- introduction of leading-edge technologies in pilot projects in support of visionary programmes
- consideration of new technical, managerial and financial approaches from outside the space industry
- adaptation of R&D activities to individual company strategies
- improvement of the end-to-end development and exploitation life-cycle of space programmes, including the introduction of effective changes in the managerial, design, production and utilisation methods.

Acknowledgement
The authors would like to acknowledge the specific contributions made by F. Gampe and M. Novara to the preparation of 'Dossier 0', on which this article is largely based.

An ECU-Based Financial System for ESA

M. von Harpe
Head of Finance, ESA, Paris

This article addresses the background to the decision to introduce a full European Currency Unit (ECU) within ESA, taken at last year's Meeting of the ESA Council at Ministerial Level, in Toulouse (F). It discusses the various possible scenarios in the evolution towards European Monetary Union (EMU), as well as its expected impact on the financial system of the Agency.

Monetary cooperation in Europe

The Maastricht Treaty was not the first attempt to establish European Monetary Cooperation. In the early 1960s, discussions had already started as to whether evolution to economic and monetary union was indeed necessary and politically feasible. Following the successful introduction of a Customs Union in 1969, closer monetary cooperation was set as one of the next targets. In late 1970, the so-called 'Werner Plan' established the first timetable for the realisation of Economic and Monetary Union within a period of ten years. But the time was not ripe.

Due to heavy turbulence in the financial markets, the so-called 'Gold (Dollar) Standard' was indeed abolished to provide relief to the old and rigid system of fixed exchange rates related to the US Dollar measured in gold. While the US Dollar faced the consequences of being exposed to the volatility of the market, Community countries for the first time tried vigorously to control variations within a band of 2.25% above or below an average exchange rate to the Dollar: the so-called 'currency snake'. The snake did not prove sufficiently stable to provide a dam against the considerable monetary tensions and variations between European currencies and the US Dollar. The difficult situation led to a joint initiative by France and Germany in 1979 to create the European Monetary System (EMS) with in principle fixed (but in practice to some extent flexible) mechanisms and a common denominator in the form of the European Currency Unit, or 'ECU', determined on the basis of a basket of European currencies.

Until 1993, this relatively limited band for exchange variations of 2.25% was tested heavily by the financial markets. On 2 August 1993, Member States and participants decided to raise this band to 15% in both directions. Since then, the system seems to have worked quite well, weathering several speculative storms, but at the same time highlighting the persistence of the phenomenon of 'weaker' and 'stronger' currencies within and outside the EMS in countries without well-coordinated and solidly pursued economic and financial policies.

European monetary and economic union

Based on the recommendations of the Delors Report of April 1989 and the Maastricht Treaty on the European Union of 1992, the process of convergence to European Economic and Monetary Union (EMU) commenced in three stages, starting on 1 July 1990. The first stage enshrined the complete liberalisation of capital movements in the European Union, and economic and monetary convergence in certain areas, including closer coordination of financial policies. The second stage started on 1 January 1994, serving as a transition to the third and final stage, which is supposed to establish the necessary legal, institutional, financial and economic conditions for the introduction of EMU.

An important element was the creation of the European Monetary Institute (EMI) in Frankfurt as the forerunner of the future European Central Bank. The EMI's main objectives are the coordination of Central Banks' policies and mechanisms with a view to achieving price stability, the supervision and control of the functioning of the EMS in its present form, and the preparation of the third stage in terms of developing the instruments and procedures needed for a unified monetary policy.

According to the Maastricht European Union Treaty, the third stage starts on 1 January 1999.

Automaticity is implied only for those member countries that fulfil the established convergence criteria. A strict interpretation of Maastricht would presumably only allow EMU to commence with a relatively small circle of countries, leaving the door open for other member countries to fulfil the necessary conditions for joining at a later date. Special arrangements are currently foreseen for the United Kingdom and Denmark. The European Council will review and decide at the beginning of 1998 which countries will be participants in EMU in its start phase.

Quantifiable criteria for participating countries are:

- Price Stability: inflation not more than 1.5% above the rates of the three countries with the best price stability.
- Budgetary Discipline: public deficit not more than 3% of GNP per given year and total public debt not exceeding 60% of GNP.
- Level of Interest Rates: interest rates for long-term credits should not move considerably beyond interest rates for public bonds in the three countries with the best price stability.
- Stability of Exchange Rates: participants' currencies are supposed to behave in a stable fashion within the EMS band for a certain time period.

Third stage of EMU and a new currency, the EURO

The European Council decided in December 1995 in Madrid to call the new European Currency the 'EURO'. It will replace the ECU once EMU is fully established. The European Council also took decisions on the timetable and the modalities as to how the EURO should be introduced.

In a 'First Round' during 1998, the number of qualifying participants for EMU will be established. The (present) basis for the review of the main convergence criteria are the actuals of the year 1997. Until 1 January 1999 – the so-called 'Interim Period' – the new European Central Bank will have to be made operational on the basis of recommendations provided by its forerunner, the EMI. Monetary procedures and instructions for the banking and public sectors should preferably be in place in 1999 to allow financial activities to proceed undisturbed and for preparing the changeover to the new EURO banknotes and coins.

In the 'Second Round', EMU will commence on 1 January 1999 with those member countries that have qualified. Whether that early date will indeed prove to be realistic, and whether it will be feasible to start with the relatively small number of countries presently eligible for membership, will be discussed at the next European Councils. The present Maastricht decisions foresee as a major financial milestone that the beginning-of-1999 exchange rates for national currencies of EMU participants vis-a-vis the EURO will be fixed permanently. This is why it is not possible to exactly predict today the final rates at which the EURO will be frozen in parallel with national currencies as of January 1999.

What is important is the following: the EURO will not replace national currencies immediately. It is already recognised that a further three years (1999 – 2002) will be needed for sufficient EURO banknotes and coins to be produced and made available over the counter. During this period, the EURO will be used primarily as a parallel and payment-unit currency for all non-cash payments among EMU participants, more and more replacing national currencies in banking and industrial payment-transfer activities wherever feasible. All parties will have a choice during this period between continuing to use their national currencies at a fixed rate to the EURO, or using the EURO for non-cash operations. National Central Banks, in coordination with the new European Central Bank, will offer their good services in terms of conversion facilities and transfer arrangements.

In the 'Third Round' beginning in 2002, EURO banknotes and coins are supposed to be ready for exchanging with old currencies. Presently it is foreseen that this (complicated) exchange procedure will last six months, with the idea that the changeover to the new single currency will have been successfully accomplished for all EMU participants by 1 July 2002. After that date, the national currencies of EMU participants that have continued to be used in parallel with the EURO will no longer be valid. Theoretically, there will be no losses in existing assets validated at that date. Cash, deposits, loans, debts, salaries, prices, rents, life insurances, mortgages, etc. will be recalculated and transferred into EUROs from national currencies at the exact future exchange value. This recalculation is basically a technical process, so in the end market participants and European citizens should break even financially, becoming neither richer nor poorer compared with their prior status.

EMU and non-participating EU Member Countries

Despite all of the efforts to fulfil convergence criteria for monetary stability and to qualify for EMU, it could well be that several countries will not be onboard, either at the starting date of 1 January 1999 or at the final date foreseen for the replacement of national currencies by the EURO in 2002. It is therefore to be assumed that there will be participating and non-participating States within the EU after 1999. This possibility is recognised by the Maastricht Treaty. While this can eventually lead to a situation of duality, it does not necessarily mean that monetary tensions in Europe will rise. The door is left open right from the start in 1999 for all other EU countries to join, provided they make the additional effort to respect convergence criteria and to qualify for EMU participation.

A formal review process is foreseen every two years after the kick-off date of 1999. Non-participating countries will continue to cooperate with EMU members through a reformed EMS II. In that case a basket of non-EMU countries' currencies is set against one anchor, the EURO. The monetary cooperation between EMU and EMS II certainly seems to be important for overall monetary stability in the interim, but can have the built-in structural weakness of two systems floating against each other. It is therefore still under discussion whether EMS II should only be of limited existence and serve the notion of bringing non-participants into EMU, or whether EMS II should be used as a separate monetary mechanism to avoid barriers in financial transfers in Europe and to prevent unfair competitive advantage.

One of the most contentious issues of the discussion up to now has been whether non-members of EMU should have unconditional access to the planned EURO payment system, the so-called 'TARGET'. The European Monetary Institute (EMI) has issued a first report on this topic. Options on how companies, banks, public institutions and/or other entities should be afforded access to TARGET are still under review. There are no clear indications as to when this question might be fully resolved. Uncertainty in this area would be a difficulty for all industries and financial institutions of countries presently not planning to join EMU.

The issue of access to the newly emerging financial markets of EMU has become controversial since the banks of prospective EMU members do not tend to support the idea of equal treatment and automatic access to the TARGET system. In addition, several EMU candidates have requested the imposition of strict conditions for access to intra-day liquidity and Central Bank credit lines in the EURO, in order to avoid the spill-over into commercial overnight credit facilities. This will be a sensitive point for businesses situated outside the EMU members, which are already looking at best opportunities and lowest costs throughout the whole of Europe.

Eventually political wisdom will prevail, since the recommendations by the EMI and the European Commission focus on the non-controversial technical elements of the new system. If these do not affect monetary policies and maintain the eminent overall objective, which is the final participation of all, or certianly most EU Member States in EMU, then the door is open not only for further cooperation under an extended EMS II system, but also for the final merging of EMS II with EMU if prevailing convergence criteria can be met in the years to come.

Impact of an all-ECU system on ESA

The Ministers at the ESA Council Meeting at Ministerial Level in Toulouse in October 1995 decided to reform the Agency's financial system as of January 1997 through, inter alia, introducing a single payment unit in *'the form of the ECU as defined in document ESA/C(96)100, rev. 3, corr. 1'.* To achieve this goal, the old Article V (paras. 1 and 2) of Annex II of the ESA Convention was replaced with the following text:

'The Budgets of the Agency shall be expressed in ECU as currently defined by the European Union's competent bodies and subsequently in the European payment unit which may

replace it as soon as it is set into force by these bodies'.

'Each Member State shall pay its contribution in ECU and in the subsequent replacement for it as referred to in paragraph 1 above'.

While the all-ECU system of the Agency will be introduced as of 1 January 1997, Council equally decided to facilitate a smooth introduction by means of a transition period from 1997 to 2000, during which existing non-ECU contractual commitments will be phased out gradually and income in ECU increased to 100%. Full symmetry between the income and expenditure sides will exist at the beginning of the year 2000, with the exception of certain running costs still to be paid in national currencies as long as a fully-fledged EMU system does not yet exist. On the basis of the revised Article V of Annex II to the ESA Convention, the situation is quite clear: the all-ECU system of the Agency enters into force as of 1 January 1997 without automaticity or direct links with the starting of EMU and the parallel use of the EURO as from 1999 onwards, since it is not directly linked to the Maastricht agreement as such.

One can distinguish three cases that can have some bearing on the future of the Agency's financial system:

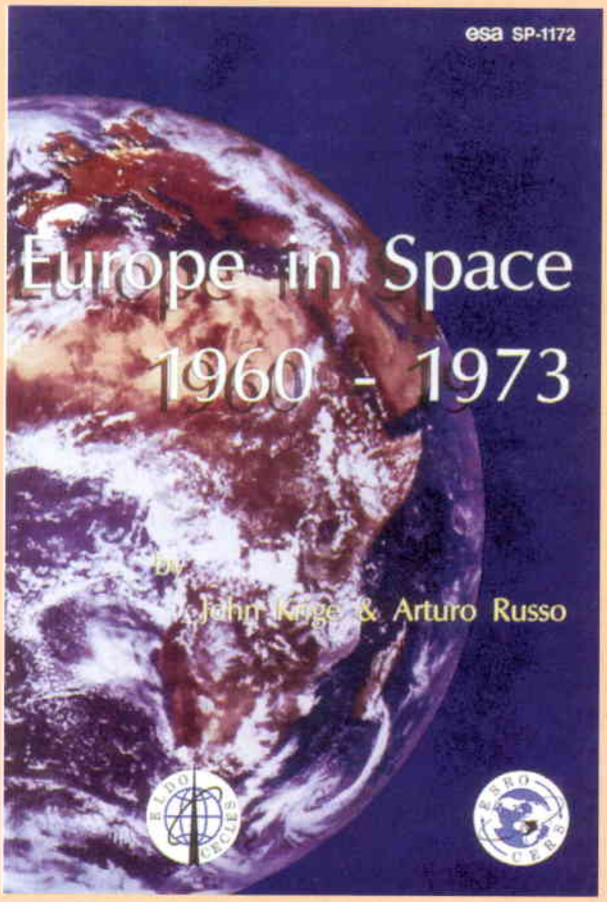
- Effectiveness of the Agency's all-ECU system as of 1 January 1997 with a transition period until 2000. The period 1997 – 1998 is different from the subsequent period starting in 1999 in so far as this is the date when EMU, in its initial structure, takes off with the (small) number of countries eligible for membership. During the initial 1997 – 1998 period, there will be no effects at all on the all-ECU system of the Agency, since the selection for EMU will have just started. The Agency's ECU will therefore remain the 'Accounting Unit' as defined by the EU and decided by the EU's competent bodies for usage under the present EMS mechanism.

- A separate phase can indeed start during the transition period with EMU becoming operational and with introduction of the new parallel payment unit and currency, the EURO. This event still seems somewhat conditioned by the political debate as to whether the (ambitious) timetable for EMU should stay on course and whether enough participating (and eligible) States can be selected at the European summit in 1998. Even if EMU exists at that date, there will be no direct impact on the all-ECU system of the Agency, except if all EU members simultaneously enter EMU. In that case the EURO would de facto become the immediate substitute for the ECU because the EU as such would through its competent organs use the EURO instead of the present ECU as a parallel currency to national currencies until final introduction of the EURO as a single currency in mid-2000.

- The situation is different if EMU would start with only a small number of participants as of 1999. In this scenario the ECU, as presently defined by the EU's competent organs and used under the EMS, would continue to be the payment and Accounting Unit for the Agency until it is formally replaced by the EURO as the new payment unit and single currency through decisions of the competent organs of the EU. The European Council, at one of its next meetings, is certainly free to establish such replacement of the ECU by the EURO under a revised EMS II. In that case EMS II could use the EURO as an anchor for calculating a reference unit to the EURO using non-participants' currencies as a basket. Only in the event of such a decision would the ECU be replaced by the EURO as laid down in Article V of Annex II of the ESA Convention.

- If no decision by the competent organs of the EU on the early replacement of the ECU by the EURO is forthcoming, the all-ECU system of the Agency would continue at least until 2002. From that date onwards, the EURO is formally foreseen as the single European currency with all EU participants onboard. This date and this event would trigger the clause contained in Article V of Annex II of the ESA Convention, whereby:

  'the budgets of the Agency shall subsequently be expressed in the European payment unit which may replace the ECU as soon as it is defined and set into force by the EU's competent bodies'.



EUROPE IN SPACE 1960 – 1973
by John Krige & Arturo Russo

This is the first part of a two-volume history covering Europe's cooperative space efforts, which traces their beginnings from the late 1950s and the subsequent developments of a European space programme from that time up to the early 1970s. It recounts the efforts of the fledgling space community that launched ESRO (the European Space Research Organisation) and ELDO (the European Launcher Development Organisation), with much government support, and shows how those two organisations gradually evolved, and how the foundation was laid for a single European Space Agency.

Drawing on the ESA documentation in the Historical Archives of the European Community at the European University Institute in Florence, and the many interviews with key players involved in the build-up of the European space programme, John Krige and Arturo Russo provide a lively picture of the complex and at times dramatic process of Europe's slow, but determined, efforts in establishing a cooperative space programme.

'This volume provides an important contribution to our understanding of the development of science and technology in postwar Europe. It should thus be of interest not only to those who were directly involved in Europe's fascinating venture into space, the space scientists, and those concerned with the organisation and implementation of the space projects in government and industry, but also to the general public who watched, and simply by virtue of their support became participants in, one of the most remarkable successes of European integration.

I hope that the reader will get a feel for what drove the pioneers in their efforts to set up a European space programme and their enthusiasm for that cause, and will read this fascinating story with a similar sense of attachment and participation as I have read it and look forward to the second volume of the study.'

Reimar Lüst
Chairman of the Advisory Committee to the ESA History Study

Europe in Space 1960–1973, ESA SP-1172

Published by:	ESA Publications Division ESTEC, Postbus 229 2200 AG Noordwijk The Netherlands
Price:	Dfl 70

Thirty Years of Sounding Rockets

– Reflections Following a Reunion at ESRANGE

A. Pedersen, P. Colson, R. Meiner*, A. Menardi & T. R. Sanderson
ESA/ESTEC, Noordwijk, The Netherlands

P. Englund
ESRANGE, Kiruna, Sweden

Even as the first launch of ESRO's Sounding Rocket Programme departed from the Salto de Quirra military range in Sardinia in June 1964, planning was already completed for ESRO's own range in Kiruna, Sweden to probe the auroral ionosphere and atmosphere. ESRANGE officially opened on 24 September 1966 and the first rockets were launched the following November. This was to be the start of several years of hectic activity at the range.

The programme came to an abrupt end in 1972 as part of the preparations for the creation and expansion of ESA, but the memories remain vivid for many of the rocketeers. An enthusiastic group, some still with ESA and others working or retired in various European countries, marked the 30th Anniversary with a reunion at ESRANGE from 28 August to 1 September this year.

ESRANGE past and present

A total of 152 sounding rockets was launched from ESRANGE between 1966 and 1972: 72 under ESRO's aegis and 80 within national programmes. Most flew during auroral activity to study the effects of energetic electrons and ions that had been accelerated in the distant magnetosphere before precipitating along magnetic field lines in the auroral atmosphere. The beautiful auroral displays are the visible manifestations of a region in space uniquely suited to studying these processes at work, both near and beyond the Earth.

Most of ESRANGE's permanent staff hailed from countries with previous sounding rocket experience, such as the United Kingdom, France, Germany, Norway and Sweden, but other nationalities added colour to Kiruna's new community. Life became more hectic during the campaigns when the payload teams from ESTEC, and the experimenters from various ESRO Member States, joined the permanent staff. This made it necessary to make use of Hotel Albert, a primitive wooden barrack built next to the main ESRANGE building – an unforgettable experience for many visitors. Launching auroral rockets often required long vigils during cold winter nights, and it was not unusual for a campaign, when no suitable launch conditions appeared, to be moved to the following winter.

Several national space agencies also exploited ESRANGE for rocket and balloon experiments. This was particularly true of Germany and Sweden, which had sizable national rocket programmes at that time.

It came as an unpleasant surprise when ESRO's Council decided in 1971 that the rocket programme would end the following year in order to clear the decks for a wider range of activities under the soon-to-be-born ESA. Most of the ESRO staff, and many of the experimenters, felt that this sudden end to a successful and smooth-running programme, with a quick turnaround time, was most unfortunate. ESRANGE was turned over to Swedish control, leaving it with a much smaller programme and, consequently, a highly uncertain future.

The members of this year's reunion were therefore delighted to find that not only has ESRANGE survived, but it is thriving thanks to new rocket programmes and other activities as a co-ordinated European programme under the responsibility of national space agencies.

Recent years have seen a new class of rocket flights: microgravity experiments on high-altitude carriers. Microgravity research on Skylark 7 and the 15 t Maxus, first launched in May 1991, has brought ESA back to ESRANGE. The steerable Maxus can reach close to 1000 km and return within 7 km of the predicted impact point. Cassini's Huygens Probe, which will land on Titan in 2004, was

* Retired

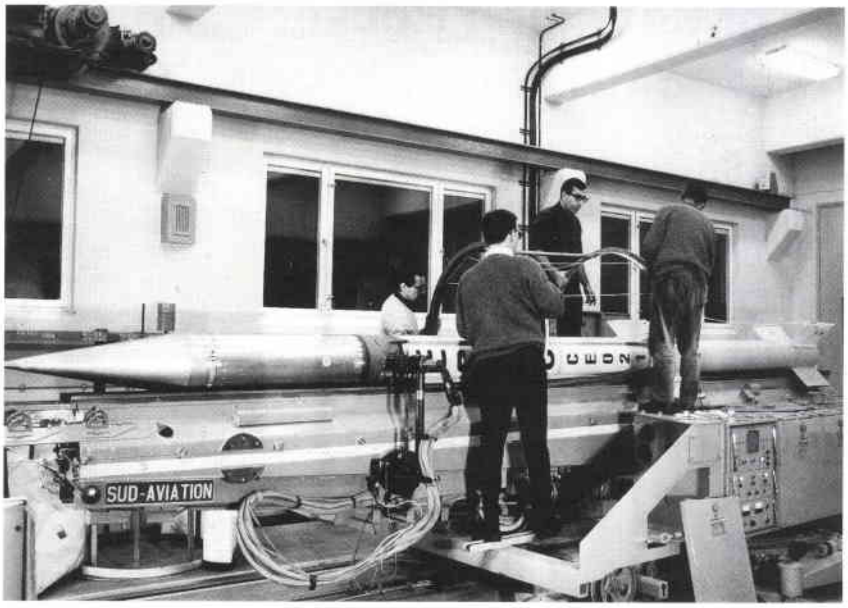


Figure 1. Preparation of a Centaure rocket for the first launch campaign at ESRANGE in late 1966

drop-tested by ESA at ESRANGE. A balloon carried Huygens up to 38 km, where it was released to demonstrate deployment and parachute performance. The Probe was successfully recovered – a standard procedure at ESRANGE.

ESRANGE's continuity has also been assured by the operation of numerous Earth-observation and science satellites for ESA and many agencies worldwide. ESA's Earth-observation ground station near ESRANGE adds to the technical and social environment in the gently sloping hills 50 km northeast of Kiruna.

The 30th Anniversary Reunion

Some 50 people travelled to Kiruna for the reunion, from ESA establishments, Belgium, Germany, Italy, Spain, the United Kingdom and France, and several ex-ESRANGE staff came from various corners of Sweden. About 60 apologies were received from ex-rocketeers unable to join the reunion; inspired letters were received from Albert Le Bras, the first ESRANGE Director, and Pierre Blassel, who was responsible for all technical installations.

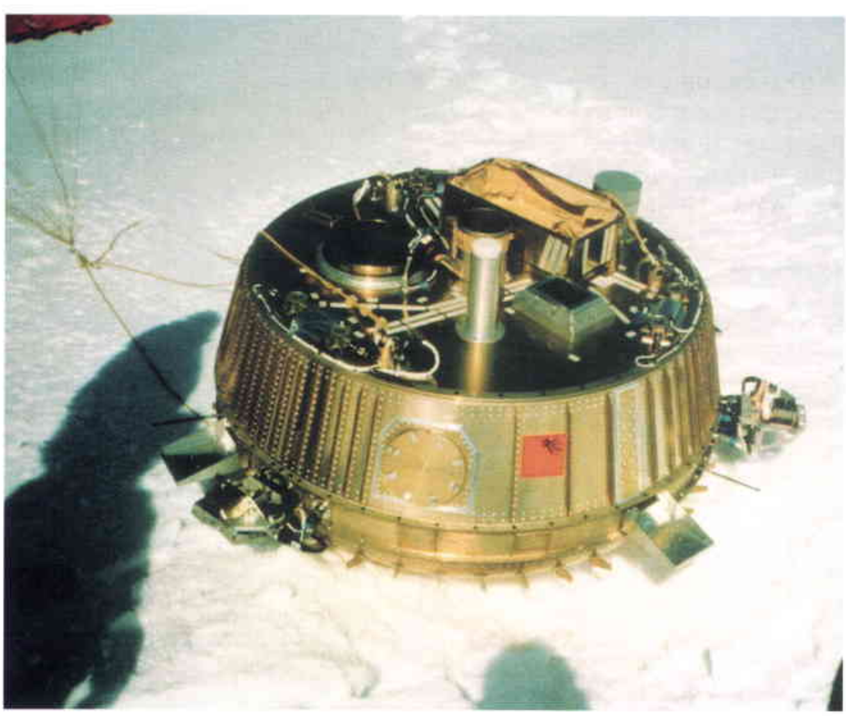


Figure 2. Cassini's Huygens probe, recovered after its ESRANGE drop test in 1995

On Thursday 29 August, ESRANGE provided a full day's programme for the visitors. They were welcomed by the present Head of ESRANGE, Jan Englund, and then staff members gave presentations of past and present range activites. Professor Bengt Hultqvist gave an historical overview of the events leading up to the establishment of ESRANGE; the early existence of what was then called the Kiruna Geophysical Observatory was certainly an important element in that process. A tour of the present facilities followed. In the evening a dinner was held in the Kiruna Town Hall for the visitors and ESRANGE staff. The Mayor of Kiruna reminded the guests that Kiruna is the largest 'community' in the World, being half the size of Switzerland!

There was also a 'ceremonial launch' to bring back old memories. A miniature Zenith was successfully launched to an altitude of several hundred metres. This model of one of ESRO's rockets was kindly provided by Nova Models of Florida, USA.

The reunion was also an opportunity to remember colleagues who have passed away. A well-known veteran from the early ESRO rocket campaign, Steve Pooley, died earlier this summer. His memory was honoured by a one-minute silence, which also served as a mark of respect for other deceased staff.

The ESRO Sounding Rocket Programme – early lessons for ESRO and ESA

In 1989, the then Director General of ESA, Reimar Lüst, said in relation to the 25th Anniversary of the first ESRO sounding rocket flight,

'The spirit of those who worked on the early sounding rockets still pervades much of the European space activities today. It is an excellent heritage: long may it remain so.'

These words have special significance coming from an ex-rocketeer whose space career began with rocket experiments at ESRANGE.

ESRO provided the first test of European co-operation in this field, proving successful in

3

4

5

6

Figure 3. Participants at the ESRANGE Reunion

Figure 4. Launching the Skylark 7/Texus-3 mission from ESRANGE in April 1980

Figure 5. Reliving old memories: launching the Zenith model rocket

Figure 6. The reunion participants picnicking on a mountain overlooking Abisko near the Swedish/ Norwegian border

Figure 7. View over ESRANGE during a Texus rocket launch

terms of technical performance, management and programmatics. An important element was that technical teams could design, build and test a significant proportion of the rocket payloads at ESTEC; the rest was built by industry. This increased the level of knowledge and experience in the Agency and formed the basis for a sound management structure.

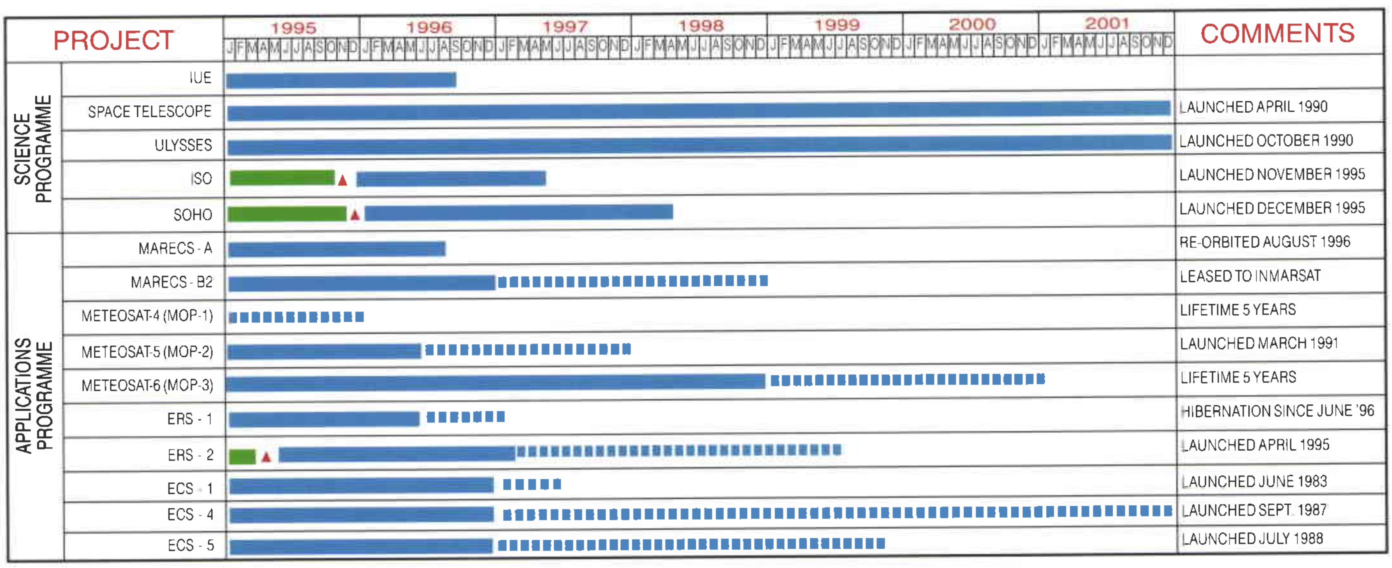
Many engineers were forced to leave ESRO after the last rockets departed in 1972. ESRANGE could still offer some employment to the Swedish staff, and a fair number of other nationalities found new positions at the various ESRO establishments, the majority of them at ESTEC. For many engineers, the experience gained on sounding rockets was a stepping stone to longer-term careers in ESA. Many made valuable contributions to satellite and manned space projects due in part to the technical insight gained by their close involvement in ESRO's rocket projects. Unfortunately, many have either retired or are close to retirement, leaving few with hands-on experience for future ESA projects.

The sounding-rocket programme made it possible for scientists from all Member States to be involved and gain their first experience in a space venture. The rocket projects, taking only a few years from concept to flight, provided ideal PhD themes, and many well-known European space scientists launched their academic careers on rockets.
Building experiments for flight was a new challenge for scientific laboratories in the mid-1960s. Colleagues on NASA programmes were initially far ahead of the Europeans, as few laboratories here had the knowledge required to produce satellite hardware. The sounding-rocket experience changed all that: European groups quickly grasped the intricacies of space instrumentation and gradually gained the confidence and knowledge to be the equals of their international colleagues, even on the more challenging space missions. It is a telling fact that most laboratories involved in the current ESA Scientific Programme were involved at some time in a rocket programme run by ESRO or a national space agency.

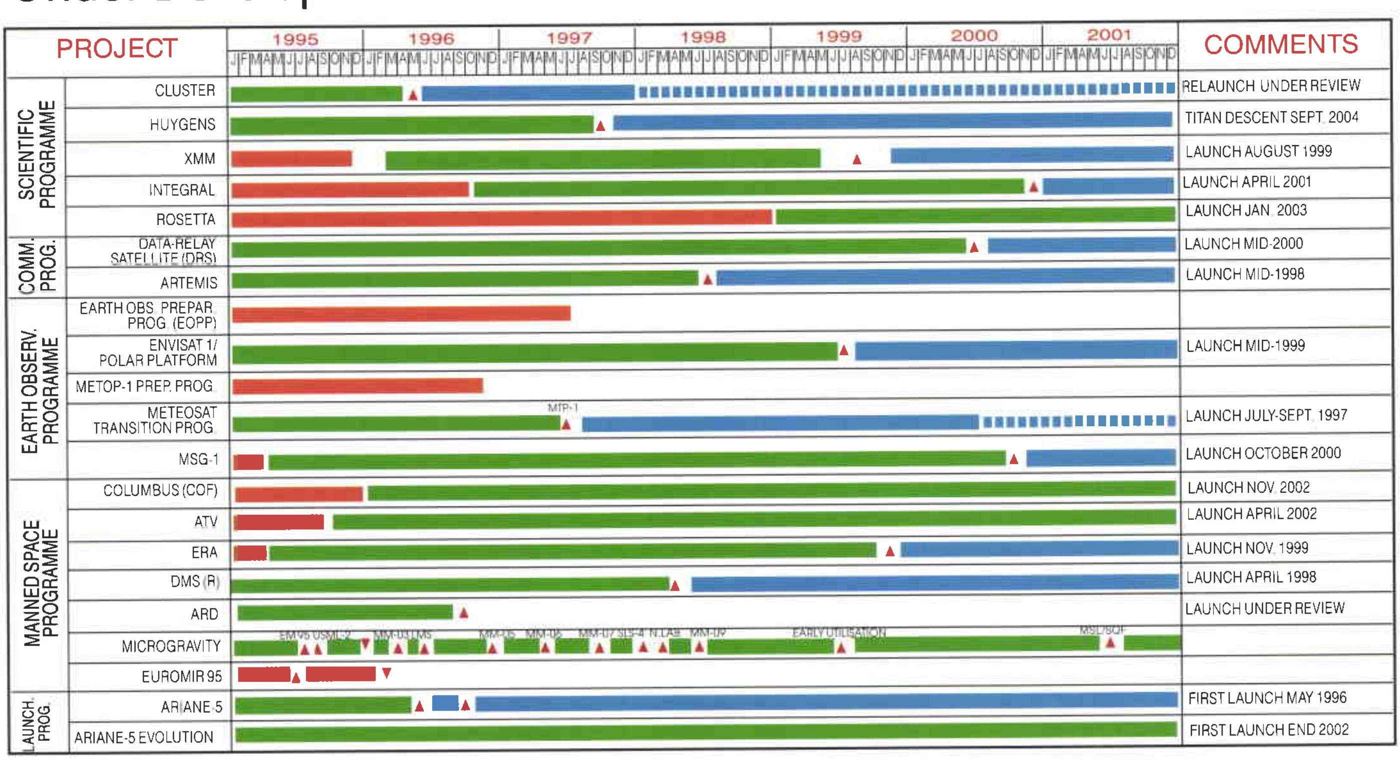
The scientific knowledge obtained via the ESRO sounding-rocket programme at ESRANGE provided new insights into the dynamic auroral ionosphere and its coupling to sources of energetic particles. Today, the early results from rocket measurements in the polar atmosphere have gained renewed relevance for the understanding of the depletion of the ozone layer. These results also formed the basis for later international and national auroral satellite missions. Even now, there are unsolved mysteries in the ionosphere and atmosphere above ESRANGE at heights reachable only by rockets and balloons.

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

In Orbit / En orbite



Under Development / En cours de réalisation



■ DEFINITION PHASE ■ MAIN DEVELOPMENT PHASE ▲ LAUNCH/READY FOR LAUNCH

■ OPERATIONS ■■■ ADDITIONAL LIFE POSSIBLE ▼ RETRIEVAL

Météosat de deuxième génération (MSG)

La fabrication de tous les équipements du modèle technologique et du modèle thermique/mécanique est en cours dans l'industrie, à l'exception du télescope et du dispositif de balayage de l'instrument SEVIRI (imageur visible et infrarouge amélioré non dégyré) qui fait l'objet d'une redéfinition tenant compte à la fois des contraintes de vol et de l'environnement thermique en orbite. On espère lancer la fabrication du SEVIRI à l'issue d'autres revues préliminaires de conception de la structure en octobre et de l'instrument de balayage en décembre. Le calendier du SEVIRI se trouve actuellement dans une phase critique.

Eumetsat contribue une somme fixe au programme ESA de développement du MSG-1 et finance entièrement les satellites MSG-2 et MSG-3 qui sont fournis par l'ESA pour le compte d'Eumetsat. Les négociations avec l'industrie pour les trois satellites MSG sont terminées et la signature du contrat devrait intervenir très prochainement.

Le lancement du premier MSG est maintenant prévu pour octobre 2000, suivi en 2002 par MSG-2 et en 2003 par MSG-3 comme satellite de réserve.

Météosat

Le satellite du programme Météosat de transition (MTP) est entièrement intégré. Les essais d'ambiance ont commencé et devraient prendre fin début 1997. Les essais de compatibilité suivront et toutes les caractéristiques de fonctionnement définitives du satellite seront également vérifiées. Il devrait faire l'objet d'un lancement Ariane-4 pendant la période juillet – septembre 1997.

MTP sera le dernier satellite construit selon le concept des satellites MOP (Programme Météosat Opérationnel). Une fois lancé, il sera exploité par Eumetsat et fournira régulièrement les cartes atmosphériques de l'Europe que nous recevons actuellement de Météosat-5, Météosat-6 jouant pour sa part le rôle de réserve en orbite. Ces deux satellites ont également été construits au titre de contrats d'approvisionnement de l'ESA.

METOP

Les travaux au niveau système ont progressé dans le cadre de la phase-B, avec notamment des analyses RF et l'élaboration de modèles structurels et thermiques d'éléments finis pour la totalité du satellite, charge utile comprise. En ce qui concerne l'analyse couplée dynamique du composite de lancement double (Métop-1 et Spot-5) sur le lanceur, les préparatifs en sont à un stade avancé.

La préparation des spécifications du système, des sous-systèmes et du soutien a bien avancée, dans la perspective de la revue des impératifs système qui doit se tenir à la fin de l'année.

La sélection des sous-traitants chargés de la mise au point des nouvelles unités s'est faite dans le cadre d'un appel d'offres concurrentiel dans le courant de l'été. La conception détaillée de ces équipements est maintenant en cours, l'objectif étant d'établir une définition détaillée des interfaces d'ici le dernier trimestre 1996 et des concepts consolidés ainsi que des listes de composants début 1997.

La définition de la charge utile a gagné en clarté grâce à une définition plus solide de l'instrument GRAS. On a en outre continué d'évaluer la possibilité de remplacer GOME-2 par ImS-3 et l'instrument devant assurer la mission de surveillance de l'ozone devrait être bientôt définitivement retenu.

La rédaction des documents juridiques nécessaires à l'établissement du programme de développement est en bonne voie, un large consensus s'étant dégagé tant en ce qui concerne la proposition de programme que l'Accord de coopération. Des réunions de participants potentiels continuent de se tenir, la dixième a eu lieu le 12 septembre.

L'approbation de la phase de transition, qui doit commencer à la fin de l'année, a été demandée. Etant donné les retards auxquels on s'attend maintenant en ce qui concerne le calendrier d'approbation du programme dans son ensemble, il est indispensable que cette phase de transition soit approuvée et financée de façon adéquate pour que le coût et le calendrier de développement de Métop/EPS soient respectés.

ERS

La charge utile d'ERS-1 est en mode hibernation depuis le 3 juin 1996. Les activités d'imagerie SAR se poursuivent au-dessus de Kiruna, avec en moyenne deux passages par jour, afin d'entretenir les batteries. La charge utile sera réactivée pendant trois jours tous les trois cycles récurrents pour procéder à des activités de maintenance.

La programmation des opérations d'ERS-2 se poursuit en accord avec le plan d'exploitation retenu.

Les problèmes enregistrés début août avec l'instrument actif à hyperfréquence (AMI) se sont traduits par une faible disponibilité des données. Ces problèmes ont été provisoirement résolus en faisant appel au sous-système redondant, dans l'attente d'une étude détaillée de la chaîne nominale prévue fin septembre.

Les petites anomalies qui continuent de se produire sur l'altimètre radar (RA) n'ont que peu d'incidence sur la disponibilité des données.

Le fonctionnement de l'expérience de surveillance de l'ozone à l'échelle du globe (GOME) demeure stable et la diffusion des produits de données a officiellement commencé le 7 juillet 1996.

Le radiomètre à balayage le long de la trace (ATSR) fonctionne de nouveau de façon pleinement nominale et l'équipement de mesure précise de la distance et de la vitesse radiale (PRARE) continue de bien fonctionner.

La plate-forme du satellite en elle-même ne pose toujours aucun problème.

Cluster

Après la perte des quatre satellites Cluster lors du premier vol d'essai d'Ariane-5, le Comité du Programme scientifique (SPC) de l'Agence a décidé de reconstruire un

Meteosat Second Generation

The manufacture of all engineering model and thermal/mechanical model equipment is now underway in industry, except for the telescope and scan assembly of SEVIRI (Spinning Enhanced Visible and Infra-Red Imager), which is being redesigned in order to meet both the launch and in-orbit thermal environments. It is hoped to release SEVIRI manufacture after supplementary Preliminary Design Reviews in October for the structure and in December for the scan assembly. The SEVIRI schedule is on a critical path.

Eumetsat is contributing a fixed amount to the MSG-1 ESA development programme and is fully financing MSG-2 and MSG-3, which are being procured by ESA on Eumetsat's behalf. Negotiations with industry for the three satellites MSG-1, 2 and 3 have been concluded and the contract is expected to be signed shortly.

The launch of MSG-1 is now scheduled for October 2000, with MSG-2 to be launched in 2002 and MSG-3 to go into storage (as the backup) in 2003.

Meteosat

The Meteosat Transition Programme (MTP) spacecraft is fully integrated and environmental tests have started which are expected to be completed in early 1997. Compatibility tests will follow and the spacecraft's final overall performance will also be verified. Launch on an Ariane-4 vehicle is anticipated in the July to September 1997 timeframe.

The MTP spacecraft will be the last of the Meteosat Operational Programme (MOP) design, and once launched will be operated by Eumetsat to provide the regular weather pictures over Europe which are currently being provided by Meteosat-5, with Meteosat-6 as the in-orbit spare. Both these spacecraft were also provided under ESA spacecraft supply contracts.

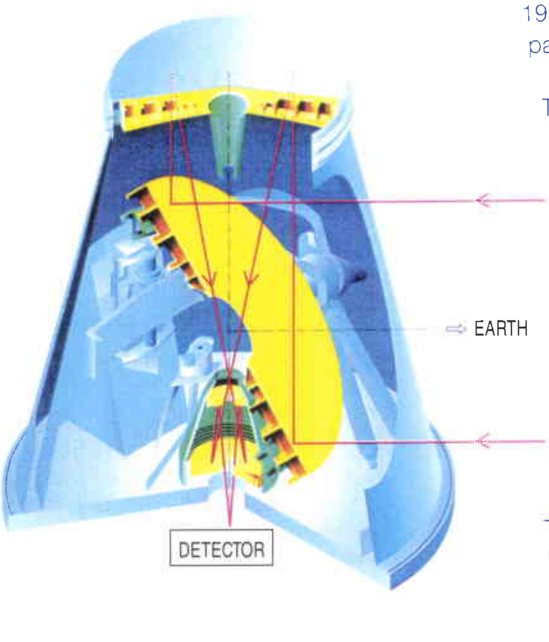
METOP

Work has progressed at system level in Phase-B, including RF analysis aand the establishment of finite-element structural and thermal models of the entire satellite including its payload. Preparations are well advanced for the coupled-load analysis of the dual-launch composite (Metop-1 and Spot-5) on the Ariane-5 launch vehicle.

The preparation of system, subsystem and support specifications, in readiness for the System Requirements Review at the end of the year, is well advanced.

The selection of subcontractors for the development of new units has been completed via a competitive tender action during the summer. Detailed design of these equipments is now in progress with the goal of establishing a detailed interface definition by the last quarter of 1996, and consolidated designs and parts lists at the beginning of 1997.

The payload definition has become clearer with a firmer definition of the GRAS instrument. Furthermore, the evaluation of ImS-3 as an alternative to GOME-2 has continued and the final selection of the candidate instrument for the ozone-monitoring mission should be completed soon.



Overall layout of the SEVIRI instrument

Vue schématique de l'instrument SEVIRI

The legal documents necessary to establish the development programme are now in good shape with broad agreement having been established with respect to both the Programme Proposal and the Cooperation Agreement. Potential Participants meetings continue to be held, the tenth such meeting having taken place on 12 September.

Approval is being sought for the bridging phase, due to start at the end of the year. In view of the delays now foreseen for the approval of the overall programme, agreement and proper funding of this bridging phase is mandatory if the cost and development schedule for METOP/EPS is to be maintained.

ERS

The ERS-1 payload continues in the hibernation initiated on 3 June 1996. SAR imaging activities continue over Kiruna for an average of two passes per day, for battery-preservation reasons. The payload will be re-awakened for three days every third repeat cycle for maintenance activities.

Scheduling of ERS-2 operations continues according to the Preferred Exploitation Plan.

Problems with the Active Microwave Instrument (AMI) during early August led to low data availability. These problems have been overcome in the short term by exploiting redundancy, pending a detailed investigation of the nominal chain in late September.

Minor anomalies continue to occur on the Radar Altimeter (RA), but have only a small impact on data availability.

The Global Ozone Monitoring Experiment (GOME) is still showing stable performance and the formal release of data products was initiated on 7 July 1996.

The Along-Track Scanning Radiometer (ATSR) has been restored to full nominal performance and Precise Range and Range-Rate Equipment (PRARE) continues to perform well.

The spacecraft platform itself continues to be problem-free.

nouvel exemplaire unique en utilisant essentiellement les modèles de rechange provenant du programme Cluster. Le contrat industriel a démarré et la livraison est attendue pour la mi-1997.

A sa réunion de novembre 1996, le SPC examinera le lancement de ce satellite dans le cadre d'une mission emportant soit un satellite unique dénommé 'Phénix', soit quatre satellites remplaçant la mission Cluster initiale. L'occasion de vol de Phénix n'est pas encore définie mais le lancement pourrait se faire au dernier trimestre 1997. Si l'on opte pour une mission composée d'un satellite unique, Phénix, placé sur l'orbite initiale de Cluster, celui-ci ne remplira pas les objectifs scientifiques initiaux de la mission Cluster mais apportera une contribution aux missions du programme international de physique des relations Soleil/Terre (ISTP). Parmi celles-ci figurent SOHO, Interball, Wind, Polar et Geotail.

On envisage également le réemport d'une mission de mesure en plusieurs points similaire à Cluster, solution qui sera présentée à la réunion de novembre du SPC. Deux options sont actuellement étudiées: reconstruire un exemplaire unique de Cluster embarquant tous les instruments initiaux ou concevoir et construire quatre satellites plus petits et plus simples embarquant pratiquement la même charge utile que Cluster mais pouvant être lancés directement sur orbite polaire, à moindre frais. Quelle que soit l'option retenue, la date de lancement devrait se situer à la mi-2000; plusieurs des missions ISTP devraient alors avoir atteint la fin de leur durée de vie utile.

Huygens

Les modèles de développement (STPM et EM) de la sonde Huygens se trouvent maintenant au Jet Propulsion Laboratory, en Californie, pour les essais avec l'orbiteur Cassini; ceux-ci se déroulent de manière satisfaisante. Les travaux en Europe se concentrent maintenant sur l'intégration et la vérification de la recette du modèle de vol de la sonde.

Les principaux accomplissements en ce qui concerne les essais d'ambiance de la sonde sont l'essai d'environnement à basse température dans l'atmosphère de Titan en atmosphère pressurisée, l'essai thermique sous vide et l'essai cyclage thermique, ainsi qu'un essai de choc pyrotechnique conduit après le déroulement de la séquence pyrotechnique complète de descente de la sonde jusqu'à la surface de Titan. L'évaluation des résultats de chacun de ces essais très significatifs a balayé tous les doutes qui avaient pu être exprimés lors de revues indépendantes.

Les essais de recette de la sonde se sont poursuivis par les parties 1 et 2 de l'essai du système intégré (IST), suivies des préparatifs des derniers essais d'ambiance, à savoir essais en bruit acoustique et vibrations. L'essai en bruit acoustique était en cours à la mi-septembre. Tout semble montrer que les essais auront été menés à bien début 1997 et seront suivis de la recette de la sonde fin février puis du démarrage de la campagne de lancement à la mi-mars.

XMM

Le maître d'oeuvre de XMM, Dornier (D), a arrêté les arrangements contractuels avec la plupart de ses sous-traitants. L'une des principales difficultés de ce projet sera de respecter le calendrier très serré; les responsables de Dornier et de l'ESA sont conscients des efforts qu'ils devront faire pour respecter la date de lancement, fixée à août 1999.

Les travaux se sont poursuivis en préparation des revues préliminaires de conception au niveau équipements, qui devaient s'achever fin août.

Les essais d'ambiance du modèle de qualification du module miroirs ont été menés à bien par le Centre spatial de Liège (CSL, B) et montrent qu'il n'y a pas de dégradation des propriétés optiques ni de problème d'intégrité de la structure. L'institut Max Planck de Garching a conduit en août les essais dans le rayonnement X avec illumination complète de la surface des miroirs. Une analyse préliminaire des données obtenues confirme les bons résultats du CSL.

Media Lario (I) poursuit la fabrication des miroirs par électrodéposition de nickel à une cadence de cinq par semaine et obtient des miroirs de très bonne qualité. Un quart des modèles de vol des miroirs avaient été intégrés début septembre dans le premier des quatre modules miroirs aux

Huygens Probe flight model, during testing at IABG in Ottobrunn (D)

Modèle de vol de la sonde Huygens aux essais chez IABG à Ottobrunn (D)

Cluster

Following the loss of the four Cluster spacecraft on the first Ariane-5 test flight, the Agency's Science Programme Committee (SPC) has agreed to the building up of a single spacecraft largely from the spare models from the Cluster programme. The industrial contract is underway and delivery is expected in mid-1997.

At its November 1996 meeting, the SPC will discuss the launch of this spacecraft, either as a single spacecraft mission called 'Phoenix', or as part of a new four-spacecraft mission to replace the original Cluster mission. A launch opportunity for Phoenix has not yet been finalised, but it could be during the last quarter of 1997. If Phoenix is launched as a single-spacecraft mission into the original Cluster orbit, it will not fulfil the original Cluster scientific objectives, but would instead support the existing fleet of international missions forming the ISTP (International Solar Terrestrial Physics) Programme. These missions include SOHO, Interball, Wind, Polar and Geotail.

Options for a reflight of a multipoint measurement mission such as Cluster are also being studied and will also be presented to the SPC at its November meeting. Currently the two options under study are either a single rebuild of Cluster including all of the original instruments, or the design and building of four smaller, simpler spacecraft carrying essentially the same payload as Cluster, but capable of being launched more cheaply into a direct polar orbit. Whichever option is chosen, the expected launch date would be mid-2000, by which time several of the other ISTP missions could be expected to have reached the ends of their useful lifetimes.

Huygens

With the development models (STPM and EM) of the Huygens Probe now at Jet Propulsion Laboratory in California satisfactorily performing tests with the Cassini Orbiter System, attention in Europe is concentrated upon the integration and acceptance verification of the flight-model Probe.

Major achievements in Probe environmental testing have been the successful accomplishment of the Titan-entry cold-soak test in a pressurised atmosphere, the thermal-vacuum/ thermal-cycling test and a pyrotechnic shock test which followed the full pyrotechnics firing sequence for the Probe's descent to Titan's surface. Evaluation of the results of all these very significant tests has dispelled all of the doubts expressed at earlier times by independent reviewing authorities.

The Probe's acceptance testing continued with the Integrated System Test (IST) parts 1 and 2, followed by preparations for the final environmental tests, namely acoustic noise and vibration. The acoustic noise test is currently (mid-September) in progress. The future outlook is good, all indications pointing towards successful completion of testing early in 1997, with Probe acceptance at the end of February, leading to the start of the launch campaign in mid-March.

XMM

The XMM Prime Contractor, Dornier (D), has finalised the contractual arrangements with most of its subcontractors. The tight schedule remains one of the biggest challenges for this project and Dornier and ESA management are well aware of the effort they have to make in order to achieve the agreed objective of launching in August 1999.

Work has continued for the Preliminary Design Reviews at equipment level which were due for completion at the end of August.

The environmental tests performed at Centre Spatial de Liège (CSL, B) on the qualification-model Mirror Module have been successfully completed, showing no optical performance degradation and no structural-integrity problems. Full-illumination X-ray tests on the Mirror Module at the Max Planck facility in Garching were conducted in August. Preliminary analysis of the test results confirms the good results obtained at CSL.

Production of the electroformed nickel mirrors is progressing at Media Lario (I) at the rate of five mirrors per week, and their quality is very good. By early September, a quarter of the flight mirrors had been integrated into the first of four flight Mirror Modules. Integration of a second module is progressing in parallel, with six mirrors integrated. One of the structural and thermally representative STM mirror modules is reaching the final stages of integration, with only nine of the fifty-eight dummy mirror shells still to be integrated. Four out of seven flight-quality

Artist's impression of the XMM spacecraft (courtesy: Visulab-ESTEC)

Vue conceptuelle du satellite XMM (image Visulab-ESTEC)

normes de vol. L'intégration d'un deuxième module, sur lequel six miroirs sont intégrés, se poursuit parallèlement. Un modèle structurel et thermique représentatif des modules miroirs parvient au stade final de l'intégration, puisqu'il ne reste que neuf coques de miroirs factices à intégrer sur 58. Sur les sept roues à rayons (ou araignées de montage) de haute précision aux normes de vol devant recevoir les miroirs, quatre ont été livrés par APCO (CH), qui a également livré les conteneurs ultrapropres nécessaires au transport et au stockage des modules miroirs complets aux normes de vol. Carl Zeiss (D) a terminé la fabrication des 58 moules de miroirs (mandrins) en avance sur le calendrier.

Les modèles de qualification et d'identification des expériences sont en cours de fabrication et soumis aux essais. Le spectromètre à grille sera, avec le modèle de qualification des miroirs, le premier instrument soumis aux essais dans le rayonnement X dans l'installation Panter (D); il sera suivi des caméras X. La revue de conception de la partie structurelle du télescope de suivi optique ayant été conduite, la fabrication des miroirs a commencé.

La mise au point du secteur sol complet de XMM est confiée à l'ESOC, à Darmstadt (D). Les documents des impératifs utilisateurs portant sur tous les éléments logiciel et matériel du secteur sol ont été revus et publiés. L'évaluation des propositions industrielles portant sur la réalisation du secteur sol s'est terminée en août et le contrat a été lancé début septembre.

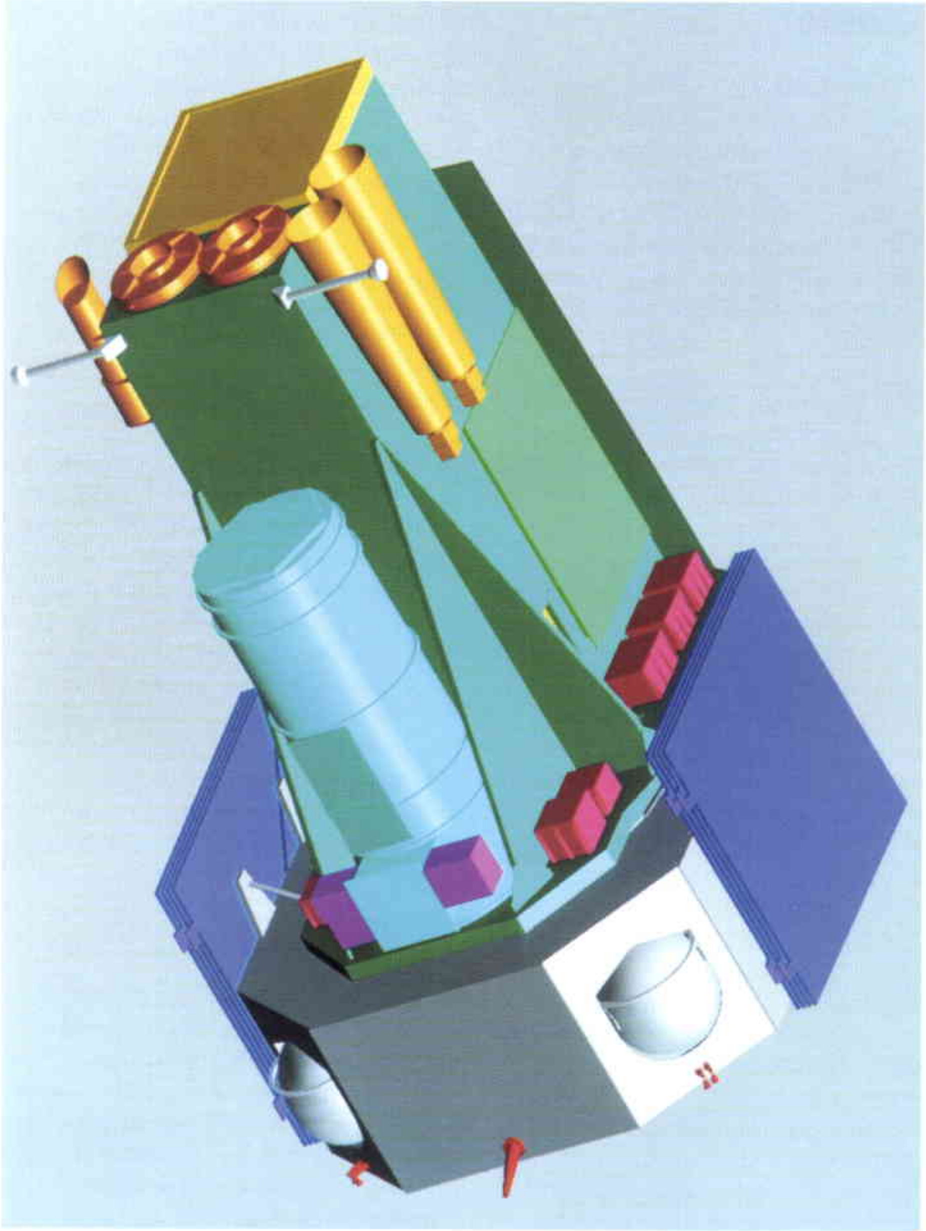
En préparation du lancement prévu sur Ariane-5, la définition des interfaces mécaniques a été mise à jour et une étude détaillée de la phase balistique a été lancée. Les critères de tolérance aux pannes requis par l'autorité lanceur ont été adoptés, ce qui ouvre la voie à la phase 1 de la soumission sauvegarde.

Integral

La revue préliminaire de conception du véhicule spatial a été menée à bien; certains points mis en lumière au cours de la revue doivent toutefois être résolus de façon satisfaisante. Les activités se sont ensuite concentrées sur des éléments liés au système de contrôle d'orbite et d'attitude, le logiciel de bord et les caractéristiques du lancement par Proton. Les points communs entre la conception du module de servitude d'Integral et celle d'XMM ont été examinés et confirmés. Parallèlement à cette revue, l'Agence a reçu et évalué la proposition du maître d'oeuvre (Alenia, I) relative à la principale phase de développement (phase C/D).

On procède à la mise au point de technologies clés d'instruments, comme les ASIC de l'imageur et le système de refroidissement cryogénique du spectromètre. La plupart des équipes 'instruments' reçoivent un soutien complet de la part de leurs partenaires industriels et de grands progrès devraient être accomplis dans les prochains mois. Le calendrier de certains travaux 'instruments' a été remanié de façon à pouvoir respecter le calendrier général du programme.

La définition de divers éléments du secteur sol scientifique et opérationnel a progressé et les interfaces ont été précisées.



Current configuration of the Integral spacecraft (with stowed solar arrays)

Configuration actuelle du satellite Integral (panneaux solaires non déployés

Rosetta

Les propositions de l'industrie en réponse à l'invitation à soumissionner ont été high-precision spoke wheels ('spiders') into which the mirrors are integrated have been delivered by APCO (CH), which has also delivered all of the superclean containers for the transport and storage of the complete flight Mirror Modules. The production of the 58 mirror masters (mandrels) by Carl Zeiss (D) was completed ahead of schedule.

Manufacture and testing of the engineering qualification models of the experiments is in progress. The grating spectrometer will be the first instrument to be X-ray-tested with the mirror qualification model in the PANTER facility (D), followed by the X-ray cameras. Following a design review of the structural part of the optical monitoring telescope, manufacture of the mirrors has started.

Development of the complete Ground Segment for XMM is entrusted to ESOC in Darmstadt (D). User Requirements Documents for all ground-segment software and hardware elements have been reviewed and issued. The evaluation of industrial proposals received for the ground segment's development was completed in August and contract kick-off took place in early September.

In preparation for the baselined launch on Ariane-5, the definition of the mechanical interface has been updated and detailed study of the coast phase has been initiated. Failure-tolerance criteria required by the launch-vehicle authority have been agreed, clearing the way for the Phase-1 Safety Submission.

Integral

The spacecraft Preliminary Design Review has been successfully completed, subject to the satisfactory close-out of certain items highlighted during the review process. The further actions focused mainly on items linked to the attitude and orbit control system, the onboard software and the specifics of the Proton launch. The commonality of the Service Module design with that for XMM was examined and further confirmed.

In parallel with this review, the Prime Contractor's (Alenia, I) proposal for the main development phase (Phase-C/D) was received and evaluated.

Key instrument technologies are under development, such as ASICs for the Imager and cryo-cooling for the Spectrometer. Most instrument teams are now fully supported by industrial partners and good progress is expected in the coming months. Some instrument tasks have been rescheduled to meet the overall schedule objectives of the programme.

The various components of the science and operations ground segments have been further defined and the interfaces clarified.

Rosetta

The industrial responses to the spacecraft Invitation to Tender have been received on schedule and are currently under evaluation. The offers cover the entire development programme (i.e. Phases-B and C/D) and their evaluation is scheduled to be completed in early 1997.

The project team have commenced the second round of meetings with the potential payload groups and the definition of the Orbiter's payload is converging rapidly. The majority of the tasks assigned to the confirmation phase will have been completed in time for the payload to be fully defined by the start of Phase-B, currently scheduled for March 1997.

Work on the definition of the Rosetta Surface Science Packages – Champollion and Roland – has continued, together with an investigation of the ability of a single Lander to satisfying the majority of the requirements. The latter has been instigated due to uncertainty about the availability of resources, both on the spacecraft side and in the participating Member States, to fully support two separate Landers. The outcome of these deliberations is due to be presented to the SPC at its November meeting.

Ground-segment definition is continuing with the possibility of providing an ESA deep-space terminal in the Southern Hemisphere to support the mission under consideration.

The second Science Working Team Meeting took place at ESTEC (NL) in early October.

EOPP

Future programmes

Following on from the consultations with the European Earth Science Community on the nine candidate Earth Explorer Missions, reported in the last Bulletin, the Reports for Assessment and the comments of the Science Community have been examined by the Earth Science Advisory Committee. This has resulted in a recommendation to ESA's Earth Observation Programme Board for Phase-A studies of four missions:

- the Gravity and Steady-State Ocean-Circulation Mission
- the Atmospheric Dynamics Mission as an experiment utilising the International Space Station
- the Earth Radiation Mission
- the Land Surface Processes and Interaction Mission.

Campaigns

Activities in the last quarter have focussed on the flights associated with the INDREX campaign over the Indonesian rain forests. In parallel, data processing for both the EMAC and POLRAD campaigns has continued.

Envisat/Polar Platform

Envisat system

Detailed planning for the Critical Design Reviews (CDRs) to verify the Envisat system's overall coherency has been established, following bottom-up approach and culminating with the EMS CDR planned to start mid-February next year.

A Data Policy Working Group has been set up to define the policy that will govern user access to the data products to be made available after launch.

Polar Platform (PPF)

Following the recent detailed discussions with the Delegate Bodies representing the Member States participating in the programme, cost reductions have been implemented in PPF activities by reducing test, analyses and hardware, particularly as regards spare units. These measures have been reflected in the planning and detailed development documents.

The PPF structural-model programme has continued with the execution of the reçues dans les temps et sont en cours d'évaluation. Ces offres portent sur la totalité du programme de développement (phases B et C/D) et leur évaluation devrait s'achever début 1997.

L'équipe projet a commencé une deuxième série de réunions avec les responsables potentiels des charges utiles et la définition de la charge utile de l'orbiteur se précise rapidement. La plupart des tâches à mener pendant la phase de confirmation seront finies à temps pour que la charge utile soit entièrement définie avant le démarrage de la phase B, actuellement prévu en mars 1997.

Les travaux de définition des modules scientifiques de surface de Rosetta (Champollion et Roland) se poursuivent, de même qu'une étude visant à déterminer si un seul atterrisseur pourrait satisfaire la majorité des besoins. Cette étude a été entreprise car on ignore si les ressources nécessaires au soutien complet de deux atterrisseurs distincts seront disponibles, tant au niveau du véhicule spatial que des Etats membres participants. Le résultat de cette enquête doit être présenté à la réunion de novembre du SPC.

La définition du secteur sol se poursuit; il est envisagé de contribuer à la mission en mettant à disposition un terminal pour l'espace lointain de l'ESA situé dans l'hémisphère sud.

La deuxième réunion de l'équipe de travail scientifique s'est tenue à l'ESTEC (NL) début octobre.

EOPP

Programmes futurs

Après avoir interrogé les spécialistes européens des sciences de la Terre sur les neuf missions candidates d'exploration de la Terre (voir dernier Bulletin), le Comité consultatif des sciences de la Terre a examiné les Rapports d'évaluation et les commentaires des chercheurs. Il a recommandé au Conseil directeur du Programme d'observation de la Terre de l'ESA de procéder à l'étude de phase A de quatre missions, à savoir:

- *Mission d'étude du champ gravitationnel et des paramètres permanents de la circulation océanique*
- *Mission d'étude de la dynamique atmosphérique comme expérience utilisant la Station spatiale internationale*
- *Mission sur le rayonnement terrestre*
- *Mission d'étude des processus à la surface du sol et de leurs interactions.*

Campagnes

Au cours du trimestre passé, les activités ont porté, pour l'essentiel, sur les vols associés à la campagne INDREX au-dessus des forêts équatoriales de l'Indonésie. Parallèlement, on a poursuivi le traitement des données EMAC et POLRAD.

Envisat/Plate-forme polaire

Système Envisat

Les revues critiques de conception (CDR) s'inscrivent désormais dans un planning détaillé; l'objectif est de vérifier la cohérence globale du système Envisat, après une démarche ascendante qui a abouti à la CDR de l'EMS dont le début est prévu pour la mi-février 1997.

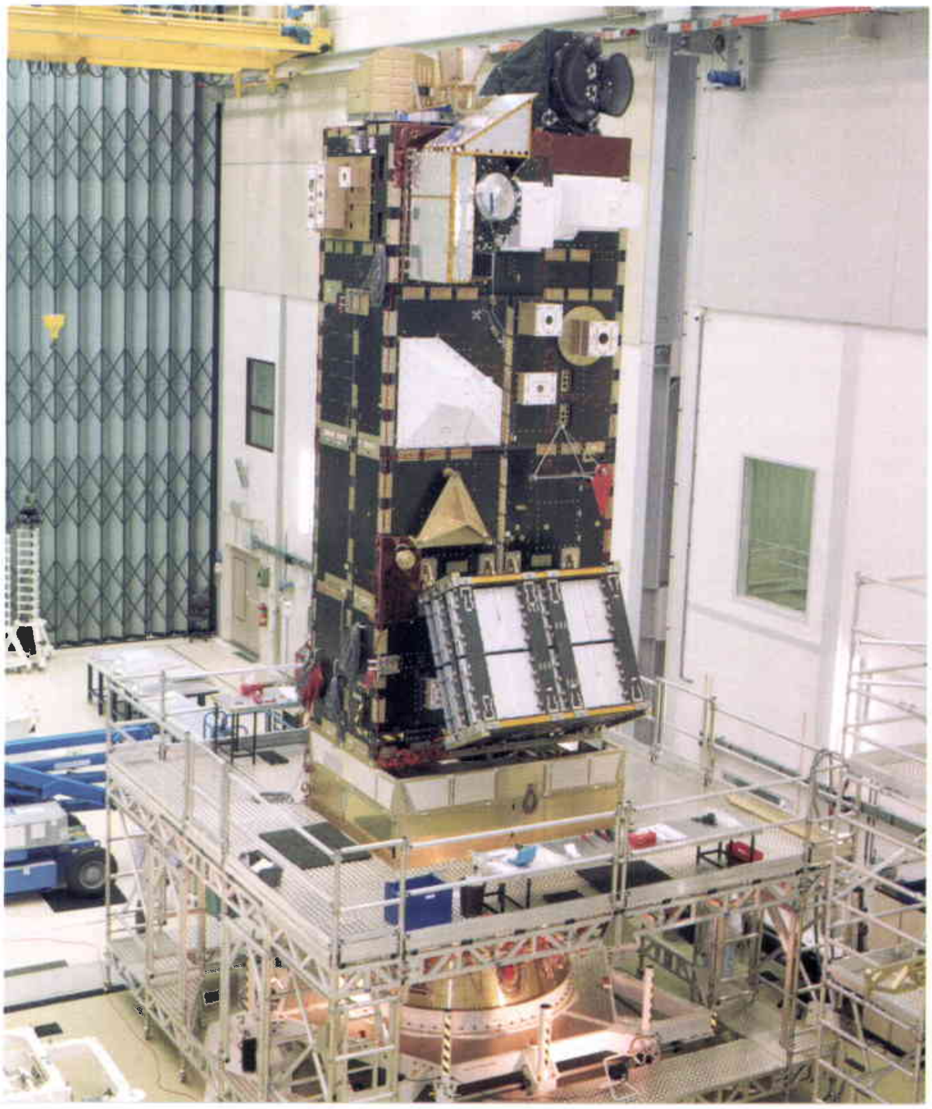
Un Groupe de travail 'Politique en matière de données' a été mis sur pieds pour définir la politique qui régira l'accès des utilisateurs aux produits de données disponibles après le lancement.

Plate-forme polaire (PPF)

Les organes délibérants qui représentent les Etats membres participant au Programme ont récemment eu des discussions approfondies qui ont débouché sur l'application d'une réduction des coûts des activités relatives à la PPF

Structural model of the PPF under test at ESTEC (NL)

Modèle structurel de la PPF aux essais à l'ESTEC (NL)



acoustic test, the appendages release, shock test and the fit-check with the Large Space Simulator (LSS). This fit check has been performed to prepare for thermal test activities to be executed later with the flight-model Payload Module.

The Payload Module Equipment Bay (PEB) engineering model's acceptance has been completed by Dornier (D), and the Module has been delivered to Matra Marconi Space (B) where the integration and test activities will continue.

The proto-flight Service Module's integration at Matra Marconi Space (F) has been completed, but the acceptance tests are being delayed by electrical compatibility problems with the reaction wheels and the recently delivered Dual-Mode S-Band Transponder.

Envisat-1 payload

A major achievement in the payload's development programme was the signature of the contract between ESA and Dornier, the mission Prime Contractor, in Paris on 17 July. Coming at the end of a long and difficult cost-reduction exercise, this contract with strict financial and schedule conditions has established a solid basis for the Envisat instrument development by industry.

Following the delivery of all of the instrument structural models, the emphasis is now on engineering-model development and testing. The engineering model of the AATSR instrument has already been delivered; the remaining instruments are now under test and are expected to be delivered in September/October.

Work is also well in hand on the flight-model units, most of which are now in manufacture. In several cases, equipment-level acceptance tests have been completed and the units delivered for integration. Overall planning remains consistent with a mid-1999 launch date.

At instrument level, the Critical Design Reviews are now being carried out and are expected to be completed by the end of the year.

Envisat-1 ground segment

Flight Operation Segment development is progressing according to plan and the Baseline Design Review is planned for the end of this year.

The ground-segment Payload Data Segment (PDS) Critical Design Review was successfully completed mid-July, providing an adequate basis for finalising the PDS contract negotiations, aiming for contract signature in the fourth quarter of 1996.

The definition of the instrument data-processing algorithms is progressing well, with those for GOMOS and MIPAS having been delivered and the corresponding PDS developments having been initiated in July 1996. The various algorithm documents are being reviewed with the support of the corresponding Scientific Advisory Groups.

Manned Spaceflight and Microgravity

International Space Station Programme (ISS)

Automated Transfer Vehicle (ATV)

Phase-B1 was completed with a final presentation in Bremen (D) at the end of May. Following the Industrial Policy Committee's (IPC) approval for Phase-B2, a Request for Quotation (RFQ) was sent out by ESA in early June. The proposal was received by the end of that month and, following the Tender Evaluation Board's approval, the kick-off meeting was held on 4 July 1996. The RFQ for Phase-C/D is in preparation and its formal issue is expected by the end of October, assuming approval by the September IPC of the procurement proposal.

Early deliveries

Data Management System for the Russian Service Module (DMS-R)

The delay in the development of the SPARC chipset used by the DMS-R was giving cause for concern, but this issue has now been successfully resolved.

European Robotic Arm (ERA)

The ESA/RSA Arrangement for ERA was signed on 29 July by the Director Generals of the two agencies. This signature has facilitated the cooperation between the European and Russian partners, and work is proceeding at a greater pace as a result.

The ERA Preliminary Design Review (PDR) Board meeting in May had identified a number of key issues which needed priority assessment before the Review could be declared closed. Satisfactory progress has since been made at Fokker Space (NL), and the PDR has now been declared formally closed.

The first deliverables to the Russian segment are expected to be completed towards the end of the next quarter, with the Geometric Model being delivered to RSC-Energia. This model will be used for fit checks and configuration analysis.

A change to the ERA Contract to accommodate a change to a Shuttle launch (with the Russian Scientific and Power Platform), instead of the originally foreseen Russian vehicle, is in progress.

Laboratory Support Equipment

The Memorandum of Understanding that identifies the European early utilisation early deliveries for the Space Station has been further negotiated by NASA and ESA representatives and is now ready for signature.

Following issue of the competitive Invitation to Tender for MELFI (Minus Eighty Degree Centigrade Laboratory Freezer for ISS) and the selection of the contractor, the Phase-c/D negotiation were started. In parallel a preliminary authorisation to proceed has allowed industrial activities to start. Contract signature is expected in the second half of October. In the same period, the subsystem PDRs will take place, to be followed by the Crew Review at NASA and by the system PDR closeout that will take place at Matra Marconi Space in December.

Following thr submission of the industrial proposal for MSG (Microgravity Science Glovebox) and a first round of negotiation, a preliminary authorisation to proceed has allowed Phase-C/D activities to start. In parallel, the final Phase-B work on the development model has been successfully completed. The project PDR will take place at DASA (D) in the second half of October.

Industry's programmatic assessment for the Hexapod is expected in October and will be followed by issue by the Agency of the RFQ for Phase-C/D in early November. The Phase-B Final Review is scheduled for December.

Utilisation

At its meeting on 2/3 July, the Manned

rendue possible par un allégement de certaines activités intéressant les essais, les analyses et le matériel, notamment en ce qui concerne les unités de réserve. Les documents relatifs au planning et au développement détaillé tiennent compte de ces mesures.

Le programme de développement du modèle structurel de la PPF s'est poursuivi dans le grand simulateur spatial où l'on a procédé à des essais acoustiques, à des essais aux chocs lors du déverrouillage des appendices et à des vérifications d'ajustement. Ces dernières ont pour objet de préparer les essais thermiques du modèle de vol du module de charge utile qui doivent être exécutés plus tard. Dornier (D) a terminé la recette du modèle d'identification du compartiment des équipements du module de charge utile; le module a été remis à Matra Marconi Space (B) chez qui se poursuivront les activités d'intégration et d'essai.

Matra Marconi Space (F) a intégré le prototype de vol du module de servitude mais des problèmes de compatibilité électrique avec les roues à réaction et le répéteur en bande S à double mode récemment livré ont retardé les essais de recette.

Charge utile d'Envisat-1

La signature à Paris, le 17 juillet, du contrat de développement de la charge utile par l'ESA et Dornier, maître d'oeuvre Mission, marque une étape majeure à la fin d'un long et difficile exercice de réduction des coûts; ce contrat est assorti de conditions financières et de calendrier strictes mais constitue pour l'industrie une assise solide sur laquelle s'appuyer pour développer les instruments Envisat.

Tous les modèles structurels des instruments ayant été livrés, la pression s'exerce maintenant sur les travaux de développement et les essais des modèles d'identification. Le modèle d'identification de l'AATSR a déjà été livré. Les autres instruments sont en cours d'essai et devraient être livrés en septembre/octobre.

La réalisation des unités des modèles de vol suit son cours; la fabrication de la plupart d'entre elles a été lancée. Dans plusieurs cas, les essais de recette au niveau 'équipement' sont terminés et les unités ont été livrées pour intégration. Le planning d'ensemble reste compatible avec le lancement fixé à la mi-1999.

Les revues critiques de conception au niveau 'instrument' sont en cours d'exécution et devraient s'achever d'ici la fin de l'année.

Secteur sol d'Envisat-1

Les travaux de développement du secteur chargé des opérations en vol se poursuivent selon les plans; la revue de conception de référence est prévue pour la fin de l'année.

La revue critique de conception du système de gestion des données de charge utile a été menée à bon terme à la mi-juillet; elle constitue une base saine pour arrêter les négociations contractuelles du PDS; la signature du contrat devrait intervenir dans le courant du 4ème trimestre 1996.

La définition des algorithmes de traitement des données des instruments progresse normalement; les algorithmes pour les instruments GOMOS et MIPAS ont été livrés et les travaux de développement du PDS correspondants ont été engagés en juillet 1996. On passe actuellement en revue, avec l'aide des Groupes consultatifs scientifiques, les divers documents relatifs aux algorithmes.

Vols spatiaux habités et microgravité

Programme de Station spatiale internationale (ISS)

Véhicule de transfert automatique (ATV)

La phase B1 s'est terminée fin mai avec une présentation finale des travaux à Brême (D). Après que le Comité de la politique industrielle (IPC) eut donné son feu vert à la phase B2, l'Agence a envoyé une demande de prix (RFQ) début juin. La proposition a été reçue fin juin et approuvée par la Commission d'évaluation des offres. La réunion de lancement des activités s'est tenue le 4 juillet 1996. En ce qui concerne la phase C/D, la RFQ est en préparation et devrait être officiellement envoyée fin octobre, à condition que l'IPC approuve la proposition d'approvisionnement lors de sa réunion de septembre.

Livraisons à court terme

Système de gestion de données pour le module de service russe (DMS R)

Le problème préoccupant du retard enregistré dans la mise au point du jeu de puces du SPARC destiné au DMS-R est maintenant résolu.

Bras télémanipulateur européen (ERA)

L'arrangement entre l'ESA et la RKA relatif à l'ERA a été signé le 29 juillet par les directeurs généraux des deux agences. Cette signature a pour effet de faciliter la coopération entre les partenaires russe et européen et d'accélérer le déroulement des travaux.

La revue préliminaire de conception (PDR) de l'ERA, tenue en mai dernier, a permis de recenser un certain nombre de points importants qu'il fallait traiter en priorité avant de pouvoir clore cette revue. Depuis, les travaux ont avancé de façon satisfaisante chez Fokker Space (NL) et la PDR est officiellement close.

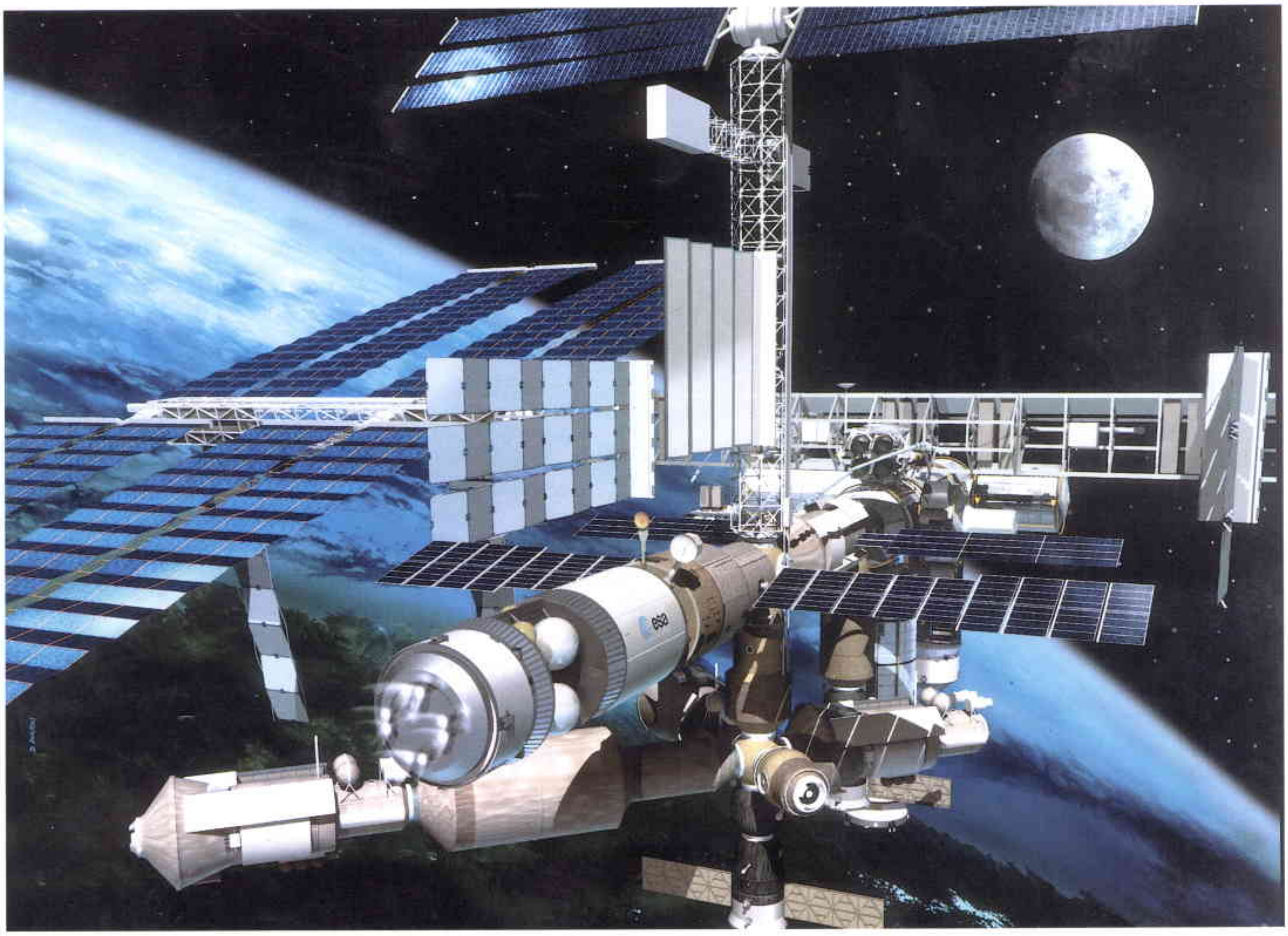
Les premiers éléments destinés à la composante russe devraient être prêts vers la fin du trimestre prochain, date prévue pour la livraison à RSC Energuia de la maquette à l'échelle 1. Cette maquette sera utilisée pour des vérifications d'ajustement et des analyses de configuration.

Des modifications sont actuellement apportées au contrat relatif à l'ERA pour tenir compte du fait que ce dernier sera lancé par une Navette américaine (avec la Plate-forme Science et Energie de la Russie), et non par le véhicule russe prévu à l'origine.

Equipements de soutien de laboratoire

Les représentants de l'ESA et de la NASA ont poursuivi leurs négociations sur le Memorandum d'Accord relatif aux livraisons européennes à court terme destinées à l'utilisation initiale de la Station spatiale. Ce texte est maintenant prêt à la signature.

Après envoi de l'appel d'offres relatif au MELFI (Congélateur –80°C pour l'ISS) et sélection du contractant, les négociations de phase C/D ont démarré. Parallèlement, une autorisation préliminaire d'engagement des travaux a été donnée pour le démarrage des activités industrielles. Le contrat devrait être signé dans la deuxième quinzaine d'octobre. Les PDR au niveau sous-systèmes auront lieu à la même époque, suivies de la revue des équipages à la NASA et de la clôture de la PDR au niveau système, prévue en décembre chez Matra Marconi Space.



Artist's impression of the International Space Station (by D. Ducros)

La Station spatiale internationale (vue conceptuelle par D. Ducros)

Space Programme Board discussed the terms of reference of the European Utilisation Board (EUB) and agreed with the plan of the Executive to convene the EUB's first meeting. This meeting, held on 4 September, was successful in further elaborating the EUB's terms of reference and in constructively discussing aspects of Space Station user access, as well as the formalities of the imminent release of an Announcement of Opportunities for the Space Station Early Utilisation (utilisation prior to the Columbus Orbital Facility's availability, using NASA elements).

Space Station Utilisation planning for Europe is progressing well. Agreements have been reached with the ESA User Directorates (Space Science, Earth Observation, Technology) on how to organise their involvement in Utilisation Preparation. Preliminary plans for major facilities to be provided via these Directorates have been drafted and will be further defined through studies to be initiated in the next few months. For the Microgravity discipline, the gore utilisation element will be the Microgravity Facilities for Columbus (MFC) Programme.

Space Station Utilisation for Europe was further discussed at the First Symposium on Space Station Utilisation, held at ESOC in Darmstadt (D), at the end of September.

Microgravity Programmes

European Microgravity Research (EMIR-1 and 2)

The EMIR-2 Programme was approved at the Microgravity Programme Board meeting on 5 July. The run-out EMIR-1 and the start of EMIR-2 will overlap in the years 1996 to 1998, with EMIR-2 then continuing through 2001.

The Life and Microgravity Spacelab (LMS)/STS-78 mission from 20 June to 7 July 1996 carried five ESA multi-user facilities: the Advanced Gradient Heating Facility (AGHF, maiden flight), the Advanced Protein Crystallisation Facility (APCF, fourth flight), the Bubble, Drop and Particle Unit (BDPU, second flight), the Torque Velocity Dynamometer (TVD, maiden flight) and the Microgravity Measurement Assembly (MMA, second flight). STS-78 was the longest Shuttle mission to date, lasting 16 d 21 h 48 min. It was also extremely successful in that all of the ESA experiments could be performed exactly as planned.

Biobox and Biopan are in preparation for their two-week flights in a Russian Foton capsule in late 1996, and Biorack for its fifth flight on Shuttle flight STS-81 in January 1997.

Microgravity Facilities for Columbus (MFC)

The Phase-B studies for the major elements of Biolab, the Fluid Science Laboratory and the Materials Science Laboratory for this new microgravity programme are progressing well, financed from the EMIR-1 Programme. MFC funds, approved at the Toulouse Ministerial Council in October 1995, will become available in 1997 for Phase-C/D work on the above facilities.

L'industrie ayant soumis une offre au sujet de la boîte à gants pour la recherche en microgravité (MSG), l'Agence a donné, à l'issue d'une première phase de négociations, une autorisation préliminaire d'engager les travaux pour le lancement de la phase C/D dans l'industrie. Dans un même temps, les derniers travaux de phase B relatifs au modèle de développement se sont terminés de façon concluante. La PDR du projet se tiendra chez DASA (D) dans la deuxième quinzaine d'octobre.

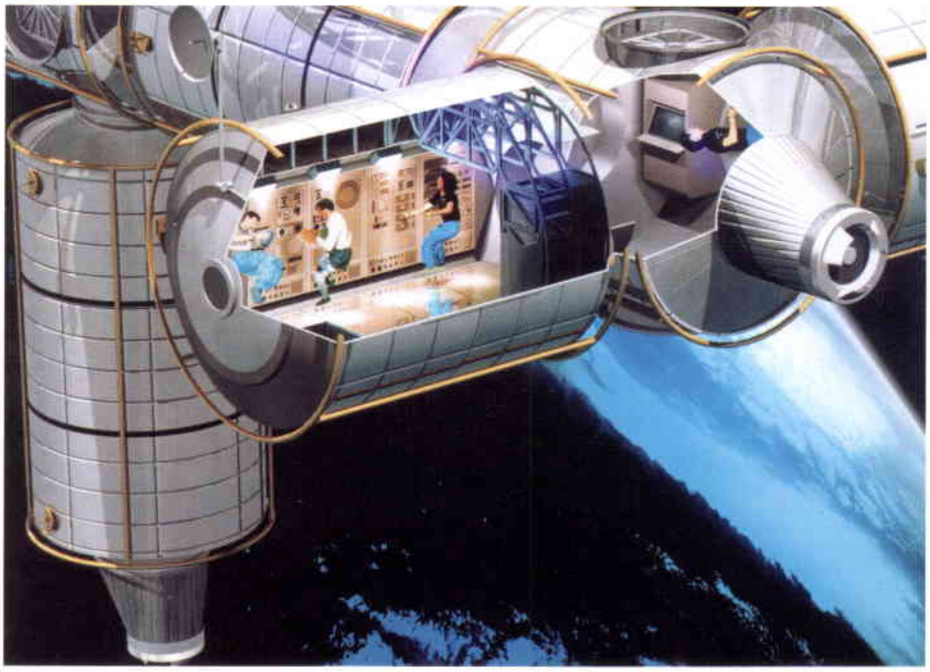
L'évaluation des aspects programmatiques de l'Hexapod par l'industrie devrait avoir lieu en octobre. L'Agence enverra ensuite début novembre une demande de prix pour la phase-C/D. La revue finale de la phase B est fixée à décembre.

Utilisation

Lors de sa réunion des 2 et 3 juillet, le Conseil directeur des programmes spatiaux habités a examiné le mandat de la Commission européenne de l'utilisation (EUB) et approuvé la convocation, proposée par l'Exécutif, de la première réunion de cette commission. Cette réunion, organisée le 4 septembre, a permis d'affiner le mandat de l'EUB et de débattre dans un esprit constructif de l'accès des utilisateurs à la Station spatiale ainsi que du lancement imminent d'un avis d'offre de participation pour l'utilisation initiale de la Station spatiale (accès à des éléments de la NASA avant le raccordement de l'Elément orbital Columbus (COF) à la Station).

La planification de l'utilisation de la Station spatiale par l'Europe suit son cours. Des accords ont été conclus avec les directions utilisatrices de l'ESA (science spatiale, observation de la Terre, technologie) sur les modalités de leur participation à la préparation de l'utilisation. En ce qui concerne les principales installations à fournir par ces directions, des plans ont été ébauchés et seront définis de façon plus approfondie dans le cadre des études à lancer dans les mois à venir. Pour ce qui est de la recherche en microgravité, les principaux outils des utilisateurs seront ceux du programme MFC (Installations de recherche en microgravité pour Columbus).

La question de l'utilisation de la Station spatiale par l'Europe a également été examinée lors du premier symposium sur l'utilisation de la Station spatiale, qui s'est tenu fin septembre à l'ESOC (Darmtadt, D).



Artist's impression of the Columbus Orbital Facility (COF) (by D. Ducros)

Le laboratoire orbital Columbus (vue conceptuelle par D. Ducros)

Programmes de recherche en microgravité

Programme européen de recherche en microgravité (EMIR-1 et 2)

Le programme EMIR-2 a été approuvé par le Conseil directeur du programme de recherche en microgravité le 5 juillet. La phase finale d'EMIR-1 et le lancement d'EMIR-2 se chevaucheront pendant la période 1996 – 1998, EMIR-2 prenant le relais jusqu'à 2001.

La mission de sciences de la vie et de recherche en microgravité LMS/STS 78, qui s'est déroulée du 20 juin au 7 juillet 1996, comprenait cinq installations de l'ESA à utilisateurs multiples: le four à gradient de haute technologie (AGHF, premier vol), l'installation de cristallisation des protéines de pointe (APCF, quatrième vol), le dispositif bulles, gouttes et particules (BDPU, deuxième vol), le dynamomètre force-vitesse (TVD, premier vol) et l'ensemble de mesure du niveau de microgravité (MMA, deuxième vol). Le vol STS-78, qui a duré 16 jours 21 heures et 48 minutes, est à ce jour la plus longue des missions de la Navette américaine. Il s'agit également d'une grande réussite dans la mesure où toutes les expériences de l'ESA ont pu être menées à bien comme prévu.

Le Biobox et le Biopan sont en cours de préparation pour leur vol de quinze jours fin 1996 à bord d'une capsule russe Photon, et les préparatifs sont également en cours pour le cinquième vol du Biorack dans le cadre de la mission STS-81 de la Navette américaine en janvier 1997.

Installations de recherche en microgravité de Columbus (MFC)

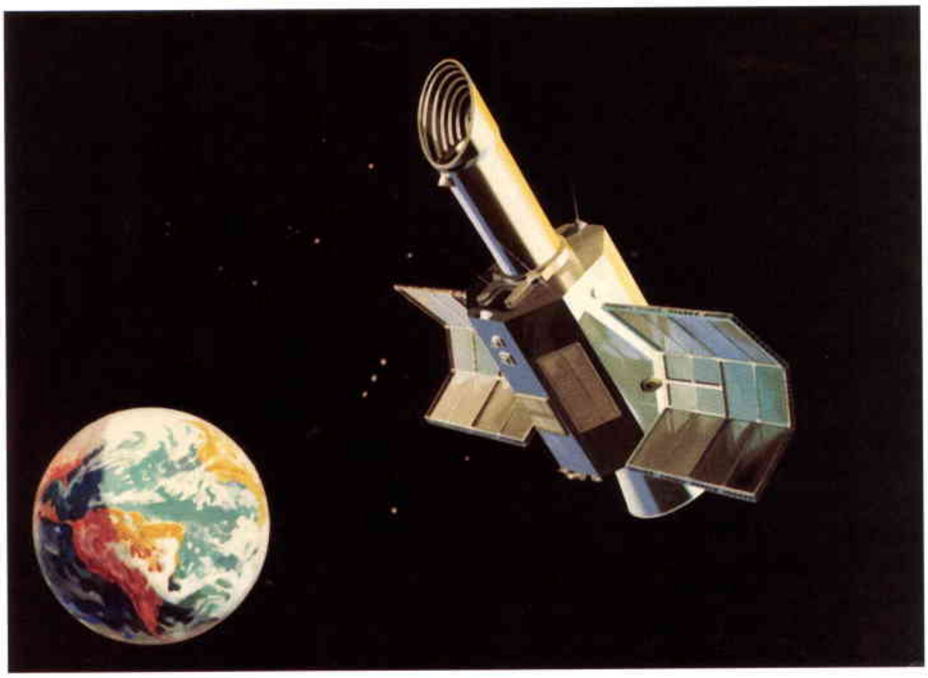
Les études de phase B relatives au Biolab, au laboratoire de science des fluides et au laboratoire de science des matériaux, principaux éléments du nouveau programme qu'est le MFC, se poursuivent normalement. Elles sont financées sur le programme EMIR-1. Approuvés par le Conseil lors de sa session au niveau ministériel de Toulouse en octobre 1995, les crédits du MFC seront disponibles en 1997 pour les travaux de phase C/D à mener sur ces éléments.

In Brief

IUE Project Comes to an End

The IUE project has come to an end after 18+ years of extremely successful orbital operations.

At a meeting of ESA's Science Programme Committee (SPC) in February, the decision was taken to terminate the orbital operations of the International Ultraviolet Explorer (IUE) satellite on 30 September. Science operations were terminated shortly before that date to allow the necessary end-of-life testing of the spacecraft. Only a year ago, when NASA - the major partner in the IUE project - decided to terminate its IUE science operations, ESA had been able to extend its support to include full responsibility for the scientific operations, under the 'hybrid science operations' scheme (described in detail in ESA Bulletin No. 87), and thus maintain this important capability for the astrophysics community. As a consequence of the budgetary restrictions placed on ESA's Science Programme, the earlier recommendation of the Space Science Advisory Committee (SSAC), to terminate the operations of IUE in coordination with NASA in September, was accepted by the SPC.



The IUE project, using a 45cm ultraviolet telescope for spectroscopic observations in the 115 to 320 nm waveband, has been carried out jointly by NASA, ESA and the UK PPARC (formerly SERC). Launched in 1978, its designed lifetime was only three years.

In July, the SPC agreed to complete the IUE Final Archive by the end of 1997, allowing the project to reprocess all its spectroscopic observations (numbering over 100,000) with a newly designed reduction, significantly improving on the normal direct processing done during the operational phase of the IUE project. The resulting homogeneous data archive on the ultraviolet radiation of cosmic sources, collected over the 18+ years of the operational project, will remain an important resource for astrophysical studies for many years to come.

This has been one of the most successful astrophysics projects in space science, with more than 3500 papers in refereed journals based on the observational results of the spectrographs. Over 500 doctoral dissertations have used its results, clearly demonstrating the importance of the project, not least for the education of the next generation of astrophysicists.

During the last six months of science operations a number of special observational programmes (Lasting Value programmes) were conducted from ESA's IUE Observatory at its ESA Villafranca Satellite Tracking Station in Spain, to make sure that the material in the Final Archive will not lack any critical observations for which the specific capabilities of the IUE project were particularly suitable.

These programmes were associated with planetary studies (Jupiter and its Galilean satellites in coordination with the in-situ studies of the Galileo mission); critical observations of the mechanisms associated with the stellar winds in massive stars; and a major coordinated campaign in the x-ray, ultraviolet and optical wavelengths to determine the nature of the mini-quasar in the Seyfert I Galaxy NGC 7469.

The last observations were all made under single-gyro spacecraft control after another gyro failure in March 1996 left IUE with only one functional gyro, out of the original six.

ESA and Portugal Sign Cooperation Agreement

An Agreement on Space Cooperation for peaceful purposes was signed in Paris between the European Space Agency (ESA) and the Government of the Portuguese Republic on 24 July.

The Portuguese Government was represented by the Minister of Foreign Affairs, Jaime Gama and by the Minister of Science and Technology, Professor Mariano Gago. ESA was represented by its Director General, Jean-Marie Luton.

It is hoped that the new agreement will help to establish closer cooperation between Portugal and ESA in areas of mutual interest, such as space sciences, earth observation, telecommunications and microgravity.

The Agreement is also intended to increase the exchange of information on the activities of the two parties in the fields of research and development and applications related to space, as well as to foster the exchange of experts and the definition of joint pilot projects.

From right to left: Jean-Marie Luton, ESA's Director General; Jaime Gama, Portugal's Minister of Foreign Affairs and Professor Mariano Gago, Portugal"s Minister of Science and Technology.

Satellite navigation is one promising area of cooperation where Portuguese authorities have expressed their interest in participating in the Agency's activities being carried out in the framework of the Artes 9 telecommunications programme.

Similar agreements have been concluded by the Agency with Greece, Hungary, Poland and Rumania.

Scientists Discuss Euromir 95 Results

The Euromir 95 scientists met at the European Astronaut Centre on 3 and 4 September to present and exchange their preliminary findings and results from the 41 experiments carried out during the flight onboard the Mir station and on the ground.

In addition, Astronaut Thomas Reiter presented his views concerning the experimental work conducted onboard the Mir station during his 179-day flight. All participants at this meeting expressed their great satisfaction regarding the wealth and quality of scientific data obtained through the Euromir programme.

The lessons learned and experience gained, particularly in view of the utilisation of the future International Space Station, have been the subject of discussions between Astronaut Thomas Reiter and various ESA engineers/ scientists at ESTEC.

Negotiations are underway between the Agency and their relevant Russian counterparts for the continuation of selected Euromir experiments onboard the Mir station during the latter half of 1997. This extension would be based on equipment already aboard the Mir station. For the experimental work, a Russian crew member would be trained pre-flight in order to devote an agreed working time during the flight to the Euromir experiments.

Thomas Reiter unloads supplies from the Progress vehicle.

ESA Astronauts Join 1996 Astronaut Class at NASA

On Monday 12 August, ESA astronauts Pedro Duque and Christer Fuglesang arrived at NASA's Johnson Space Center to begin training as members of the 1996 Astronaut Class.

The two ESA astronauts are part of a group of international astronaut candidates, in which the Canadian, French, German, Italian and Japanese space agencies are also represented, who will train for 22 months as mission specialists for future Space Shuttle and International Space Station missions.

Pedro Duque, born on 14 March 1963 in Madrid, Spain, was selected in May 1992 to join ESA's Astronaut Corps. He trained at ESA's European Astronaut Centre in Cologne and at the Cosmonauts Training Centre in Star City, Russia. He was stand-by crew member for ESA's 30-day Euromir 94 mission and served as primary Crew Interface Coordinator for that Mission. Duque was also the Alternate Payload Specialist for Shuttle mission STS-78 in June-July this year.

Christer Fuglesang, born on 18 March 1957 in Stockholm, Sweden, was selected in May 1992 to join ESA's Astronaut Corps. He trained at ESA's European Astronaut Centre in Cologne and at the Cosmonaut Training Centre in Star City, Russia. He was the stand-by crew member for ESA's 180-day Euromir 95 mission and served as primary Crew Interface Coordinator for that mission.

The other international candidates selected by NASA are: Steve MacLean and Julie Payette of the Canadian Space Agency; Mamorou Mohri and Soichi Noguchi of the Japanese Space Agency NASDA; Philippe Perrin of the French Space Agency CNES; Gerard Thiele of the German Space Agency DARA and Umberto Guidoni of the Italian Space Agency ASI.

Pedro Duque

Christer Fuglesang

Astronauts in Training

As part of their skills maintenance programme, the ESA astronauts completed a rigorous six-day underwater training programme on Giglio Island, Italy in July. During the course, they learned and practised skills and used equipment that are required during extra-vehicular activities. Also, taking advantage of the neutral buoyancy that the underwater environment offers and which simulates space conditions, they practised moving and working while wearing bulky equipment. They also performed emergency recovery procedures.

The ESA astronaut corps currently includes: Jean-François Clervoy (F), Pedro Duque (E), Christer Fuglesang (S), Ulf Merbold (D), Claude Nicollier (CH), and Thomas Reiter (D).

Successful Launch of Ariane V91

The 91st Ariane launch took place successfully on Tuesday 10 September at 21:00:59, Kourou time (02:00:59 on 11 September, Paris time).

An Ariane 42P version (equipped with two solid propellant strap-on boosters) placed the American telecommunication satellite Echostar II into geostationary transfer orbit.

The next Ariane launch is scheduled for 7 November 1996. An Ariane 44L (the version equipped with four liquid strap-on boosters) will take into orbit the Arabian and Malaysian telecommunication satellites, Arabsat IIB and Measat, respectively.

The ESA astronauts practise using various breathing systems at depths of up to 36 metres. They learn to use standard air, Nitrox (a special gas mixture), and re-breathers, a computer-controlled, self-mixing and closed-circuit personal life support system.

Japanese Minister Visits ESA Headquarters

The Japanese Minister of State for Science and Technology, Mr Hidenao Nakagawa, visited ESA Headquarters on 12 September 1996. The Minister was accompanied by the NASDA President, Mr Takashi Matsui, who had a long and detailed discussion with ESA's Director General on the ongoing, cooperative projects between the Agency and Japan, and prospects for widening such cooperation in the future.

Mr Hidenao Nakagawa (Japanese Minister of State for Science and Technology) shakes hands with Mr Jean-Marie Luton (ESA's Director General) on the occasion of his visit to ESA Headquarters.

Science and Medical Applications Developed by ISU Students

The 1996 International Space University Summer Session Programme was held this year in Vienna, Austria from 1 July to 6 September.

The intensive 10-week programme was attended by some 100 graduate students and professionals from around the world. They were provided with a unique educational experience centred around an interdisciplinary, intercultural and international perspective of the world's space activities.

The curriculum consisted of three parts: core lectures, specialised lectures and design projects. This year, the two projects selected and successfully carried to completion were:
- 'Ra; The Sun for Science and Humanity' which presents a 'Strategic Framework for pursuing solar science and applications', defined in three time frames: Near-, Mid- and Far-Term.
- 'Distant Operational Care Centre' which outlines a design for a medical facility in space and that will also 'lead to significant advances in medical knowledge and spin-off Earth applications of the technology'.

ESA-sponsored attendees this year were Mr F. Sarti (ESTEC), Mr G. Carra (HQ) and Mr J. Sanchez (ESRIN). The session was also attended by Mr G. Scoon (ESTEC), a supporter of the programme for many years, who this year served as co-chair for the 'Ra' design project.

For more information concerning the two design projects or on ISU activities in general, contact:

International Space University
Parc d'Innovation
Boulevard Gonthier d'Andernach
67400 Illkirch
France

'Ra: The Sun for Science and Humanity' project team.

Space Again on Show at Farnborough 96

The European Space Agency, the British National Space Centre and the UK Industrial Space Committee shared a Space Pavilion at this year's Farnborough International Air Show (2 to 8 September).

The spotlight in the Space Pavilion this year was on space science models and particularly on Huygens, ESA's space probe to Saturn's moon Titan, to be launched in October 1997, and on SOHO, Europe's Sun observer launched at the end of 1995. A 3D virtual reality theatre allowed visitors to discover the International Space Station 'as if they were there', while an Ariane-5 1:5 mock-up towering outside the main entrance showed the way to the Pavilion. The Pavilion also hosted an interactive display area: a cyberspace terminal with the latest Internet news, and hands-on units featuring the best of space R&D and space teaching information. Many demonstrations of space applications, including technology transfer, were also on display.

The Pavilion opening was hosted by Ian Taylor, Britain's Minister for Space; Jean-Marie Luton, ESA's Director General; and Pat Norris, the UK Industrial Space Committee's Chairman.

ESA Organises Space Agency Forum in Beijing

The IAF (International Astronautical Federation) held its 47th Congress on 7-11 October in Beijing this year. The IAF is a non-governmental association of national societies, institutions and industrial companies. Founded in 1950 with 11 members, it now has 129 members in 46 countries. The IAF Congress is held annually in a different country.

During the Congress, and with the active support of the Chinese National Space Agency (CNSA), ESA organised the fourth meeting of the Space Agency Forum (SAF-4) on 8 October.

On this occasion, the Chinese Prime Minister received the main representatives of the various space agencies for an exchange of views. Most papers and reports presented were directed towards space activities in the 21st century, detailing long-term and future programmes. Other topics of interest included: benefits of the mission to planet Earth for developing countries, space in education, space science activities and Earth observation studies.

Furthermore, proposals were made for a SAF Award and a Space Millennium event, though no final decisions were taken. The AIAA (American Institute of Aeronautics and Astronautics) reported on its 3rd international space cooperation workshop 'From Recommendations to Action' which was held at ESRIN earlier this year.

The keynote address for this year's Space Agency Forum was given by Mr K. Doetsch, President of the IAF.

Participants in the Fourth Space Agency Forum held in the guest house of the Chinese government in Beijing.

International Symposium on Mission Control

The Fourth International Symposium on Space Mission Operations and Ground Control Systems was held at the Forum der Technik near the Deutsches Museum in Munich, from 16 to 20 September. The subject of the symposium was 'Global Space Operations in the next Century'.

Some 600 experts from over 30 countries were invited to discuss the latest trends in the satellite sector and ground control systems, with special emphasis on greater cost effectiveness and the increasing internationalisation and standardisation of future space projects.

With nearly 1000 operational satellites already in orbit and some 500 more to come in the next five years, there were several key themes to be addressed:

— Operations Management
— Ground Segment Engineering and Architectures
— Mission Planning
— Mission Control and Mission Product Processing
— Simulation and Modelling
— Operations Automation
— Standardisation
— Cost Efficient Operations
— Experience from Current or Recent Missions.

Reports on the latest developments were presented by the two organisers, the German Space Agency (DLR) and the European Space Agency (ESA), and by the representatives of the American, Russian, French, Japanese, Chinese, Indian, Brazilian, Canadian and Ukrainian space agencies. Space industry representatives from all over the world contributed to the general exchange of information and experience.

Copies of the Proceedings (ESA SP-394) can be ordered from ESA Publications Division (see inside back cover for details).

Envisat, Signing of Prime Contract

Envisat-1 is an environmental multidisciplinary Earth-observation mission. It will not only provide continuity with and enhancement of the ERS data, but will add significant new capability principally in the area of environmental monitoring, both of the atmosphere and of the oceans.

Formally, the Envisat activities are covered by a combination of two Programmes:

- The Envisat-1 Programme, which essentially covers the mission system activities and instrument development (space segment), the ground segment development and the five-year exploitation phase.
- The Polar Platform (PPF) Programme, which essentially covers the development of the Polar Platform, the integration of all instruments with it, the preparation of the satellite for launch, the launch and in-orbit commissioning as well as the development of the Flight Operations Segment (FOS) by ESOC.

The Envisat-1 Programme has required extensive contractual negotiations. The contract with the PPF Industrial consortium led by Matra Marconi Space (UK) was concluded and signed in July 1995. After lengthy and difficult negotiations, the contract with the Mission Prime consortium led by DASA/Dornier was concluded and signed on 12 July 1996. The Payload Data Segment contract (consortium led by Thomson-CSF) as well as the Launch Services Agreement (with Arianespace) are currently under negotiation and are expected to be finalised before the end of 1996.

Signing of the Envisat Mission Prime contract. From right to left seated: ESA's Director General, Mr J-M. Luton and Dornier's Managing Director, Mr K. Ensslin; right to left standing: Mr P. Rinio (ESA), Mr K. Reuter (Head of ESA Cabinet), Mr L. Emiliani (Director of ESA's Earth Observation Programme), Mr K. Gluitz (Dornier), Mr B. Pfeiffer (ESA), Mr W. Thoma (ESA), Mr R. Knöfel (Dornier), Mr R. Benz (Dornier), Mr B. Gardini (ESA).

METEOSAT Second Generation

On 16 October 1996, Mr Jean-Marie Luton, the ESA Director General, and Mr Tillmann Mohr, the Director of Eumetsat, signed a Cooperation Agreement on the procurement by ESA of two further weather satellites of the Meteosat Second Generation (MSG-2 and MSG-3) for Eumetsat.

The MSG series of satellites and ground processing facilities will provide continuity of observations with the current generation of Meteosat satellites until well into the next century.

MSG-1, the first satellite in the series, will carry as its main payload an advanced radiometer for Eumetsat's requirements and a radiation budget experiment as a result of an ESA Announcement of Opportunity. It is currently being developed by ESA and scheduled for launch in the year 2000.

MSG-2 and MSG-3 will be procured by ESA on behalf of Eumetsat. They will be built by European industry under ESA

contract and are scheduled for launch in 2002 and 2007.

Eumetsat will launch and operate the three satellites and provide data until 2012.

The MSG design makes effective use of the most advanced technology to significantly improve the quality of weather satellite data. A new weather image will be provided every 15 minutes in 12 channels of the visible and infrared spectrum, instead of every 30 minutes in 3 channels on the current Meteosat satellites, and with twice the resolution. This, together with enhanced data dissemination capacities, will result in a dramatic increase in capabilities for monitoring weather patterns over the Atlantic Ocean, Europe and Africa and for the prediction and warning of severe storms and other potentially hazardous phenomena. The MSG satellites will also contribute significantly to climate monitoring.

Following the signature of the ESA/ Eumetsat Agreement, Mr Jean-Marie Luton and Mr Yves Michot, President and Chief Executive Officer of Aerospatiale the prime contractor, signed the contract covering the industrial development of the three MSG satellites for an amount of 601.4 Million ECU.

From right to left: ESA's Director General, Jean-Marie Luton and Eumetsat's Director, Tillmann Mohr sign a Cooperation Agreement for two further weather satellites of the Meteosat Second Generation.

12th International Symposium on Space Flight Dynamics

2-6 June 1997
Darmstadt, Germany

ESA's European Space Operations Centre (ESOC) has been operating spacecraft missions since 1968. Within this period, support has been provided to a variety of satellite missions such as satellites in near-Earth, geostationary and highly-eccentric orbits, as well as satellites with interplanetary trajectories.

International symposia on flight dynamics were founded by ESOC in 1981. During the past 15 years, 11 symposia have been organised by ESA, CNES, GSFC, IKI/CUP, INPE and ISAS.

This next International Symposium on Space Flight Dynamics, to be organised by ESOC's Orbit Attitude Division, will give the specialists in the flight dynamics field a unique opportunity to present, discuss and exchange information on the various aspects of spacecraft support in the orbit and attitude areas.

The symposium will cover all aspects of space flight dynamics with its associated support on ground and on board. It will consist of:

- lectures by invited speakers in the form of survey papers and introductions to special subjects;
- presentations by flight dynamics specialists, selected from the proposals received in response to the call for papers.

The deadline for receipt of the proposals for papers in the form of an extended abstract is 15 December 1996. The conference language will be English.

Information regarding the symposium, the call for papers and registration is maintained on a World Wide Web page at the following address:
http://www.esoc.esa.de/external/mso/conf.html

For further information, please contact the chairman of the Programme Committee:

Mr R.E. Muench
ESOC - European Space Operations Centre
Robert-Bosch-Str. 5
64293 Darmstadt
Germany

Tel: +49-6151-902226
Fax: +49-6151-902271

ISO Performing Well

ESA's ISO scientific spacecraft continues to operate very smoothly in orbit with an average of 45 scientific observations being made each day, and a vast quantity of high-quality astronomical data being returned.

On 5 September, a station-keeping manoeuvre was successfully executed. The hydrazine reaction-control system was used for 6 min 16 sec to increase the semi-major axis of the spacecraft's orbit by about 40 km. This stopped ISO's previous eastwards drift and gave it a small west-wards drift. This drift will naturally decrease and reverse, and so another manoeuvre is expected to be necessary in mid-1997.

On the same day, the first direct measurement of the mass of remaining liquid helium was successfully made. Two heaters were activated for 112 secs to inject a known quantity of heat into the helium. By precisely measuring the temperature rise (around 5 mK), the mass of helium present was calculated to be 203 kg, which is slightly in excess of the modelling prediction 192 kg. Using a mass flow rate from the thermal models and the measured helium mass, it is estimated that the onboard helium supply will last until December 1977. This confirms previous estimates, made from indirect measurements, that ISO's lifetime in orbit will be about 2 years, compared to the 18 months originally specified.

A few spacecraft anomalies have occurred since launch, but they have had only a minor impact on the scientific return. At the end of May, a sequence of onboard events led to the Earth entering ISO's field of view for about 2 min. To prevent a recurrence of this event, linked to the extreme narrowness of the safe corridor for pointing during perigee passage at certain seasons, some of the onboard autonomy was temporarily overridden by ground commands. On the 16 August and 12 September, ISO unexpectedly re-configured itself into an autonomy mode. The cause of this has been traced to a 'Remote Terminal Unit' and ISO is now operating using a redundant unit. Just 2.5 days of science were lost during these anomalies.

The four scientific instruments continue to operate well and are returning high-quality data. An additional observing mode, using the high-resolution Fabry-Perot interferometer of the Long Wavelength Spectrometer, has been commissioned.

Ground operations are also proceeding very satisfactorily. Observing schedules containing highly-rated observations are being routinely produced and executed with efficiences of up to 95%.

The initial scientific results from ISO were presented to an enthusiastic international audience of about 260 astronomers at a workshop held at ESTEC in Noordwijk (NL) on 29 – 31 May. These results and others were published in the November issue of the journal 'Astronomy and Astrophysics', which is dedicated to ISO and contains close to 100 scientific papers.

A 'Supplementary Call for Observing Proposals' was issued to the European, American and Japanese astronomical communities at the beginning of August. This solicited for observations to be carried out in the period December 1996 to December 1997. The deadline for response was 7 October and a total of 551 proposals were received, requesting almost four times the available observing time. The results of the proposal review process will be made available at the end of November.

An image of the Rho Ophiuchi dark cloud taken with ISOCAM. The scattered bright dots are new stars of moderate size, comparable in mass to the Sun. The bright fuzzy object, above and slightly to the right of centre, is a new massive star, much heavier than the Sun, still wrapped in the placental cloud from which it formed. A similar object appears partly veiled towards the bottom right of the picture. The conspicuous wisp right of centre is the interface between the dense cloud and the general interstellar medium. In a dark region near the centre of the image, the dust is so dense that even an infrared telescope can look no further into the murk.

This ISO image is a colour-composite of data taken at wavelengths of 7 and 15 microns of an approximately 0.75 x 0.75 degree area of the sky.

INTEGRAL Enters New Phase

The INTEGRAL (International Gamma-Ray Astrophysics Laboratory) mission was selected by the ESA Scientific Programme Committee on 3 June 1993 as the next ESA medium-size scientific mission (M2) to be launched in 2001. The mission utilises the service module (bus) under development for the ESA XMM project. Contributions to the programme will be made by Russia and NASA.

The nominal lifetime of the observatory will be two years with a possible extension of up to five years. During this period, most of the observing time will be made available to the worldwide scientific community.

On 6 November 1996, INTEGRAL officially entered the next part of its evoluton, Phase C/D. This main development and verification phase has the objective of producing a fully integrated and tested satellite compliant with the technical, schedule and cost requirements of the INTEGRAL programme.

Signing for INTEGRAL's Phase C/D are ESA's Director General, Mr Jean-Marie Luton and the prime contractor Alenio Spazio's Managing Director, Mr Antonio Rodota.

Space Station Utilisation Symposium

The first symposium on the utilisation of the International Space Station (ISS) was held in the period 30 September through 2 October at ESOC. The symposium was devoted to all disciplines with a potential interest in the ISS. Approximately 350 participants attended.

The symposium was structured into three parts: an introductory plenary session, discipline oriented splinter sessions, and a closing plenary session.

During the introductory plenary session, presentations covering the content and schedule of the International Space Station Programme were given. The European contributions and the resulting utilisation rights were highlighted. The session was complemented by introductory papers on discipline oriented utilisation of the Space Station.

The three main objectives of the splinter sessions, held on the second day of the symposium, were:
- to give an overall discipline assessment on the usefulness of Space Station,
- to identify specific discipline projects to be pursued on Space Station,
- to develop an overall discipline strategy identifying necessary follow-up activities.

Output from the sessions included reports on the following topics:
- Physical Sciences in Microgravity,
- Life Sciences in Microgravity,
- Space Sciences on Space Station,
- Earth Observation from Space Station,
- Technology on Space Station.

The closing plenary session included summaries from the splinter sessions and presentations of overall discipline strategies.

From the results of the symposium, it was concluded that there is a strong demand to establish and enlarge the community of potential Space Station users. This community will have to ensure a pronounced visibility, both to the tax payer and to the political decision maker. Furthermore, although routine operations are still far in the future, it will be necessary to initiate promotion of potential applications and to start science activities of ground based type research at the university level.

There will also be an increasing demand to focus Space Station activities on topics of high relevance and visibility. Potential users of ISS should therefore join together to create large ventures that have challenging goals and are capable of attracting public interest. Examples of current and potential projects include a magnetic spectrometer to investigate antimatter in our Universe, the search for Near Earth Objects, disaster monitoring and the x-ray telescope accommodated on a coorbiting Free Flyer.

The Proceedings of the symposium have already been published by ESA Publications Division as ESA SP-385 (further details and an order form can be found inside the back cover of this Bulletin).

Publications

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

ESA Newsletters

EARTH OBSERVATION QUARTERLY
NO. 53, SEPTEMBER 1996
ED. T.D. GUYENNE
NO CHARGE

PREPARING FOR THE FUTURE
VOLUME 6 NUMBER 3
ED. M. PERRY
NO CHARGE

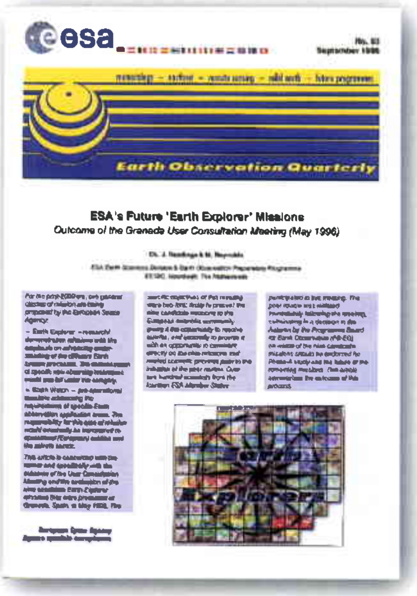
ESA Brochures

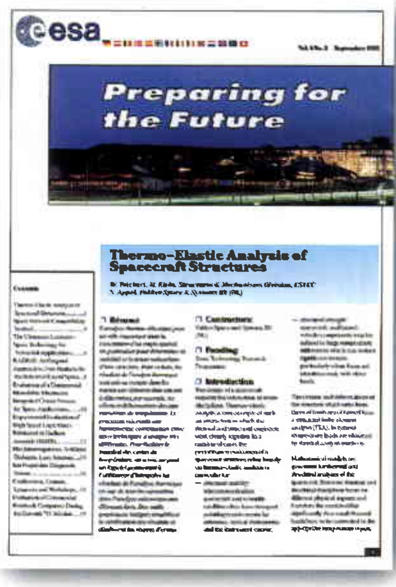
THE EUROPEAN SPACE OPERATIONS CENTRE (OCTOBER 1996)
NYE H. & LANDEAU-CONSTANTIN J.
(KALDEICH B. ED.)
ESA BR-110 // 32 PP
PRICE: 50 DFL

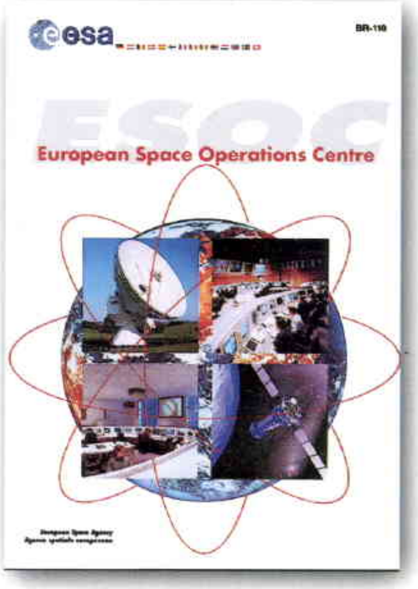
THE ESA TECHNOLOGY R&D FRAME PROGRAMME (JULY 1996)
DE PEUTER W. & BRISSON P.
(BATTRICK B. ED.)
ESA BR-120 // 8 PP
NO CHARGE

Special Publications

THE ROLE OF ERS-SAR DATA FOR CENTRAL AFRICAN COUNTRIES (JUNE 1996)
HUSSON A. & HARMS J., SCOT CONSEIL
(BATTRICK B. ED)
ESA SP-1199 // 53 PP
PRICE: 50 DFL







Credit Card Payments for ESA Publications

It is now possible to purchase the Agency's publications from the ESA Publications Division 'Bookshop' using your corporate or your personal credit card (Eurocard or Mastercard).

You can telephone or telefax your orders to the numbers given below, quoting your card's number and its expiry date:

The Bookshop (attn. Mr Frits de Zwaan)
ESA Publications Division
ESTEC
Keplerlaan 1
2200 AG Noordwijk
The Netherlands

Telephone: (31) 71 5653405
Telefax: (31) 71 5655433

Other methods of payment are also accepted. Please call or fax for details.

A list of the latest publications can be accessed via the ESA Publications Division's Home Page at the following Internet/WWW address:

http://esapub.esrin.esa.it/esapub.html

Printed annual Catalogues of ESA Publications are available free of charge from the Bookshop.

THE INTERNATIONAL SPACE STATION — A GUIDE FOR EUROPEAN USERS: EARLY OPPORTUNITIES ISSUE (SEPTEMBER 1996)
LARTER N. & GONFALONE A.
(BATTRICK B. ED.)
ESA SP-1202 // 71 PP
PRICE: 50 DFL

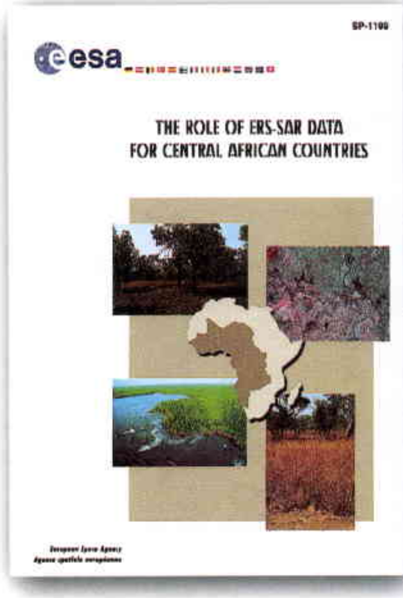
EUROMIR 95: CREW DEBRIEFING AND LESSONS LEARNT. PROCEEDINGS OF A MEETING AT MONSCHAU, GERMANY, 15 – 19 APRIL 1996 (AUGUST 1996)
GUYENNE T.D. (ED.)
ESA SP-396 // 98 PP
PRICE: 50 DFL

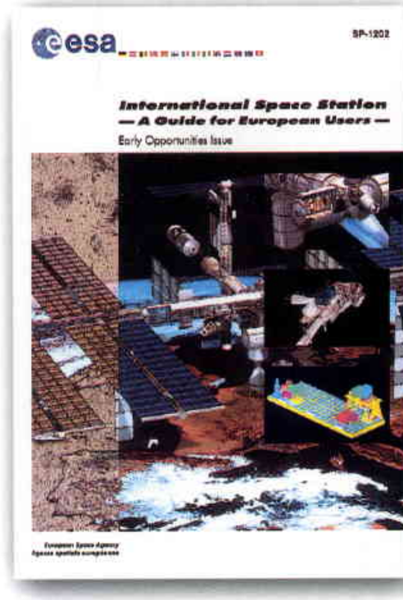
PROCEEDINGS OF THE SIXTH EUROPEAN SYMPOSIUM ON LIFE SCIENCES RESEARCH IN SPACE, TRONDHEIM, NORWAY, 16 – 18 JUNE 1996 (OCTOBER 1996)
KALDEICH B. (ED.)
ESA SP-390 // 436 PP
PRICE: 100 DFL

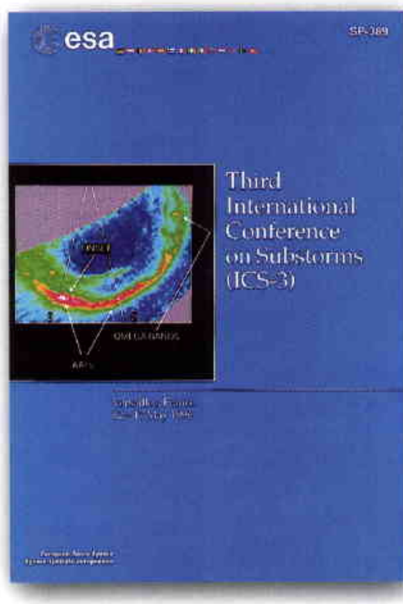
PROCEEDINGS OF THE THIRD INTERNATIONAL CONFERENCE ON SUBSTORMS (ICS-3), VERSAILLES, FRANCE, 12 – 17 MAY 1996 (OCTOBER 1996)
ROLFE E. & KALDEICH B. (EDS.)
ESA SP-389 // 777 PP
PRICE: 100 DFL

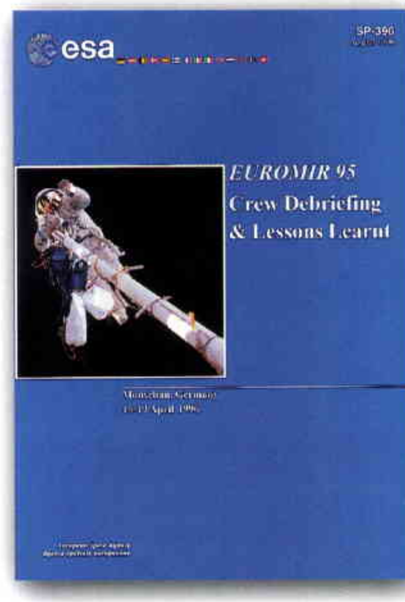
ESA History Reports

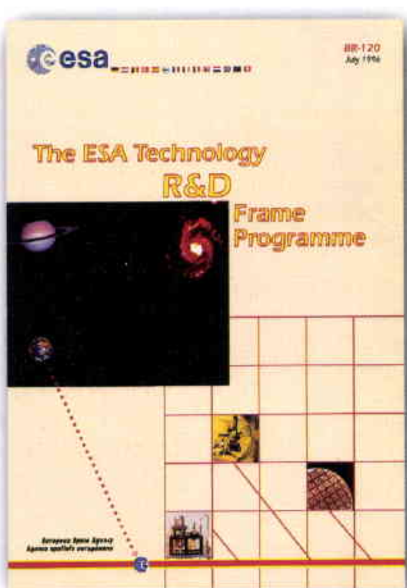
THE AVAILABILITY OF AMERICAN LAUNCHERS AND EUROPE'S DECISION 'TO GO IT ALONE' (SEPTEMBER 1996)
SEBESTA L. (BATTRICK B. ED.)
ESA HSR-18 // 56 PAGES
PRICE: 35 DFL

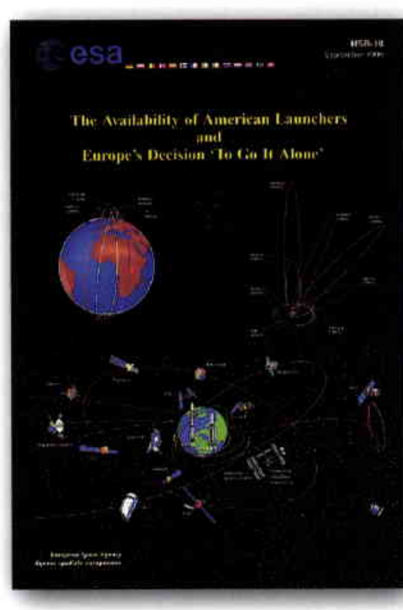


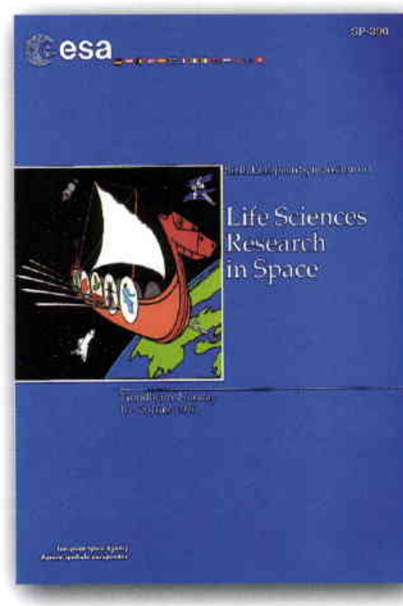












Contractor Reports

RADIATION HARDENED CCD DEMONSTRATOR — FINAL REPORT AND EXECUTIVE SUMMARY (JANUARY 1996)
IMEC, BELGIUM
ESA CR(X)-3975 // 18 PP AND 22 PP
AVAIL MF

VLSI DESIGN TOOLS: MODULE GENERATION FOR ANALOGUE SILICON COMPILATION – FINAL REPORT (DECEMBER 1995)
KU LEUVEN, BELGIUM
ESA CR(X)-3976 // 126 PP
AVAIL MF

ADVANCED POWER SUBSYSTEM FOR LEO MISSIONS — FINAL REPORT (FEBRUARY 1996)
MATRA MARCONI SPACE, FRANCE
ESA CR(P)-3977 // 185 PP
AVAIL MF

SUB-MM OBSERVATION OF PROCESSES IN THE ATMOSPHERE (SOPRANO) — FINAL REPORT AND EXECUTIVE SUMMARY (DECEMBER 1995)
DAIMLER-BENZ AEROSPACE, GERMANY
ESA CR(P)-3978 // 260 PP AND 24 PP
AVAIL MF

USE OF HYPERTEXT AND STRUCTURED NATURAL LANGUAGE IN REQUIREMENTS SPECIFICATION — FINAL REPORT (DECEMBER 1995)
SIEMENS, AUSTRIA
ESA CR(P)-3979 // 96 PP
AVAIL MF

RELIABILITY STUDY PROGRAMME FOR CCDS: PHASE C — FINAL REPORT (NOVEMBER 1995)
EEV, UK
ESA CR(P)-3980 // 192 PP
AVAIL MF

BROADBAND COMMUNICATIONS BY SATELLITE USING HIGH-SPEED PACKET SWITCHING — EXECUTIVE SUMMARY AND FINAL REPORTS (NOVEMBER 1995)
CSEM, SWITZERLAND
ESA CR(P)-3981 // 36, 175 AND 237 PP
AVAIL MF

LUNAR RESOURCES EXPLOITATION STUDY — FINAL REPORT AND EXECUTIVE SUMMARY (JANUARY 1996)
AEA, UK
ESA CR(P)-3982 // 110 PP AND 12 PP
AVAIL MF

CRYOGENIC HEAT-PIPE AGEING — FINAL REPORT (JANUARY 1995)
SABCA, BELGIUM
ESA CR(P)-3983 // 43 PP
AVAIL MF

Contractor Reports

There are two types of Contractor Reports: CR(P) and CR(X) reports.

ESA CR(P) documents are available on microfiche from either of the following addresses:

British Library — Doc. Supply Centre
Customer Service
Boston Spa
Wetherby, West Yorkshire
LS23 7BQ
UK

Tel: (44) 937 546 060
Fax: (44) 937 546 333

FIZ Karlsruhe
Bibliographic Service
D-76344 Eggenstein-Leopoldshafen
Germany

Tel: (49) 7247 808 333
Fax: (49) 7247 808 135

ESA CR(X) documents have a restricted distribution and are not available on microfiche. Printed copies can be requested via ESA Publications Division.

ADVANCES IN FLUID MODELLING USING THE BOUNDARY ELEMENT METHOD IMPLEMENTATION OF ASKA — FINAL REPORT: VERSION 7 (SEPTEMBER 1995)
STRACO, FRANCE
ESA CR(P)-3984 // 109 PP
AVAIL MF

PLANETARY BODY HIGH-RESOLUTION 3D MODELLING — FINAL REPORT (JANUARY 1996)
JOANNEUM RESEARCH, AUSTRIA
ESA CR(P)-3985 // 164 PP
AVAIL MF

TRIBOMETER ROUND-ROBIN — FINAL REPORT (JANUARY 1996)
ESTL, UK
ESA CR(P)-3986 // 28 PP
AVAIL MF

STRUCTURAL INTEGRITY OF LAUNCHERS (PART C) — FINAL REPORT AND EXECUTIVE SUMMARY (MAY 1995)
DAIMLER-BENZ AEROSPACE, GERMANY (VOL I)
ESA CR(P)-3988 // 148 PP AND 117 PP
AVAIL MF

FREQUENCY ANALYSIS OF TIME SERIES IN SPACECRAFT ATTITUDE DETERMINATION — FINAL REPORT (NOVEMBER 1994)
UNIV. OF PADOVA, ITALY
ESA CR(P)-3989 // 370 PP
AVAIL MF

THERMAL CONTROL IN EXTRATERRESTRIAL PLANETARY ENVIRONMENTS — FINAL REPORT (MARCH 1996)
DORNIER, GERMANY
ESA CR(P)-3997 // 133 PP
AVAIL MF

DEFINITION OF A SATELLITE COMMUNICATION SYSTEM FOR SUPPORT TO VSAT NETWORKS OPERATING AT 20/30 GHZ — EXECUTIVE SUMMARY (MAY 1996)
TELESPAZIO, ITALY
ESA CR(P)-3998 // 46 PP
AVAIL MF

ROBOTICS FOR LUNAR EXPLORATION 'ROLEX' — EXECUTIVE SUMMARY (MAY 1996)
TECNOMARE, ITALY
ESA CR(P)-3999 // 34 PP
AVAIL MF

DIGITAL SATELLITE BROADCASTING FOR PROFESSIONAL SERVICES — FINAL REPORT (JUNE 1995)
SIGNET COMMUNICATIONS LTD, UK
ESA CR(X)-4000 // 38 PP
AVAIL MF

MODELLING OF DISTRIBUTED EARTH OBSERVATION DATA-HANDLING FACILITIES: PLANS FOR THE YEAR 2000 — FINAL REPORT (DECEMBER 1995)
CAP SESA, FRANCE
ESA CR(P)-4001 // 151 PP
AVAIL MF

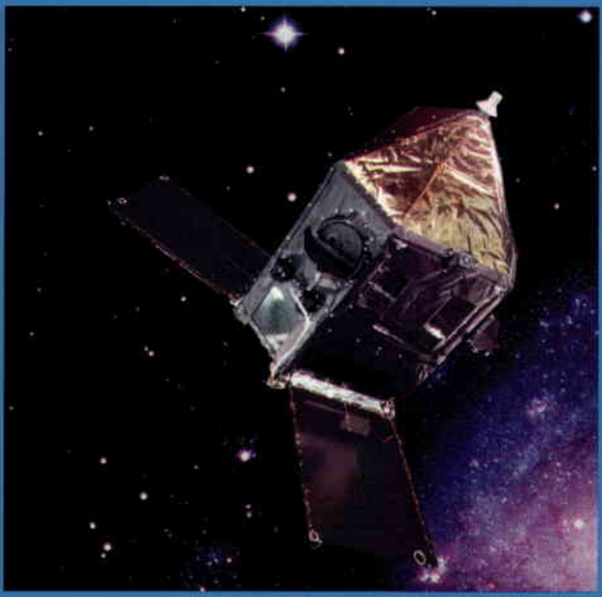
CARBON-DIOXIDE REMOVAL BY HYDROPHOBIC MOLECULAR SIEVES, PHASE II — FINAL REPORT AND EXECUTIVE SUMMARY (MAY 1996)
CARRAR, FRANCE
ESA CR(P)-4002 // 185 PP AND 21 PP
AVAIL MF

CHALLENGING POSSIBILITIES FOR VSAT SYSTEMS IN EUROPE — FINAL REPORT (AUGUST 1995)
TNO, THE NETHERLANDS
ESA CR(P)-4003 // 129 PP
AVAIL MF

MODULAR CULTIVATION SYSTEM PHASE-A STUDY — FINAL REPORT (AUGUST 1996)
DORNIER, GERMANY
ESA CR(P)-4004 // 48 PP
AVAIL MF

The Hipparcos and Tycho Catalogues

esa



The Mission Products

The principal parts of the Hipparcos Catalogue are provided in both printed and machine-readable form. Tycho Catalogue results are provided in machine-readable form only. The printed volumes include a description of the Hipparcos and Tycho Catalogues and associated annexes, a description of the satellite operational phase, a description of the corresponding data analysis tasks, and the final data.

Machine-readable versions of the catalogues are provided in two forms: the definitive mission products are released as a set of ASCII files on a series of CD-ROMs, which contain all of the printed catalogue information as well as some additional data. Auxiliary files containing results from intermediate stages of the data processing, of relevance for the more-specialised user, are also included.

A distinct single CD-ROM product, Celestia 2000, contains the principal astrometric and photometric data, in compressed form, along with specific interrogation software developed for specific platforms.

The Hipparcos Mission

The Hipparcos space astrometry mission was accepted within the European Space Agency's scientific programme in 1980. The Hipparcos satellite was designed and constructed under ESA responsibility by a European industrial consortium led by Matra Marconi Space (France) and Alenia Spazio (Italy), and launched by Ariane-4 on 8 August 1989. High-quality scientific data were acquired between November 1989 and March 1993. The scientific aspects of the mission were undertaken by nationally-funded scientific institutes. All of the scientific goals motivating the mission's adoption in 1980 were surpassed, in terms of astrometric accuracy, photometry, and numbers of stars.

The global data analysis tasks, proceeding from nearly 1000 Gbit of satellite data to the final catalogues, were undertaken by three scientific consortia: the NDAC and FAST Consortia, together responsible for the production of the Hipparcos Catalogue; and the Tycho Consortium, responsible for the production of the Tycho Catalogue. A fourth scientific consortium, the INCA Consortium, was responsible for the construction of the Hipparcos observing programme. The production of the Hipparcos and Tycho Catalogues marks the formal end of the involvement in the mission by ESA and the four scientific consortia.

The Hipparcos and Tycho Catalogues

The final products of the European Space Agency's Hipparcos mission are two major stellar catalogues, the Hipparcos Catalogue and the Tycho Catalogue.

Each catalogue includes a large quantity of very high quality astrometric and photometric data. The astrometric data in the Hipparcos Catalogue is of unprecedented accuracy: positions at the catalogue epoch (J1991.25), annual proper motions, and trigonometric parallaxes, have a median accuracy of approximately 1 milliarcsec. The Hipparcos Catalogue includes annexes featuring variability and double/multiple star data for many thousands of stars discovered or measured by the satellite. The Hipparcos and Tycho Catalogues will remain the definitive astrometric stellar catalogues for many years.

Invitation for Subscriptions

Final results from the ESA Hipparcos space astrometry mission will be made widely available in June 1997. The results will be available in three formats:

— A 16–volume hard-bound printed catalogue, containing descriptions of the data reduction techniques, along with the Hipparcos Catalogue and related annexes, plus an ASCII version of the Hipparcos and Tycho Catalogues and annexes in a set of 6 CD-ROMs;

— A subset of the above consisting of Volume 1 (Introduction and Guide to the Data) and the ASCII CD-ROM set;

— Celestia 2000: a CD-ROM package containing the Hipparcos and Tycho Catalogues and annexes along with interrogation software.

Only a limited number of the hard-bound printed catalogue will be produced. To avoid future requests exceeding the available supply, you are invited to reserve your copy now, by returning the subscription form before **15 January 1997** to:

Hipparcos Catalogue Subscriptions
Astrophysics Division (SA)
ESTEC
P.O. Box 299
2200 AG Noordwijk
The Netherlands

Fax: + 31 71 565 4690
see also http://astro.estec.esa.nl/SA-general/Projects/Hipparcos/hipparcos.html for a WWW order form

Subscription Form

Please reserve for me the following (prices include post & packing to any destination):

..... set(s) of the 16-volume printed catalogue (with ASCII CD-ROMs) @ 650 Dfl ($400) per set

..... subset(s) of Introduction & Guide to the Data only, with ASCII CD-ROM set @ 165 Dfl ($100) per set

..... set(s) of Celestia 2000 @ 80 Dfl ($50) per set

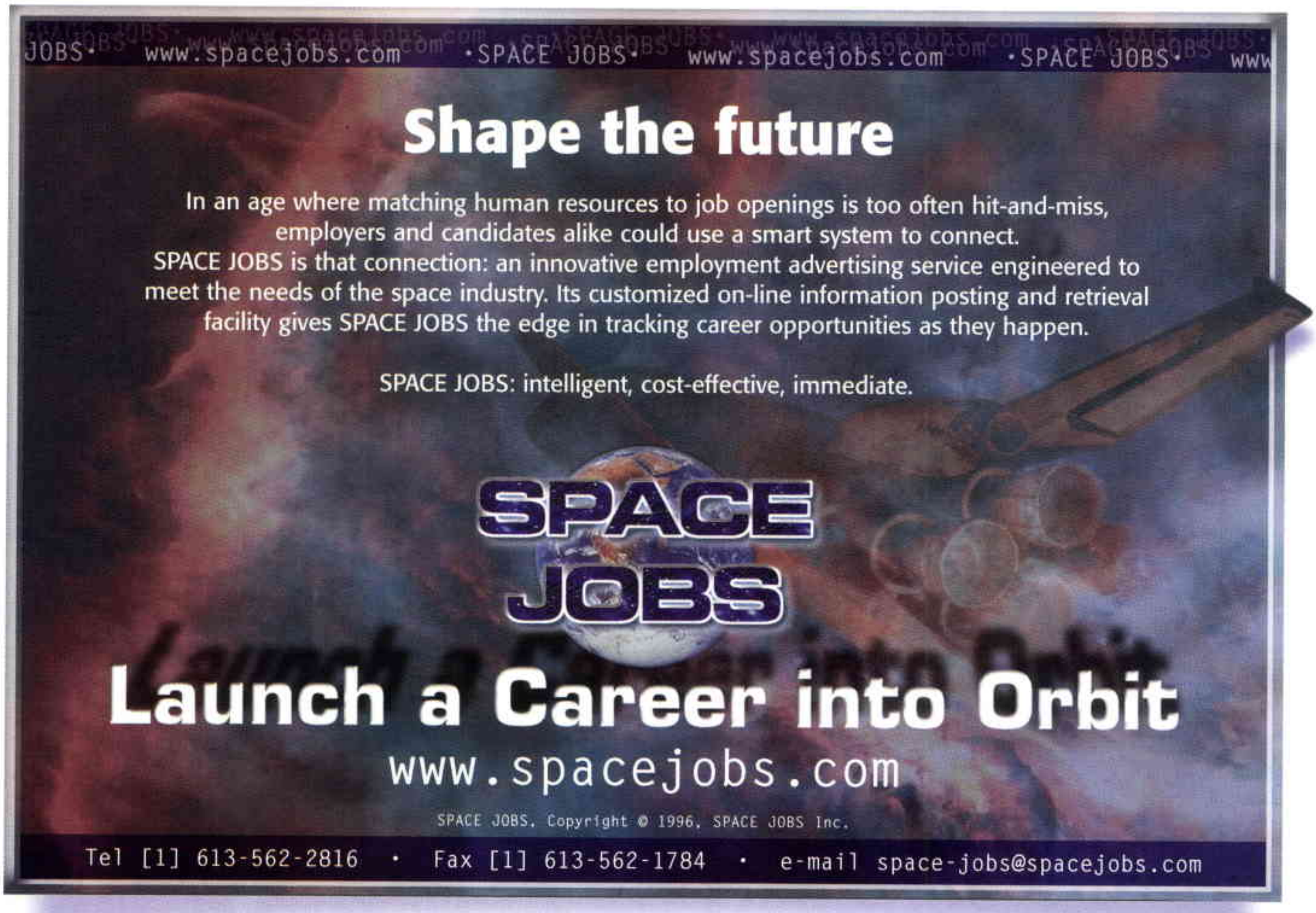
Name: ....

Address: ....

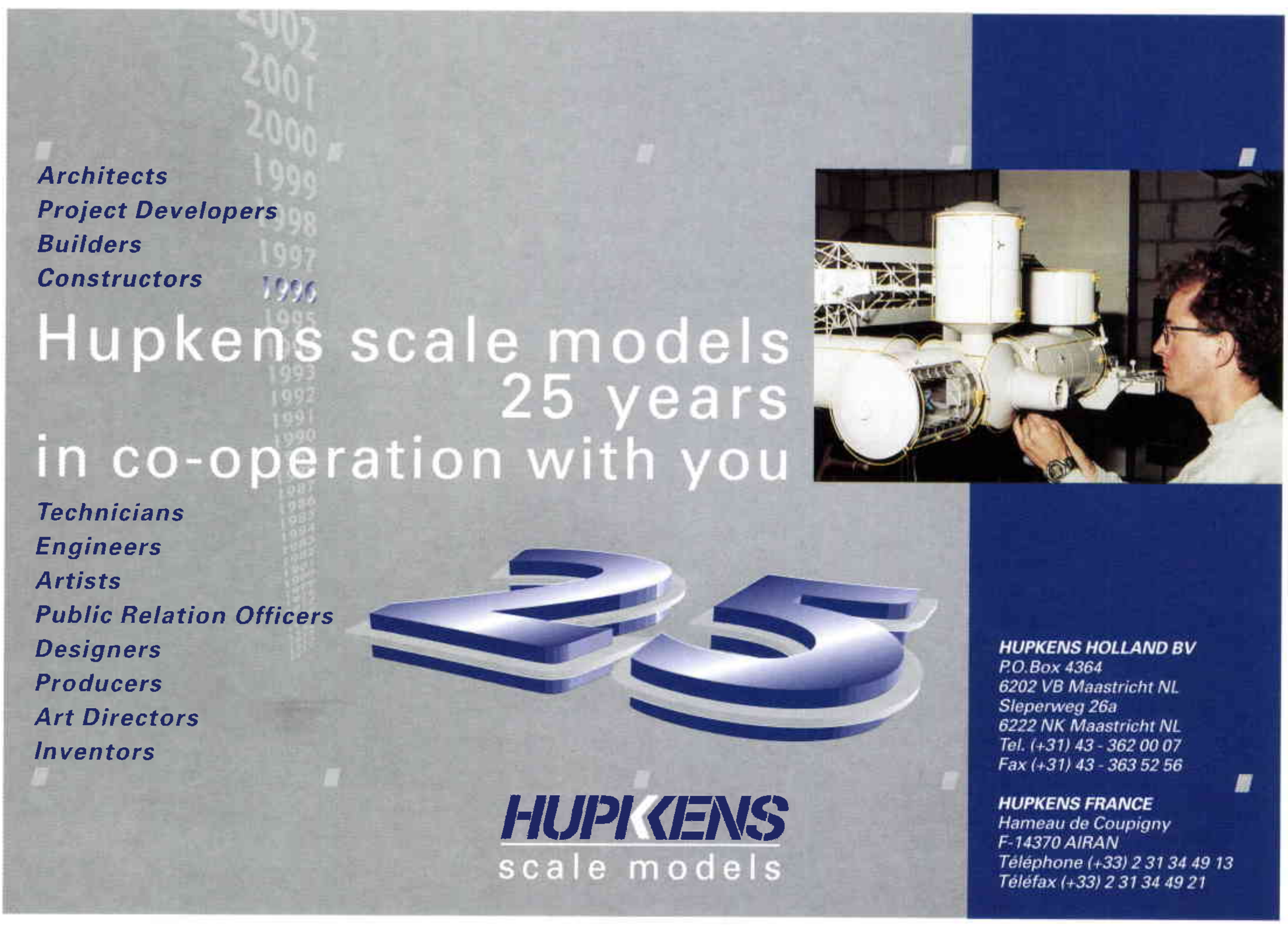
....

Signature: Date:

The number of hard-bound volumes printed will be based on the response to this announcement.
An invoice will be sent to all subscribers in early 1997.
On receipt of payment your requested product(s) will be delivered to the address filled in above.

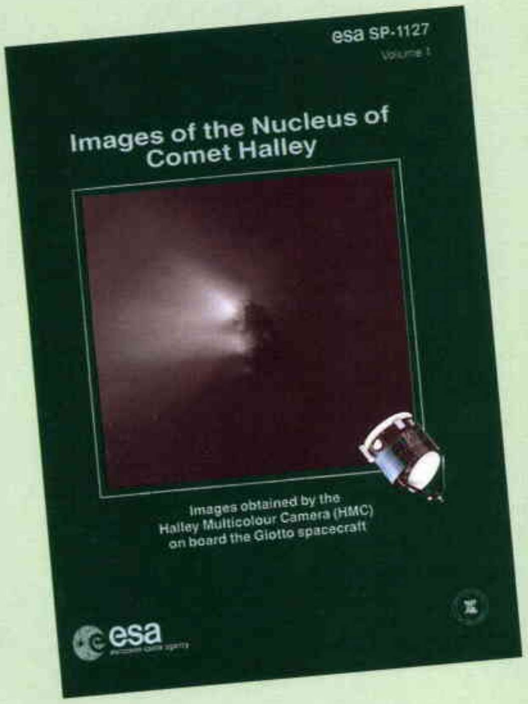


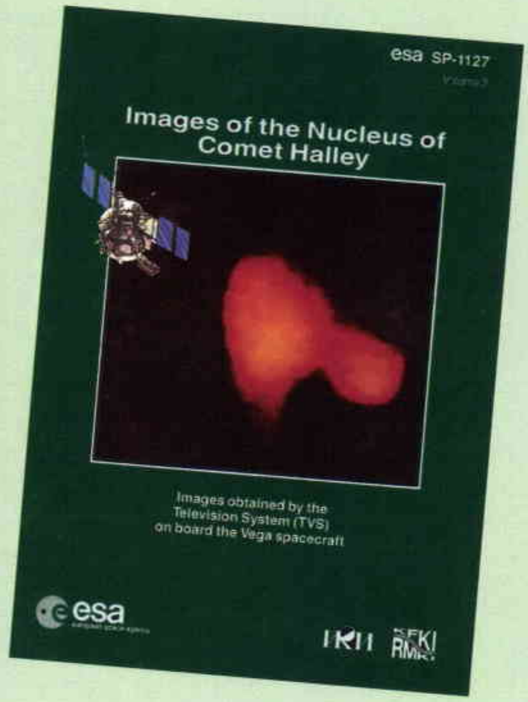
www.spacejobs.com ·SPACE JOBS· www.spacejobs.com ·SPACE JOBS·
Shape the future
In an age where matching human resources to job openings is too often hit-and-miss, employers and candidates alike could use a smart system to connect.
SPACE JOBS is that connection: an innovative employment advertising service engineered to meet the needs of the space industry. Its customized on-line information posting and retrieval facility gives SPACE JOBS the edge in tracking career opportunities as they happen.
SPACE JOBS: intelligent, cost-effective, immediate.
SPACE JOBS
Launch a Career into Orbit
www.spacejobs.com
SPACE JOBS, Copyright © 1996, SPACE JOBS Inc.
Tel [1] 613-562-2816 · Fax [1] 613-562-1784 · e-mail space-jobs@spacejobs.com



Architects
Project Developers
Builders
Constructors
Hupkens scale models
25 years
in co-operation with you
Technicians
Engineers
Artists
Public Relation Officers
Designers
Producers
Art Directors
Inventors
25
HUPKENS
scale models
HUPKENS HOLLAND BV
P.O.Box 4364
6202 VB Maastricht NL
Sleperweg 26a
6222 NK Maastricht NL
Tel. (+31) 43 - 362 00 07
Fax (+31) 43 - 363 52 56
HUPKENS FRANCE
Hameau de Coupigny
F-14370 AIRAN
Téléphone (+33) 2 31 34 49 13
Téléfax (+33) 2 31 34 49 21

Atlas of Images of the Nucleus of Comet Halley





Apparitions of Comet Halley have been recorded regularly in history since 240 BC, but it was not until its 1066 AD apparition that it was first depicted visually, and then only in a very stylistic manner. The first accurate scientific drawing of Comet Halley was made in 1682 by Hevelius. Further drawings with increasing detail were made during the 1759 and 1835 apparitions, and the first photographic plates were made during Halley's return in 1910. By the time Halley next returned in 1985/6, space flights to comets were possible and it was met by an armada of five spacecraft, three of which – Giotto, Vega-1 and Vega-2 – carried high-resolution cameras. These images revealed the existence of a cometary nucleus for the first time.

Volume 1 of this Atlas is devoted to the images obtained by the Halley Multicolour Camera (HMC) aboard ESA's Giotto spacecraft. It includes a brief description of the project, an account of the image processing and calibration procedures, and a summary of the scientific results to facilitate interpretation of the images.

In Volume 2, the consecutive sequences of images obtained by the imaging experiments aboard the Russian-led Intercosmos spacecraft Vega-1 and Vega-2 are presented and the most important scientific results obtained from these images are described.

ESA SP-1127
Volume 1: 252 pages
Volume 2: 254 pages

Price (both vols.): 100 Dutch Guilders

Available from: ESA Publications Division
(Order Form inside back cover of this Bulletin)

Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Price	Source
Periodicals				
ESA Bulletin	4	ESA's primary magazine	Free of charge	ESA Publications Division, c/o ESTEC, 2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly	4	Remote-sensing news	"	"
ECSL News	4	News from the European Centre for Space Law (under the auspices of ESA)	"	"
Reaching for the Skies	4	ESA's Space Transportation Systems news	"	"
Microgravity News	3	Microgravity Programme news	"	"
Preparing for the Future	4	Technology Programme news	"	"
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Collection of papers presented at an ESA conference	Prices vary	ESA Publications Division, c/o ESTEC, 2200 AG Noordwijk, The Netherlands
Special Publications	(SP-xxxx)	Detailed monographs on post-graduate level subjects	"	"
Brochures	(BR-xxx)	Concise summaries on specific subjects	"	"
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	"	"
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	"	"
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	"	"
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	"	"
Public-relations material		General literature, posters, photographs, films, etc.		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

All periodicals are also available via the Internet at:

http://esapub.esrin.esa.it/esapub.html

Selected public-relations material and other ESA information is available at:

http://www.esrin.esa.it

Order Form for ESA Publications

IMPORTANT

1. For credit-card orders, see page 114.
2. Orders must be accompanied by a Cheque or International Banker's Draft, in Dutch Guilders, made payable to 'ESA Publications Division'. No publications will be sent before receipt of payment.
3. Within Europe, mailing is free-of-charge. Outside Europe, airmail is free-of-charge for orders over Dfl. 110; smaller orders are sent sea mail.

RETURN TO: **FINANCE DIVISION (EFA/P)**
ESTEC, POSTBUS 299
2200 AG NOORDWIJK
THE NETHERLANDS

No. of copies	ESA reference	Title	Price per copy, Dfl.	Total Dfl.
			Total:	
		Discount for orders over Dfl. 110: 10% of total :		
		Total amount enclosed:.		

MAILING ADDRESS (Please print carefully)

Name ....

Function ....

Organisation ....

Mailing Address ....

....

Town & Postal Code ....

Country ....

Date .... Signature ....

METHOD OF PAYMENT (Please tick box)

○ Cheque
○ International Banker's Draft
} enclosed, made payable to ESA Publications Division.

Member States
Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Italy
Netherlands
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres
Allemagne
Autriche
Belgique
Danemark
Espagne
Finlande
France
Irlande
Italie
Norvège
Pays-Bas
Royaume-Uni
Suède
Suisse

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433