european space agency

agence spatiale européenne

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european space agency

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

ESRIN, Frascati, Italy.

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agence spatiale européenne

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

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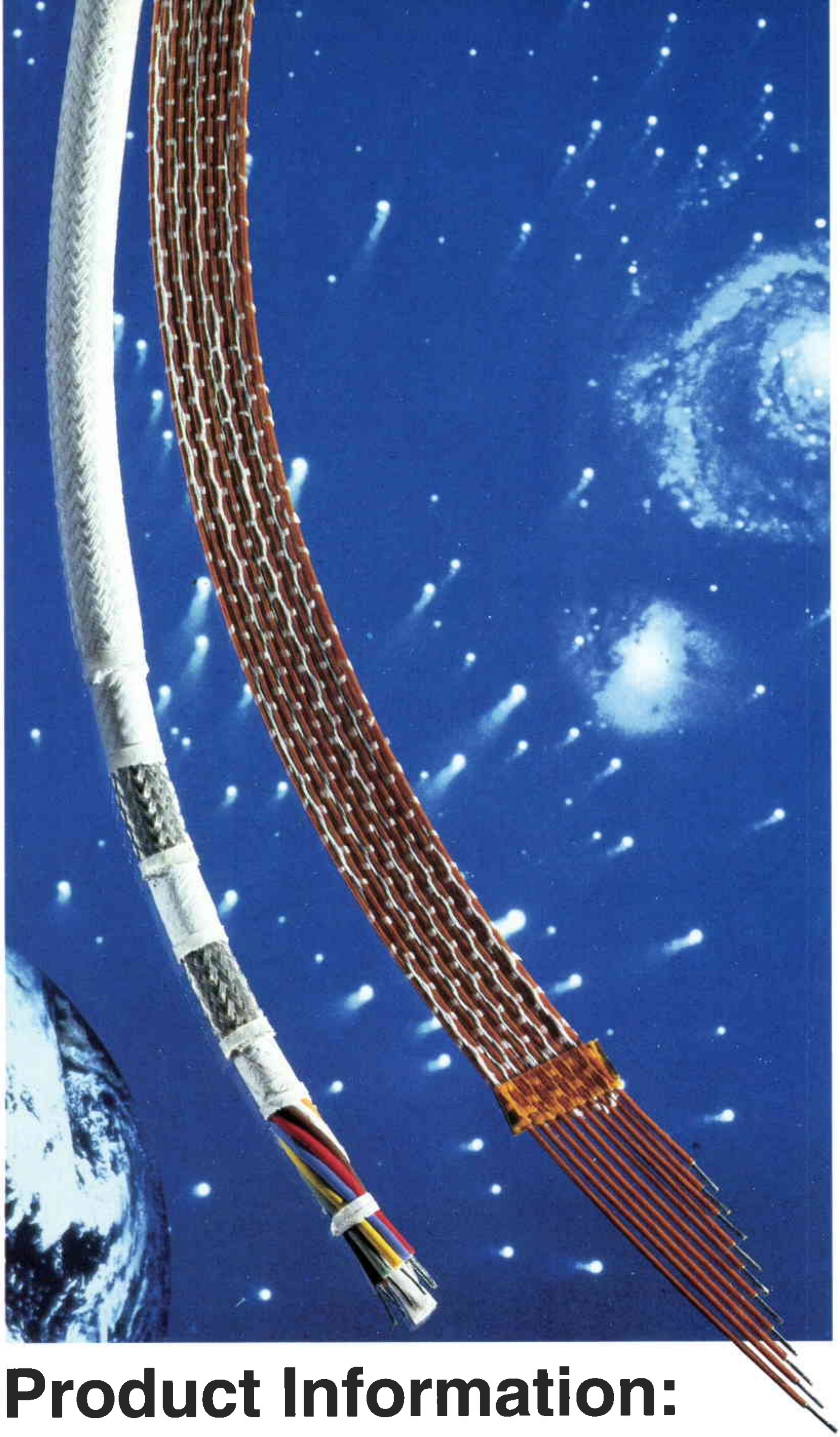

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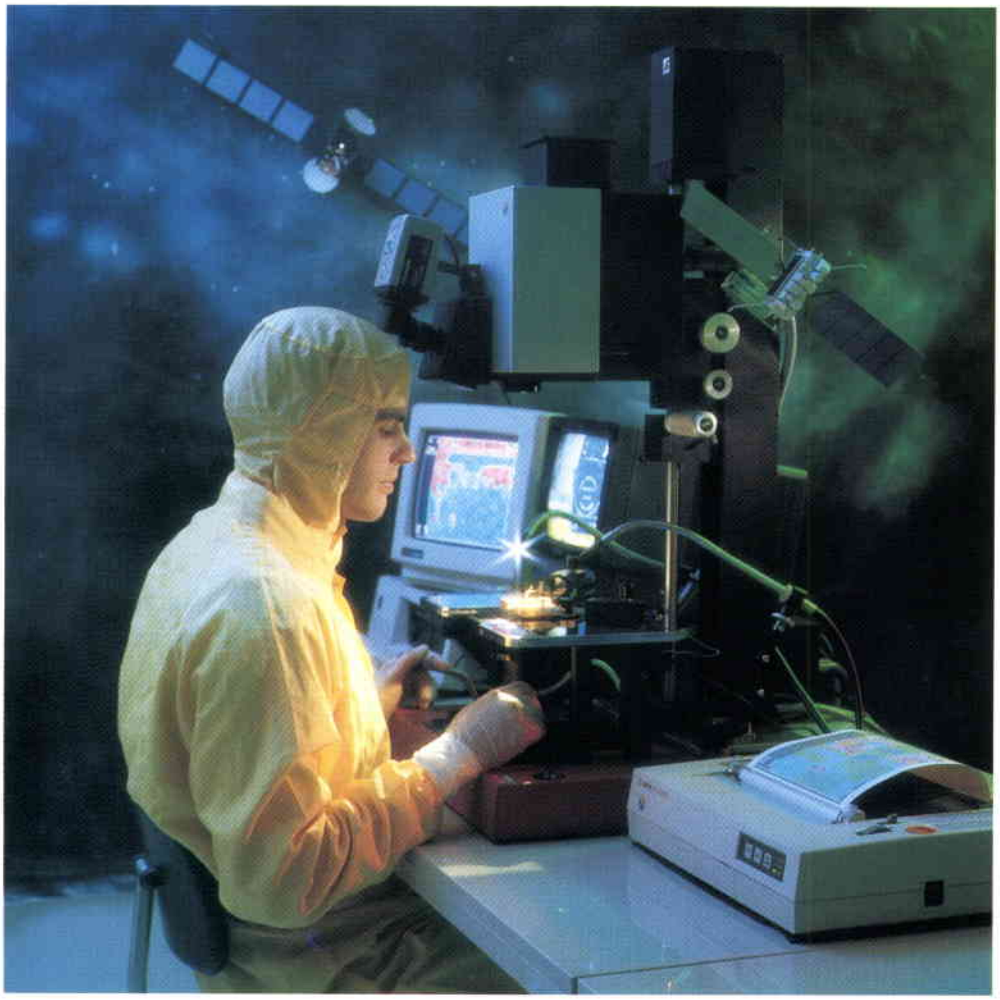
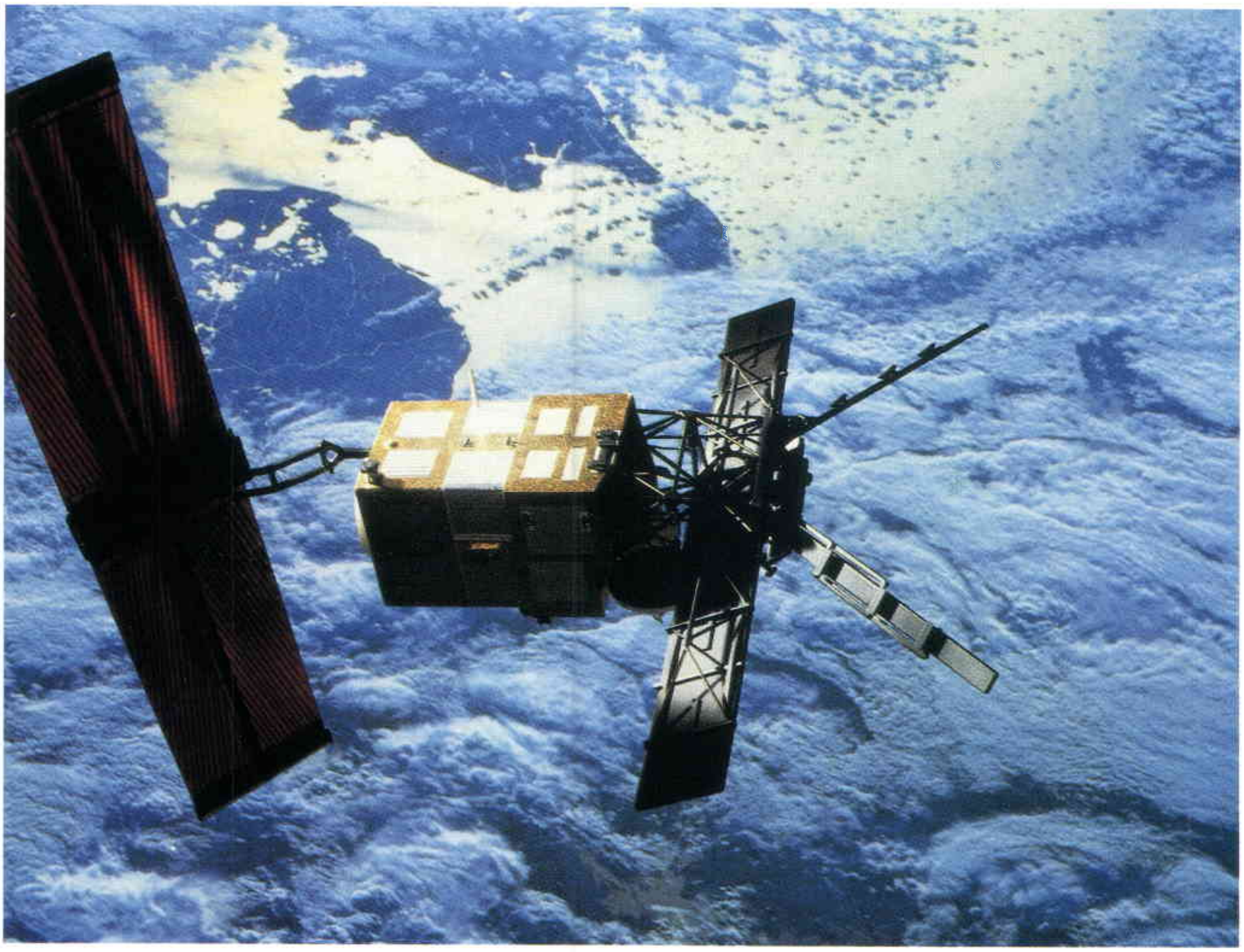




Spain at a glance

In 1992, Spain's international scope will be greatly enhanced, thanks to the Direct Broadcast Service antenna aboard the HISPASAT.

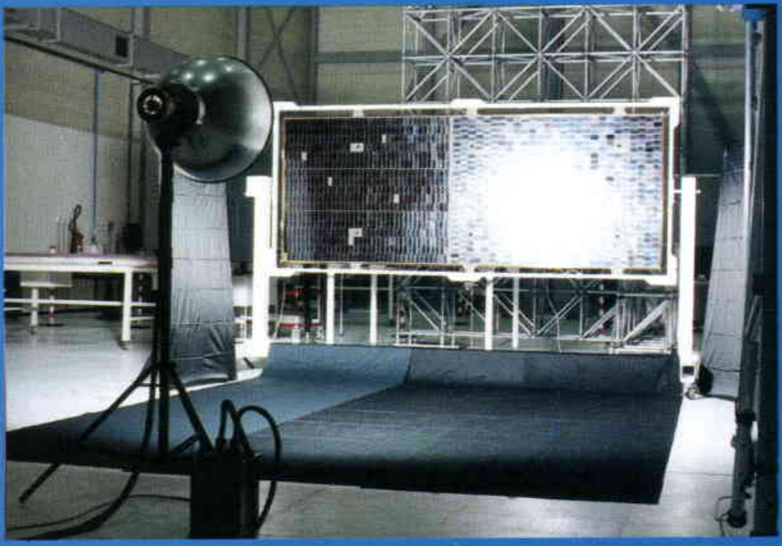
The DBS antenna was developed at CASA Space Division using the most advanced technology.

For the first time, Spain flies a telecommunications satellite that carries all the very best of CASA aboard.

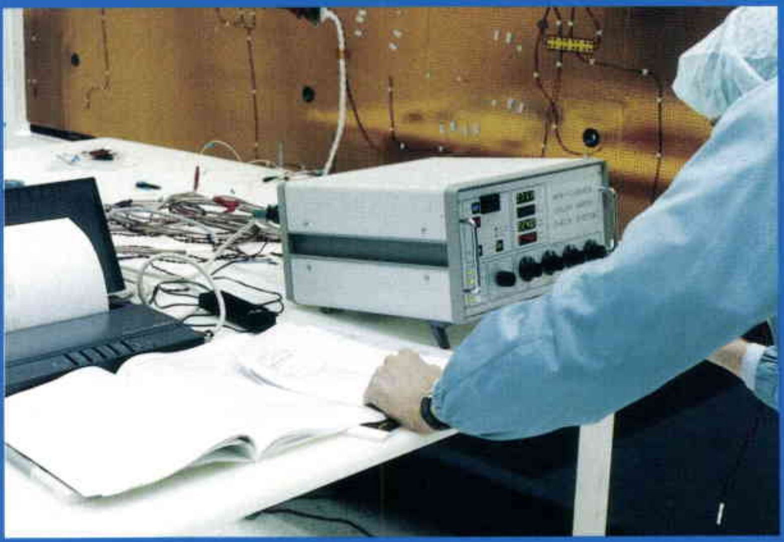
CASA has adopted a strong commitment for future missions, continuing to meet the challenges of the space age.

Mini Flasher

Solar Array Test System



The mini-flasher test system provides the Satellite manufacturer with a quick and simple means of obtaining a comparative performance check of solar arrays of varying sizes after they have been tested or transported from one location to another.



The system consists of a measurement sub-system and a photo-flash sub-system. Additional baffles and mats are provided to reduce unwanted reflections or uncontrolled light sources reaching the array under test.

The development of the Mini-Flasher was done in accordance with specifications generated by the European Space Agency.

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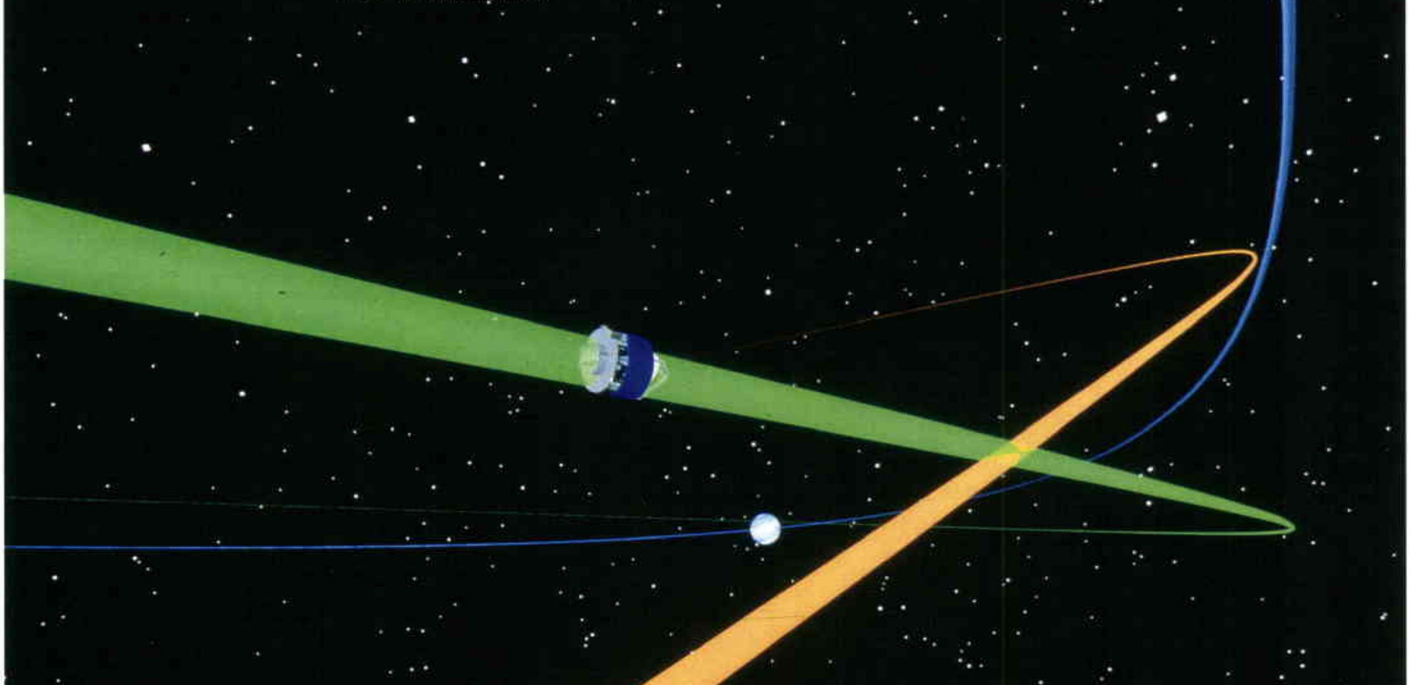
Satellite Services BV *Turning Visions into Reality*

Giotto's Encounter with Comet Grigg-Skjellerup: The First Results

G.H. Schwehm
GEM Project Scientist, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands



On 10 July 1992, the Giotto spacecraft successfully completed its second close encounter with a cometary nucleus, when it passed within approximately 200 km of Comet P/Grigg-Skjellerup at 15:30 UTC (ground receive time). At that time, the spacecraft was 214 million km from Earth and 150 million km from the Sun.

Giotto's payload had been switched-on during the evening of 9 July, with eight of the original complement of eleven experiments still operable: namely the Magnetometer, Johnstone Plasma Analyser, Energetic-Particle Analyser, Optical-Probe Experiment, Rème Plasma Analyser, Dust-Impact Detection System, Ion Mass-Spectrometer, and the Radio-science Experiment. Together, they provided a wealth of exciting data during this second cometary encounter.

Some 12 hours before closest approach, when Giotto was still about 600 000 km from the nucleus, the Johnstone Plasma Analyser detected the first cometary ions. Between 18 000 and 15 000 km from the comet, both the Johnstone Plasma Analyser and the Rème Plasma Analyser reported what looked like a bow shock or a bow wave, which was much more distinct than had been predicted for such a weak comet. The Magnetometer measurements carried out during this inbound leg of the trajectory could not confirm this finding, but reported exciting wave phenomena not previously seen in a natural plasma. On the outbound leg of the fly-by, however, the Magnetometer saw clear indications of a shock.

The Optical Probe Experiment gave the first indication of Giotto's entering the dust coma some 20 000 km from the nucleus and from its data the first estimate for the encounter distance, of approximately 200 km, could be derived. Together with Magnetometer data, there is good evidence that Giotto passed through the comet's tail-forming region, on the 'dark side' of the nucleus.

At 15:30:56, the Dust Impact Detection System reported the first impact of a fairly large particle, followed by two smaller ones.

At 15:31:02, shortly after the first impact, the spacecraft's High-Gain Antenna appeared to be oscillating slightly around its nominal position. A very small increase in spin rate, by 0.003 rpm, was also observed, while the Solar Aspect Angle readings were fluctuating between 89.26 and 89.45 deg, indicating a nutation of approximately 0.1 deg. This was also recorded by the Radio-science Experiment and is awaiting further evaluation.

The Energetic-Particle Experiment saw clear indications of the particle-acceleration regions and surprising differences in the structures between the Comet Halley and Comet Grigg-Skjellerup encounters. Last but not least, the Ion Mass-Spectrometer also gathered good data, but its analysis is quite cumbersome and complex, due to the low encounter velocity of 14 km/s, compared with 68 km/s at Comet Halley.

Thorough testing of Giotto's Camera on 7 July, 3 days prior to the encounter, could only confirm that its optical path was indeed blocked. On 12 July, however, two days after closest approach, a number of further tests were performed with the Camera's detectors, which provided very valuable engineering and calibration data on the long-term behaviour of charge-coupled devices in space.

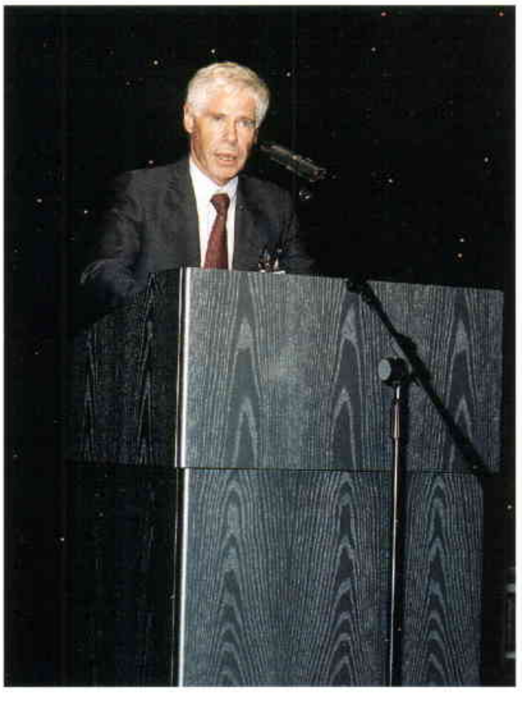
Dr. Heather Couper and Prof. Johannes Geiss hosting the event for the European television audience and for the distinguished guests present at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany

All Giotto Experimenters are extremely enthusiastic about the quality of the data returned from the encounter with Grigg-Skjellerup, which have surpassed all expectations. The outstanding success of the Giotto Extended Mission (GEM), following upon that of the spacecraft's first encounter with Comet Halley in 1986, must be considered one of the highlights of the ESA Scientific Programme to date.

The scientific data from the instruments of all eight experiments that were operating are currently being analysed and the first results will be presented at a special session during the World Space Congress in Washington DC on 30 August 1992. A more detailed account of the mission activities at ESOC, the spacecraft operations, and the science results will appear in the November issue of the ESA Bulletin.

On 21 July, about a week later than previously planned, a major orbit manoeuvre was conducted to put Giotto into an orbit that will bring it close to Earth (220 000 km) again in July 1999. There are still 4 kg of fuel left onboard for further attitude and orbit correction manoeuvres, and this orbit manoeuvre leaves the door open for some further activities in 1999.

After a final orbit trimming manoeuvre on 23 July, the Giotto spacecraft was put into hibernation for the third time.



Prof. Roger Bonnet, ESA's Director of Scientific Programmes, welcoming the audience at ESOC

The main conference room at ESOC, transformed into a television studio for the event

Manfred Grensemann, Project Manager for the Giotto Extended Mission (right) and Howard Nye, GEM Flight Operations Director, keeping a watchful eye on the spacecraft's status. Behind them, Jocelyne Landeau-Constantin, ESOC's Public Relations Officer

Gerhard Schwehm, Project Scientist for the Giotto Extended Mission

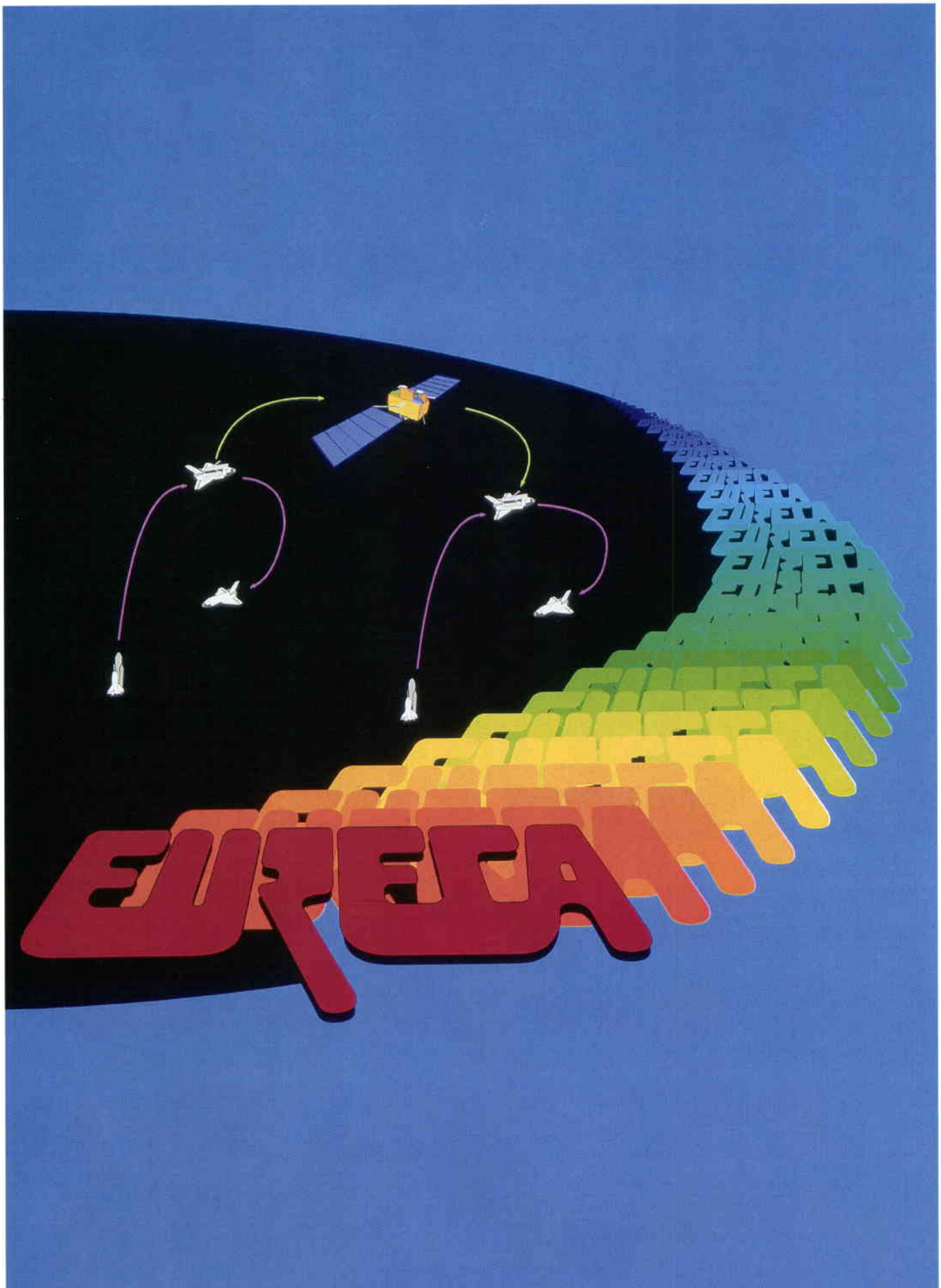
The Energetic Particle Analyser Team discussing their first results

(Top left) Dr. Alan Johnstone, Principal Investigator for the Johnstone Plasma Analyser, explaining his scientific results to his team mate Andrew Coats and to Prof. Hans Balsiger, Principal Investigator for the Ion Mass Spectrometer

(Above) A happy Prof. Anny Chantal Levasseur-Regourd, Principal Investigator for the Optical Probe Experiment, after the successful encounter

The Press Conference in progress after the cometary encounter

A toast to the successful team by Mr Jean-Marie Luton, ESA's Director General (left), Prof. Reimar Lüst, former ESA Director General (centre) and Prof. Francesco Carassa, Chairman of the ESA Council


EURECA

Eureca Data Distribution: A Practical Step towards Telescience

C. Haddow, M. Jones, N. Peccia & E.M. Sørensen
Flight Control Systems Department, European Space Operations Centre (ESOC), Darmstadt, Germany

The European Retrievable Carrier, 'Eureca', is a Shuttle-launched, low-Earth-orbiting platform capable of carrying a variety of independent payloads. More than 50 separate experiments are being conducted in microgravity during its first mission. The data from these experiments are being made available on-line to the mission's Principal Investigators (PIs), at their home institutes, using the dedicated Data Disposition System (DDS) at the Eureca Operations Control Centre. In addition, commanding requests can be submitted by the PIs via an electronic-mail interface. These facilities form the basic elements of a 'telescience' system that allows users to operate their experiments remotely, from outside the mission-control facility.

The Eureca mission

The European Retrievable Carrier (Eureca) is a reusable platform supplying power, cooling, ground communications and data-processing services to a variety of independently operated payloads (see ESA Bulletin No. 70). The first flight model, Eureca-A, was put into orbit from Space Shuttle 'Atlantis' on 31 July. The mission duration will be six months, with retrieval taking place between six and nine months after launch.

Eureca-A1 carries fifteen experimental facilities to support more than fifty individual experiments, most relying on the Carrier's unique micro-gravitational environment. The Carrier is operating at an altitude of about 500 km, in a circular orbit at 28° inclination. It is controlled from ESA's European Space Operations Centre (ESOC) in Darmstadt (D). The prime ground stations are at sited at Maspalomas in the Canary Islands, and Kourou in French Guiana. During the Carrier's deployment and retrieval phases contact is maintained via the Space Shuttle and the NASA communications network.

The spacecraft-control and data-processing tasks at ESOC run on a pair of DEC VAX 4600 computers, the overall system being known as the 'Eureca Dedicated Computer System' (EDCS).

The Eureca-A1 mission differs quite considerably from most missions hitherto supported by ESOC in several respects. One of these is the use for the first time on a space mission of packet telemetry and telecommanding (Fig. 1), based on the Recommendations of the Consultative Committee for Space Data Systems (CCSDS). On-board instruments and subsystems produce so-called 'source packets', which are encapsulated within a 'transfer frame' for downlinking to the ground. Since there is no fixed mapping of packets into transfer frames, the downlink can be used more efficiently than in fixed-format telemetry, and widely differing instrument data rates and packet-generation rates can be supported. A primary header uniquely labels source packets, so that the instrument producing each packet can be identified. For Eureca-A1, some 100 different packet formats have been defined (varying in length from 6 to 64 000 octets).

There are two other particular characteristics that affect both spacecraft/payload control and data delivery:
- Eureca's low Earth orbit, which means that the Carrier is only in contact with the ground stations for very limited periods each day (some 10 passes in total over the two prime ground stations, the average pass duration being about 6 min). The main consequence of this is that Eureca must operate mainly autonomously, i.e. without the continuous commanding and monitoring that is possible for a spacecraft that always remains in contact with a ground station (e.g. a geostationary spacecraft).
- The other is that Eureca is a flying laboratory, with a set of independent payload subsystems. This independence applies equally to the ground segment, as the mission products will be distributed to experimenters' home institutes for

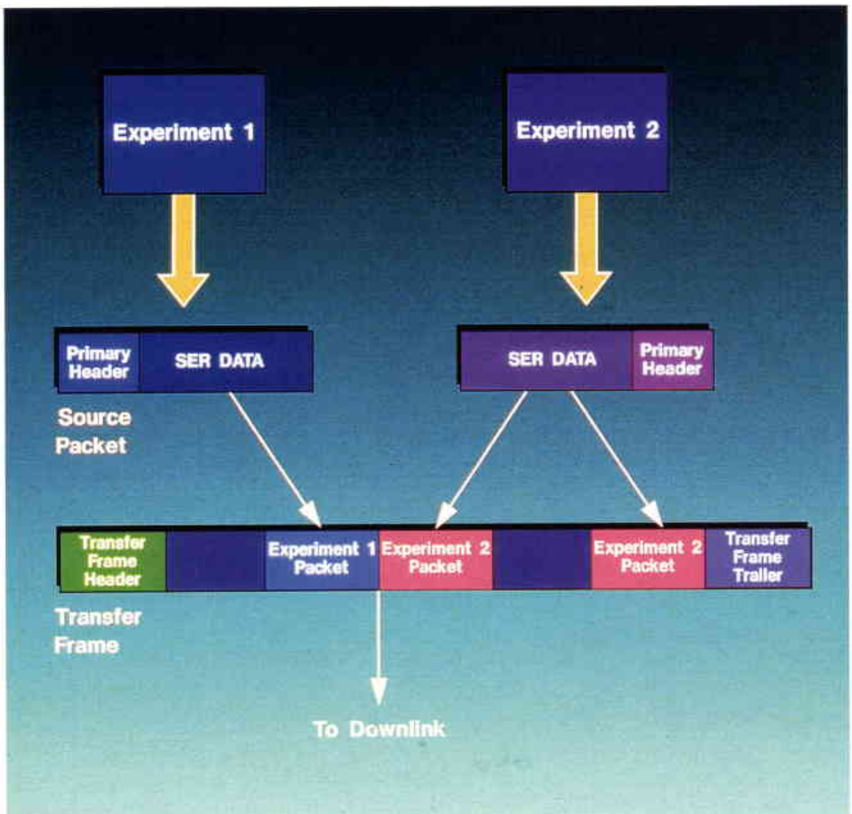


Figure 1. Packet-telemetry schematic

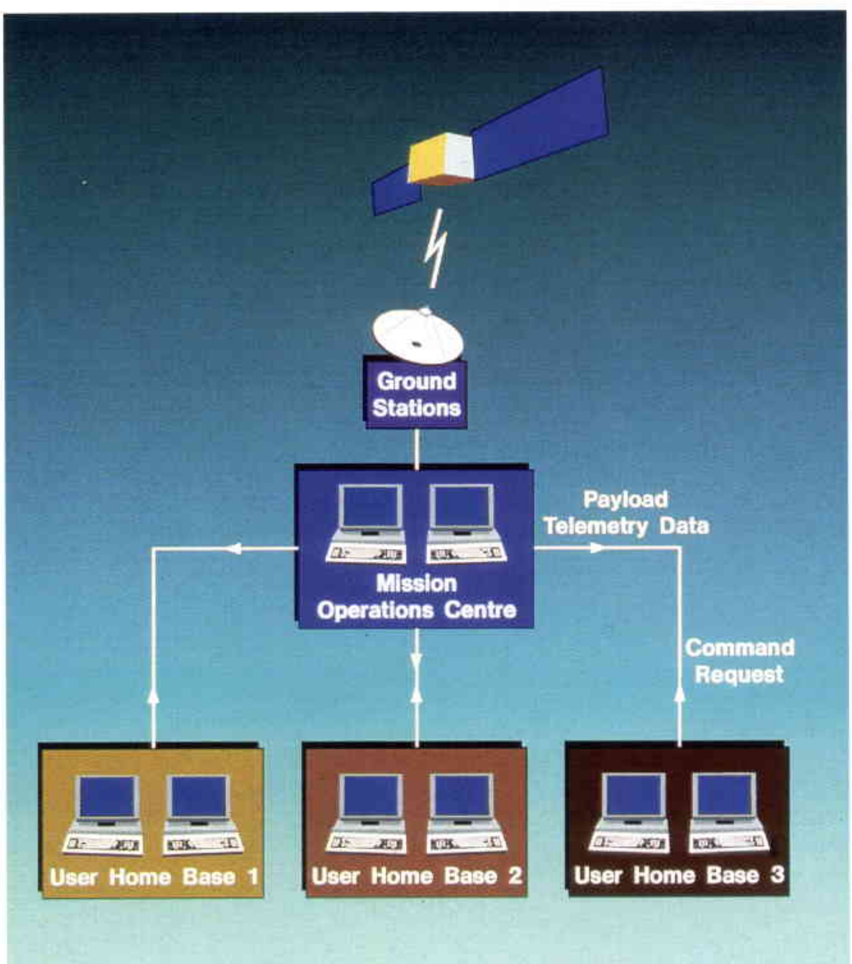


Figure 2. Basic telescience concept

processing. This makes it an ideal case for the application of packet telemetry.

Telescience

For the purposes of this article, the term 'telescience' will be defined as the 'capability of space mission users (e.g. users/owners of payloads) to conduct their operations remotely from a centralised mission-control facility'. The fundamental idea of telescience is to exploit the emerging technology of Open Systems Interconnection (OSI), which allows communication between computers ('platforms') from different manufacturers on the basis of common services or protocols.

Figure 2 shows a general telescience scheme, in which there is a Mission Operations Centre, responsible for space-craft control and monitoring, and a set of remote users at their home bases. In an even more general case, the remote users could be connected to a Payload Operations Control Centre (POCC), which coordinates the remote users and presents a single interface to the Mission Operations Centre. In the case of Eureca there is no POCC as such. In the general case of telescience, users would be able to:
- receive telemetry data from their on-board experiments
- send some form of command request to their experiments.

There are a number of ways in which such a system could be operated. One extreme would be as real-time dialogue, which would simulate direct operation of the instrument from the Control Centre, with real-time displays of payload telemetry parameters and access to manual command facilities (this case could more properly be called 'teleoperations'). At the other extreme would be offline operations, in which data is delivered to users in batches, for example downloaded from the Mission Control Centre overnight, the users processing the data during working hours, deciding on what operations they want for the next day, and transmitting a file of operations requests to the Control Centre.

This article concentrates on the particular approach to telescience adopted for the Eureca mission, which takes into account the constraints imposed by the limited contact between spacecraft and ground.

Eureca data delivery

It was decided early in the Eureca mission system-design process that the payload data would not be delivered on transportable media such as magnetic tape, as was the standard practice for scientific missions in the 60's through to the mid-80's. The comparatively short mission duration, the relatively large number of users ('Principal Investigators') and the decision to have a Microgravity User Centre, led to the choice of electronic means for data distribution.

The following constraints or requirements had to be taken into account in specifying the data-delivery system:

1. Each user receives the data packets from his own payload.
2. Some of the users may only have access to low-data-rate communications lines (9.6 kbaud).
3. 'Off-the-shelf' file-transfer protocols must be used.
4. A variety of user platforms must be supported (DEC/VAX, IBM PC, HP-1000, etc.).
5. Security of the spacecraft control system must be provided, i.e. remote users must not be able to impact operations by, for example, corrupting operational files or causing overloading of the computers.

Constraints 1 and 2 ruled out a system based on the 'broadcasting' of all data to all users. The approach taken is to provide data on request and for this reason the system is called a 'Data Disposition System' (DDS).

The Control Centre's computer systems are DEC/VAX machines and the communications protocols supported are FTAM, DECNET, FTP (for DEC/VAX platforms) and KERMIT (for IBM PCs). This satisfies requirement 3.

The security requirement is met by hosting the DDS on a separate computer from either of the mission-control (EDCS) computers, using a different protocol (i.e. not DECNET or any of the other protocols mentioned above) for communication between the EDCS and the DDS host computer. Data is supplied to the DDS by 'pushing' it from the EDCS, i.e. the EDCS is in control of the transfer, and the DDS cannot directly update any part of the EDCS's storage (Fig. 3).

Data-delivery formats

The driving requirement for the formatting of data on the DDS is the need to handle a large variety of packet sizes (i.e. the source packets and the various units of ancillary data) and file sizes. The number of packets in the various files over a given time span can differ according to the planned operation of the corresponding experiments.

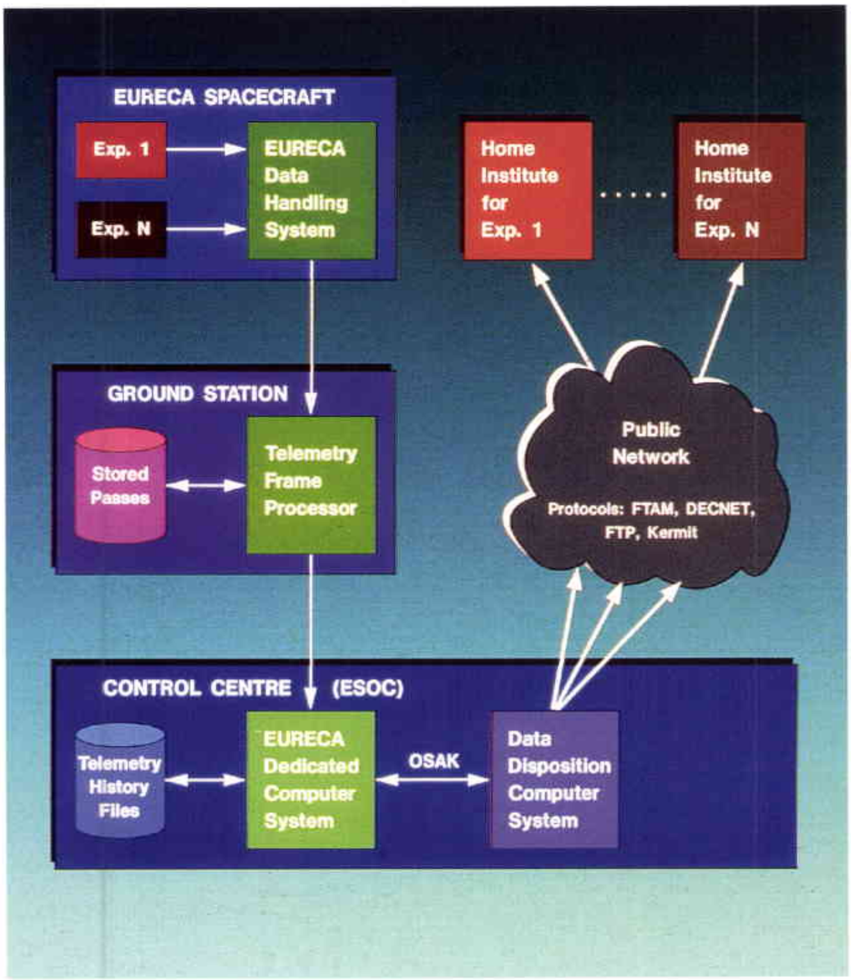


Figure 3. Overview of Eureca Data Disposition System (EDDS)

The particular technique proposed corresponds to an already published CCSDS Recommendation defining and giving construction rules for the Standard Formatted Data Unit (SFDU). A forwards-compatible update to this Recommendation, which considerably extends the power of the technique, has been formally approved and is in press. The SFDU concept has been applied for Eureca in a very simple way, so that the overhead to the users will be minimal, and users can treat the extra label fields involved as 'spare bytes'.

The SFDU concept provides a technical and administrative framework for the handling and exchanging of data descriptions, so that the data can in principle be self-describing. For the Eureca application, the SFDU concept is simply used as a packaging technique, without any computer-processable data descriptions.

An overall schematic of the format is shown in Figure 4, where it can be seen that it is in three parts:
- Acknowledgement: this echoes the request being responded to, and gives other information relating to the request handling, including, if relevant, error codes.

- Catalogue information (giving the date and time at which the data was produced, the name of the instrument producing the data, and other descriptive information).
- The science data itself.

Figure 4 also shows a characteristic of the SFDU concept, that of encapsulation, in which data objects of different types are enveloped together within a single larger object.

The labels all conform to the SFDU standard, and in the form used for Eureca contain a field giving the length of the rest of the object. This has considerable advantage for the science data, where variable numbers of packets can be requested: the length field in the label is then produced dynamically by the formatting software.

Command request handling and mission planning

As mentioned earlier, telescience also involves some kind of capability to send commands or command requests to the user's experiment. Because of the very short contact periods with the ground stations, Eureca operates mainly autonomously, i.e. a command schedule (called a 'Master Schedule') is uplinked from the Control Centre via a ground station during say one pass per day. Operations are then carried out according to this on-board schedule. A further consideration is that on-board resources such as power and downlink capacity are limited. Both of these points mean that operations must be very carefully pre-planned.

A mission-planning system is therefore provided, running on a DEC workstation. This is used to process command requests that users have sent to the DDS computer.

The concept is as follows:
- a complete plan for the entire routine phase of the mission is made prior to launch
- the plan is made in terms of pre-defined operations, which can be translated by the control system into sequences of commands (also pre-defined)
- command requests are received via an electronic-mail interface (Fig. 1). Inputs are in free format on A4 telefax-type forms. Any kind of change to the baseline plan must be described in such a request
- command requests must be received at least 48 h before they are due to be executed.

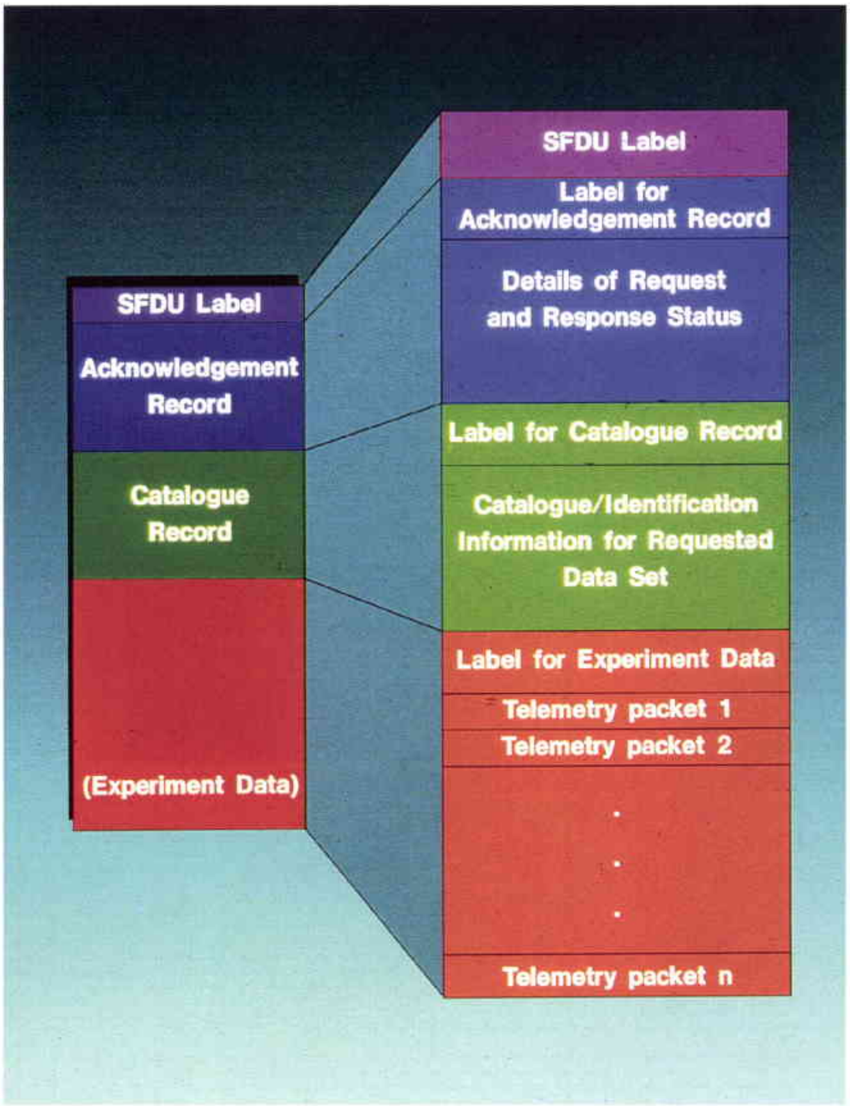
Obviously, considerable restrictions are imposed on the users by the nature of the mission commanding process. Restrictions of one kind or another are, however, likely to be inherent in most missions, with the concept of a user carrying out an interactive real-time dialogue with his on-board experiment from his own office likely to remain a dream for some time to come!

Lessons learned and pointers for the future

The Data Disposition System and the associated command-request handling had been implemented and extensively tested with the users prior to Eureca's launch. As such, it is an example of an operational telescience system, not just a testbed or prototype.

It has been shown that the extent to which telescience can be interactive is limited by the characteristics of the mission, rather than by the underlying communications and computer technology.

Figure 4. Data delivery format

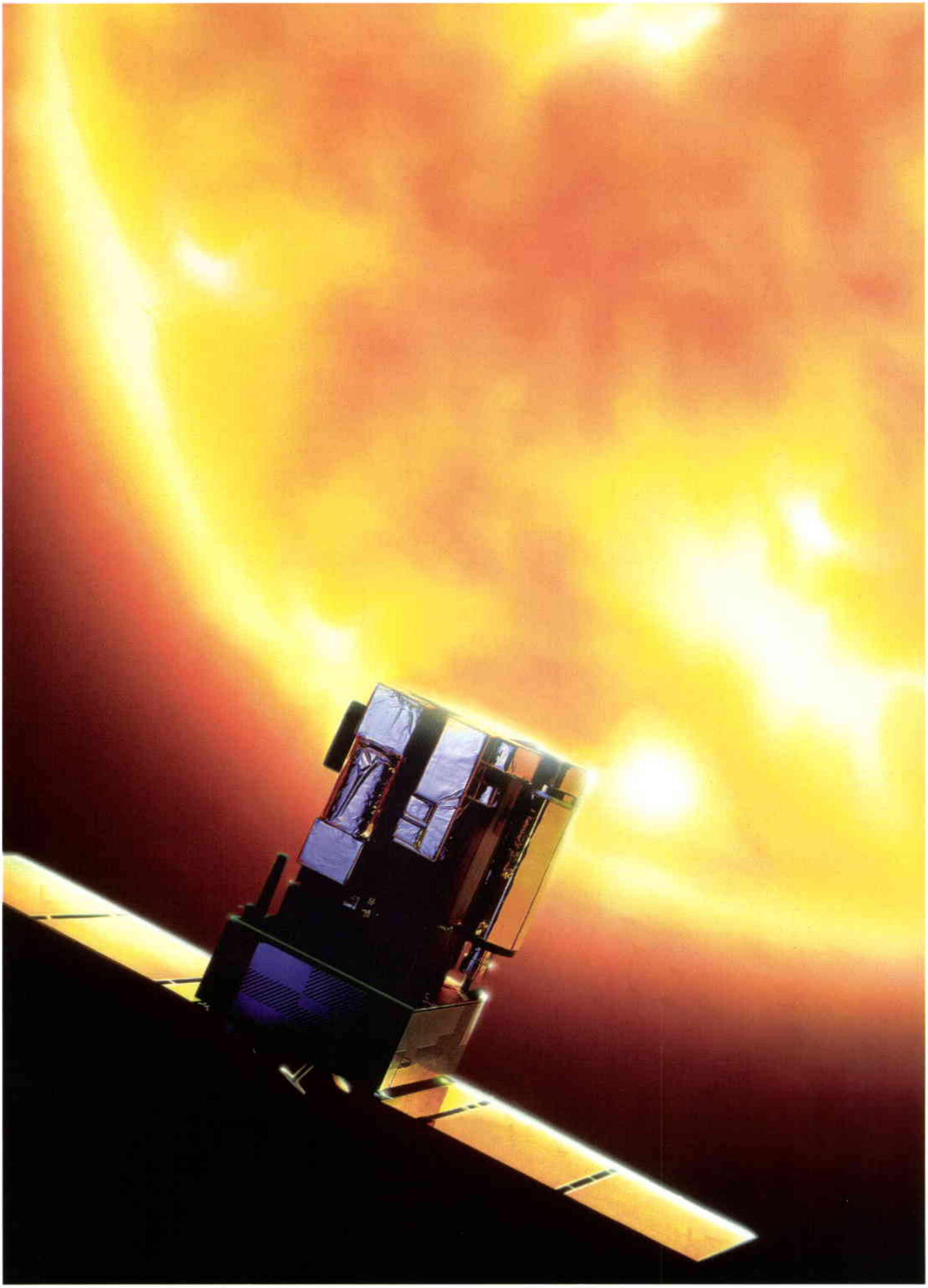


The DDS itself (i.e. the data delivery part) was implemented at low cost, less than a man year being expended in writing the supporting software, and about an equivalent amount being spent on the writing of the interface agreements, and the setting up of hardware and communications.

Tests with the system have revealed that the performance of the spacecraft control computer system (the EDCS) is a bottleneck for data delivery. The problem here is that the functions supporting spacecraft control must take priority over data delivery, for mission-safety reasons. Thus, at times when intensive spacecraft operations are in progress, response times for remote users will increase noticeably, particularly when dumps of the on-board memory are being received from a ground station. This means that there will be a period of an hour or so each day when service to the user will be degraded. Outside this period, however, users can expect to get data within minutes of requesting it (exact time depends on the capacity of the network connection used).

An improved design would have been to route packets in parallel from the ground station to the EDCS and to a separate computer dedicated to handling the DDS. This approach will be pursued for future projects.

It is intended to use a similar approach on the Cluster Project, which is an ESA mission forming part of the International Solar Terrestrial Science Programme (STSP). Cluster consists of a set of four spacecraft, each carrying identical complements of instruments built by Principal Investigators (PIs). As for Eureca, the PIs will be wanting to work from their own home institutes. The approach described here is appropriate. One difference is that the volume of data involved is vastly greater than for Eureca, which makes on-line delivery of all mission data impracticable. The plan is to allow users to request data on-line, but to systematically deliver all data to all PIs on transportable media, CD-ROM being the medium likely to be chosen. It is assumed that only a fraction of the data will be requested on-line.



SOHO – A Cooperative Scientific Mission to the Sun

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The Solar and Heliospheric Observatory (SOHO), together with the Cluster mission, constitutes ESA's Solar Terrestrial Science Programme (STSP), the first Cornerstone of the Agency's Long-Term Programme 'Space Science: Horizon 2000'. STSP, which is being developed in a strong collaborative effort with NASA, will allow comprehensive studies to be made of the Sun, the acceleration and propagation of the solar wind, its interaction with the Earth, and plasma processes in both the solar and magnetospheric context.

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The SOHO mission

The SOHO mission will provide us with a far better understanding of both the Sun's interior and its corona (including its expansion into the solar wind) than has been possible to date. It will allow long uninterrupted viewing of the Sun for the first time, which is essential for optimum operation of SOHO's sophisticated payload.

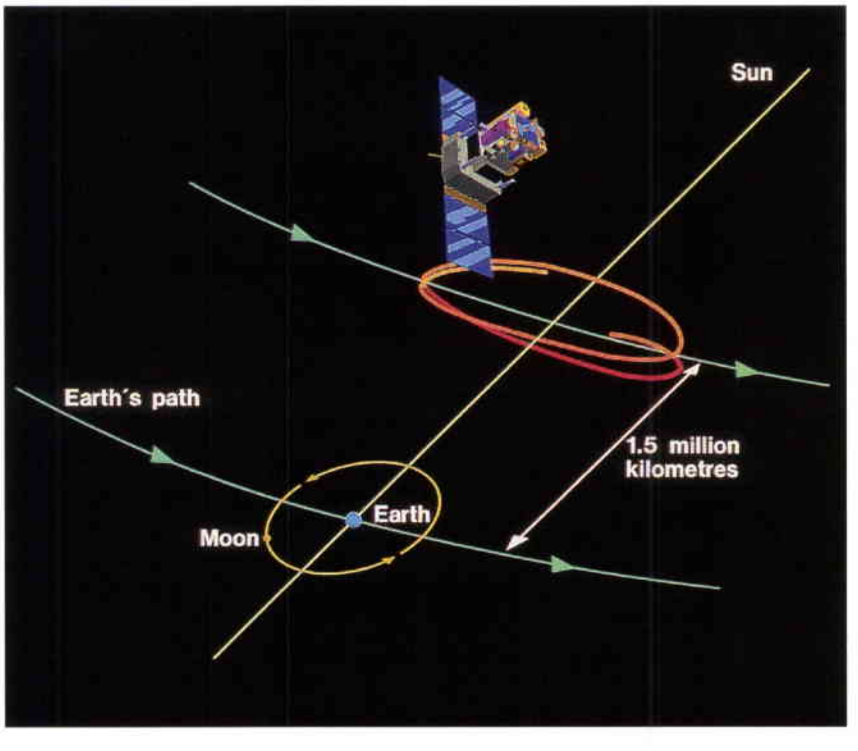

Figure 1. SOHO's halo orbit around the Sun–Earth Lagrangian Point (L1)

The mission addresses three main areas of solar-terrestrial science:

- solar spectroscopy at soft X-ray and extreme ultraviolet wavelengths, i.e. the study of the composition of the solar corona, of the structure and dynamics of the magnetic structures making up the corona, and of coronal holes, prominences, etc.
- helio-seismology, i.e. the study of the structure and dynamics of the solar interior through observation of minute oscillations on the Sun's surface
- study of the solar wind and solar energetic particles, i.e. the study 'in-situ' of the chemical and ionic composition of the particles emitted by the Sun.

SOHO will be operating at a point 1.5 million kilometres from Earth, in an orbit around the Lagrangian point L1, a point at which the gravitational forces of the Sun and the Earth balance one another. In its halo orbit around L1, the spacecraft will remain almost stationary with respect to both bodies. It will therefore be possible to view the Sun from this orbit without the perturbations that adversely affect an Earth-orbiting spacecraft, namely:

- interrupted viewing of the Sun due to eclipses
- frequent upsets in the delicate thermal balance of the scientific instruments and their supporting structures due to the eclipses
- high spacecraft velocities relative to the Sun, which may obscure small variations on the Sun's surface due to solar oscillations.

It is planned to launch SOHO in July 1995 aboard an ATLAS-IIAS vehicle from Cape Canaveral. After a transfer phase lasting approximately four months, the spacecraft will be inserted into its orbit around the Lagrangian point.

At launch, the spacecraft will weigh 1850 kg, more than 600 kg of which will be dedicated to the scientific payload. The spacecraft itself consists of two distinct units: a Service Module, which provides power, thermal control, pointing and telecommunications for the whole spacecraft; and a Payload Module, which houses all of the scientific instruments.

SOHO will have to operate under the most stringent conditions. The spacecraft must be capable of pointing the scientific instruments at the Sun to an accuracy of just 1 arcsec, the angle subtended at the human eye by a small coin viewed from a few kilometres away. For a spacecraft of SOHO's mass and dimensions (3.8 m high, 3.65 m deep and 3.65 m wide; 9.5 m wide with solar array deployed), that is a substantial feat of engineering.

From concept to reality

The SOHO mission was first proposed to ESA by the scientific community in November 1982 and was selected for an assessment study, which was conducted in 1983. Subsequently, a Phase-A design study, supported by both European and American scientists, was carried out between mid-1984 and late-1985.

In November 1985, ESA's Science Programme Committee agreed that SOHO and Cluster could be selected as the first 'Cornerstone Mission' for the Agency's Space Science: Horizon 2000 Programme, provided that both missions could be implemented within the budget allocated to that Cornerstone.

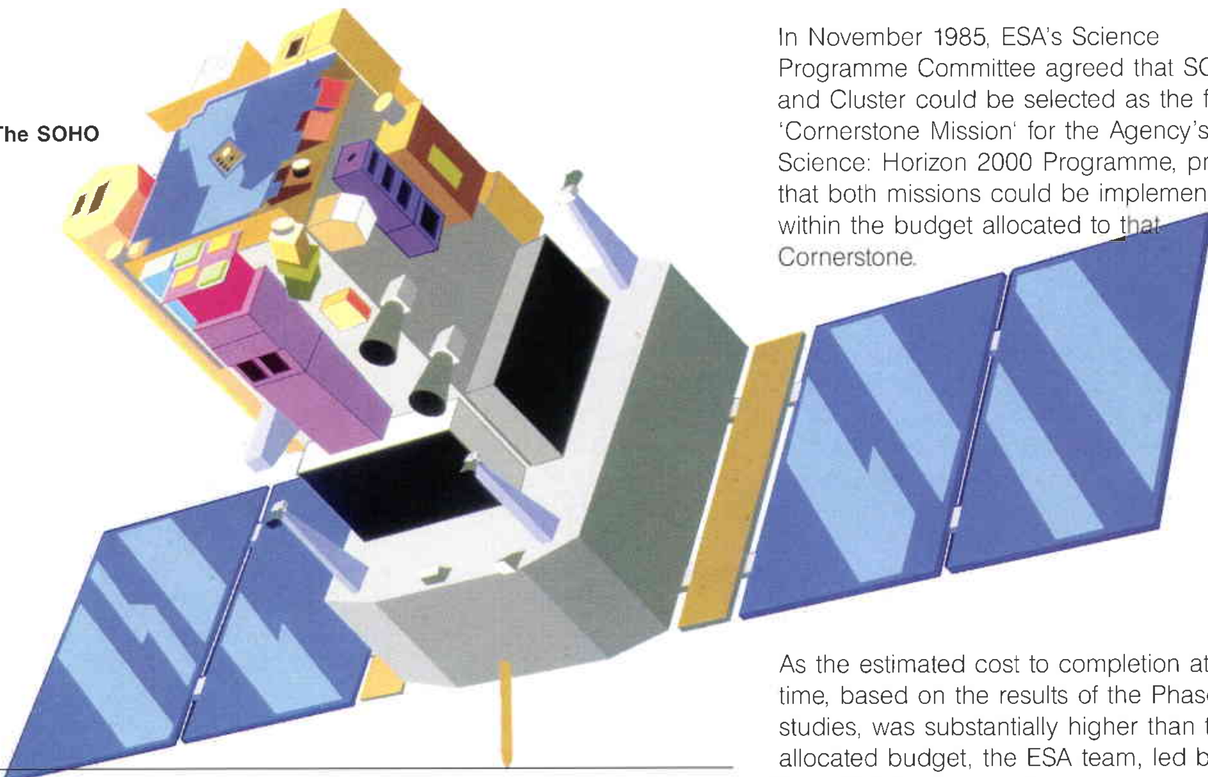

Figure 2. The SOHO spacecraft

Table 1. Main characteristics of the SOHO spacecraft

Launch	Atlas-II AS, July 1995
Launch Mass	1850 kg (Instruments 610 kg, Propellant 240 kg hydrazine)
Attitude Control	Three-axis stabilised, Sun-pointing: 1 arcsec stability over 1.5 minutes 10 arcsec stability over 6 months
Power	1350 W from solar cells 950 Wh from NiCd batteries
Telemetry	S-band 220 kbps down-link 1 Gbit storage capability
Lifetime	2 years
Operations	Deep Space Network (NASA) GSFC Control Centre 48 h autonomy with no ground contact

As the estimated cost to completion at that time, based on the results of the Phase-A studies, was substantially higher than the allocated budget, the ESA team, led by the STSP Programme Manager, re-examined the Programme with a view to descoping and restructuring it such that the allocated budget could be respected.

Since the primary objective was to reduce the ESA programme cost, this re-assessment exercise concentrated on two areas:
- review of the scientific objectives and requirements
- exploration of the possibility of increasing international participation.

As a result of this re-assessment, a viable joint ESA/NASA cooperative programme was arrived at, and a joint Announcement of Opportunity (AO) for experiments to be flown on SOHO was issued in March 1987.

The high degree of sophistication of the experiment proposals received as a result of the AO created serious concerns about

Table 2. Main characteristics of the SOHO experiments

Scientific Objectives	Instruments	Principal Investigators	Measurements
Solar Atmosphere Remote Sensing	Solar Ultraviolet Emitted Radiation (SUMER)	K. Wilhelm, Max Planck Institute, Germany	Plasma flow characteristics
	Coronal Diagnostic Spectrometer (CDS)	B.E. Patchett, Rutherford Appleton Laboratory, UK	Transition region and corona temperature and density
	Extreme-Ultraviolet Imaging Telescope (EIT)	J.P. Delaboudinière, IAS/CNRS, France	Evolution of chromospheric and coronal structures
	Ultra-Violet Coronograph Spectrometer (UVCS)	J.L. Kohl, Smithsonian Astrophysical Observatory, USA	Electron and ion temperatures, densities and velocities in corona
	Large-Angle and Spectrometric Coronograph (LASCO)	G.E. Brueckner, Naval Research Laboratory, USA	Structures evolution, mass, momentum and energy transport in corona
	Solar-Wind Anisotropies (SWAN)	J.L. Bertaux, CNRS, France	Solar-wind mass flux anisotropies and temporal variations
Solar Wind 'In Situ'	Charge, Element and Isotope Analysis (CELIAS)	D. Hovestadt, Max Planck Institute, Germany	Ionic energy distribution and composition
	COSTEP/ERNE Particle Analyser Collaboration (CEPAC)	ERNE: J. Torsti, University of Turku, Finland COSTEP: H. Kunow, University of Kiel, Germany	Energy distribution of particles, energy spectrum and composition
Helioseismology	Global Oscillations at Low Frequencies (GOLF)	A. Gabriel, IAS/CNRS	Global velocity and magnetic-field oscillations (low degree modes)
	Variability of Solar Irradiance and Gravity Oscillations (VIRGO)	C. Froehlich, PMOD/WRC, Switzerland	Irradiance oscillations (low degree modes) and solar constant
	Michelson Doppler Imager (MDI)	P.H. Scherrer, Stanford University, USA	Velocity oscillations (high degree modes)

the cost and schedule risks associated with the programme, and a further Programme Review, with NASA participation, was initiated later in 1987 to rationalise the science requirements, identify cost savings, and remove the major cost-impact uncertainties.

The conclusions of this review were presented to ESA's Science Programme Committee (SPC) in March 1988, together with an acceptable plan of work to achieve an implementation consistent with the available budget. The payload was then selected, and the First SOHO Science Working Team Meeting was held in June 1988.

It has been possible to contain the cost of the Cluster and the SOHO missions, whilst still preserving the validity of the scientific missions, by not only rationalising the technical baselines (e.g. extensive use of on-board data storage), but also implementing a new cost-effective approach to industrial procurement policy. The latter, with support from the Prime Contractors, has been based on:

- maximum use of competitive procurement
- geographical industrial return on an STSP-wide basis, rather than on an individual-project basis
- implementation of joint Cluster/SOHO developments and procurements.

After the issue to Industry of the Invitations to Tender (ITTs), two dedicated Cluster and SOHO Project Offices were created within the ESA Scientific Projects Department, both reporting to the STSP Programme Manager.

Following a positive evaluation of its proposal, Matra (now Matra Marconi Space) in Toulouse (F) was selected as the Prime Contractor. The actual Phase-B start was, however, postponed by a few months, to December 1989, due to some problems with the expected delivery dates for some experiments.

The Phase-B efforts culminated in the Mission System Design Review in May 1991, followed by the start of the Main Development Phase (Phase-C/D), leading to a launch in July 1995.

International cooperation

In response to the mission-consolidation efforts of the scientific communities in the USA and Europe, SOHO was pursued from the outset as a cooperative ESA/NASA mission. This was a logical step, in order to maximise the scientific return by melding the skills, technologies and scientific interests of the two communities. In addition, it made sound economic sense to share the costs of this project in the prevailing climate of reduced budgets and increasingly expensive missions.

The cooperation between ESA and NASA for STSP is covered by a Memorandum of Understanding (MOU), which lays down the framework of the agreement and the basic responsibilities that each agency will undertake. The MOU is not however a contract, and therefore each side agrees to fulfil its obligations according to their own procedures and without exchange of funds; negotiations are the only means for the cooperation to start and to proceed.
Since the MOU is somewhat general, the document that is used in practice to implement the cooperation is a 'Programme Plan', which specifies the undertakings of each Agency, as interpreted by their respective project-management offices, and is supported by an extensive set of interface documents covering all performance, schedule, product-assurance, management and programmatic aspects.

The major contributions to SOHO from each of the Agencies are as follows:
ESA:
- overall mission and system design
- spacecraft procurement and system assembly, integration and verification, including the scientific payload
- coordination of the procurement of eight European scientific investigations (funded nationally) and three NASA-funded investigations.

NASA:
- launch by an ATLAS IIAS vehicle
- mission analysis and flight operations
- provision of tape recorders, S-band power amplifiers and high-accuracy Sun sensors
- three scientific investigations.

The cooperation with NASA involves strong interfaces with several NASA Centers – Goddard (GSFC, housing the NASA Project Office), Lewis (LRC), Kennedy (KSC) and Jet Propulsion Laboratory (JPL) – and with some of their contractors. For such a significant cooperation to function properly, each partner must respect the other as an equal in any decision affecting the established interfaces or the mission implementation.

The second element of the international cooperation is the interface with the scientific community. The ESA Project Team must meet the demanding mission objectives within strict technical, schedule and financial constraints and yet accommodate, as far as possible, the requirements of the twelve scientific Principal Investigators (PIs). These PIs, scattered thoughout Europe and the USA, are responsible in turn for providing extremely sophisticated scientific instruments that rely on state-of-the-art technology, while also subject to the pressure of the technical,

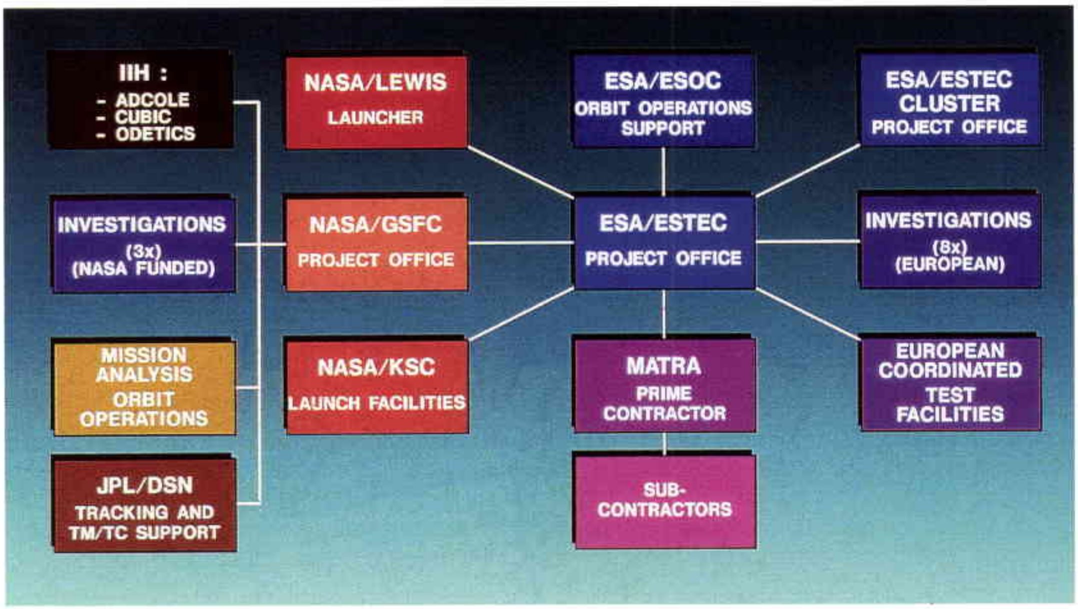

Figure 3. SOHO mission elements

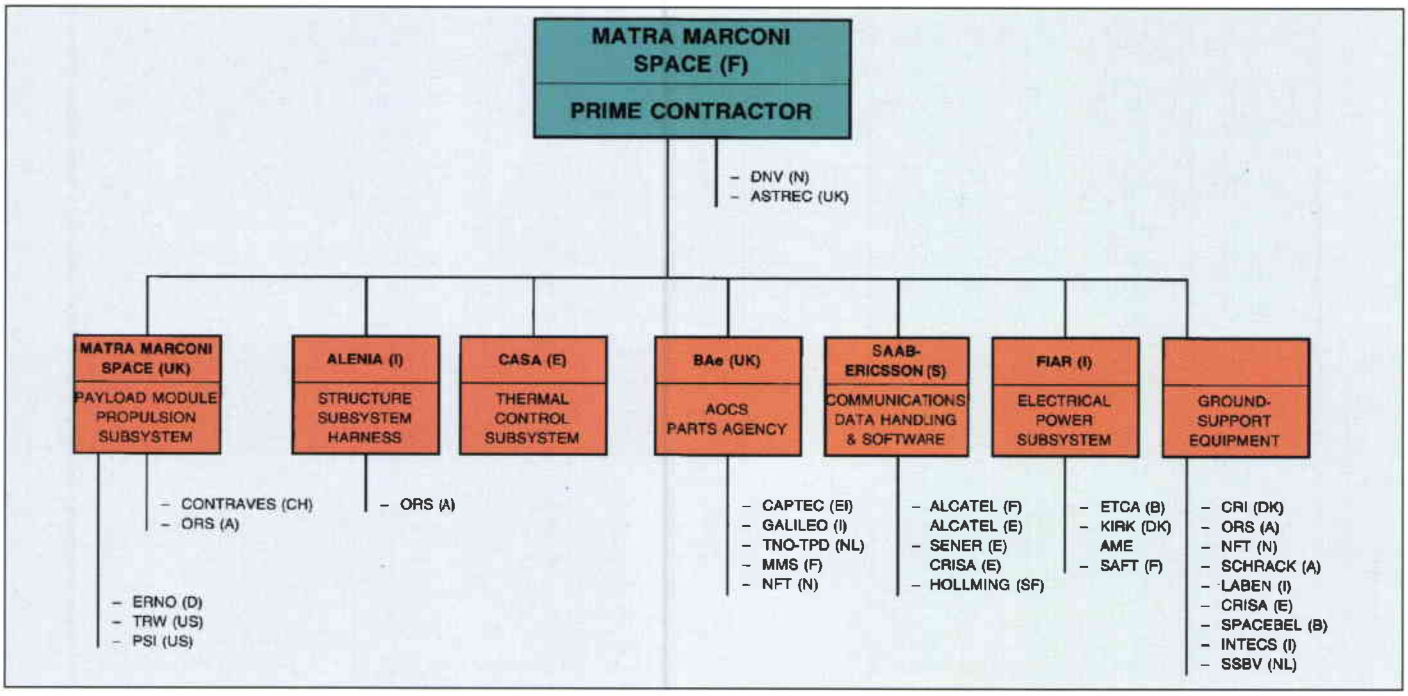

Figure 4. The SOHO Industrial Team

schedule and financial constraints. Again, there is no contractual agreement; accordingly, a good cooperative spirit on all sides is an essential ingredient to ensure the successful implementation of the mission.

The industrial effort

Industry started to be involved in the SOHO mission as early as 1984, when two parallel Phase-A studies led by Matra-Espace (now Matra Marconi Space) and British Aerospace were carried out under ESA contract. Phase-A was completed by the fall of 1985. Industry was then on standby for approximately three years, whilst the international collaboration with NASA was organised and the eleven instruments constituting the payload were selected.

Matra Marconi Space, as potential Prime Contractor for SOHO, started establishing an industrial team in mid-1988, in order to prepare for the competitive ESA ITT. Because the STSP Cornerstone is novel in that it is made up of two missions, the ITT encompassed both. In the event, Matra Marconi Space and Dornier decided to coordinate their industrial efforts, with Matra bidding for SOHO and Dornier for Cluster. The respective industrial teams were based on the same core of companies in order to maximise the commonality benefits to the programme.

This 'core team', which was already in place at the proposal stage, began the Phase-B work once Matra Marconi Space and Dornier had finally been selected by ESA. The full industrial team, including all subsystem contractors and unit suppliers, was built up in the course of Phase-B via a number of Request-for-Proposal (RFP) cycles, culminating with the submission to ESA in November 1990 of the industrial Phase-C/D proposal. The matching of the industrial organisation for the SOHO and Cluster combination with the geographical-distribution constraints imposed on STSP has been quite successful, thanks to the high degree of cooperation between the two projects during the team build-up during Phase-B.

The main development work (Phase-C/D) started in May 1991, and only then was the full industrial team, as shown in Figure 4, deployed. Now, in mid-1992, after more than one year of intensive development work, the industrial effort is at its peak; the SOHO structural and electrical models are both being manufactured. In 1993, these two engineering models will be integrated and tested, in parallel with the manufacture of flight hardware. In 1994, the flight model will be integrated and tested, with its delivery to ESTEC planned for November of that year. The ATLAS-II manifest foresees the SOHO launch for July 1995.

From an industrial point of view, SOHO is a very difficult programme. European industry, however, is well equipped to solve many of the technical challenges, such as the very stringent pointing requirements on the spacecraft, the need for 48 h autonomous operation without ground contact, and the spacecraft's exotic operating location.

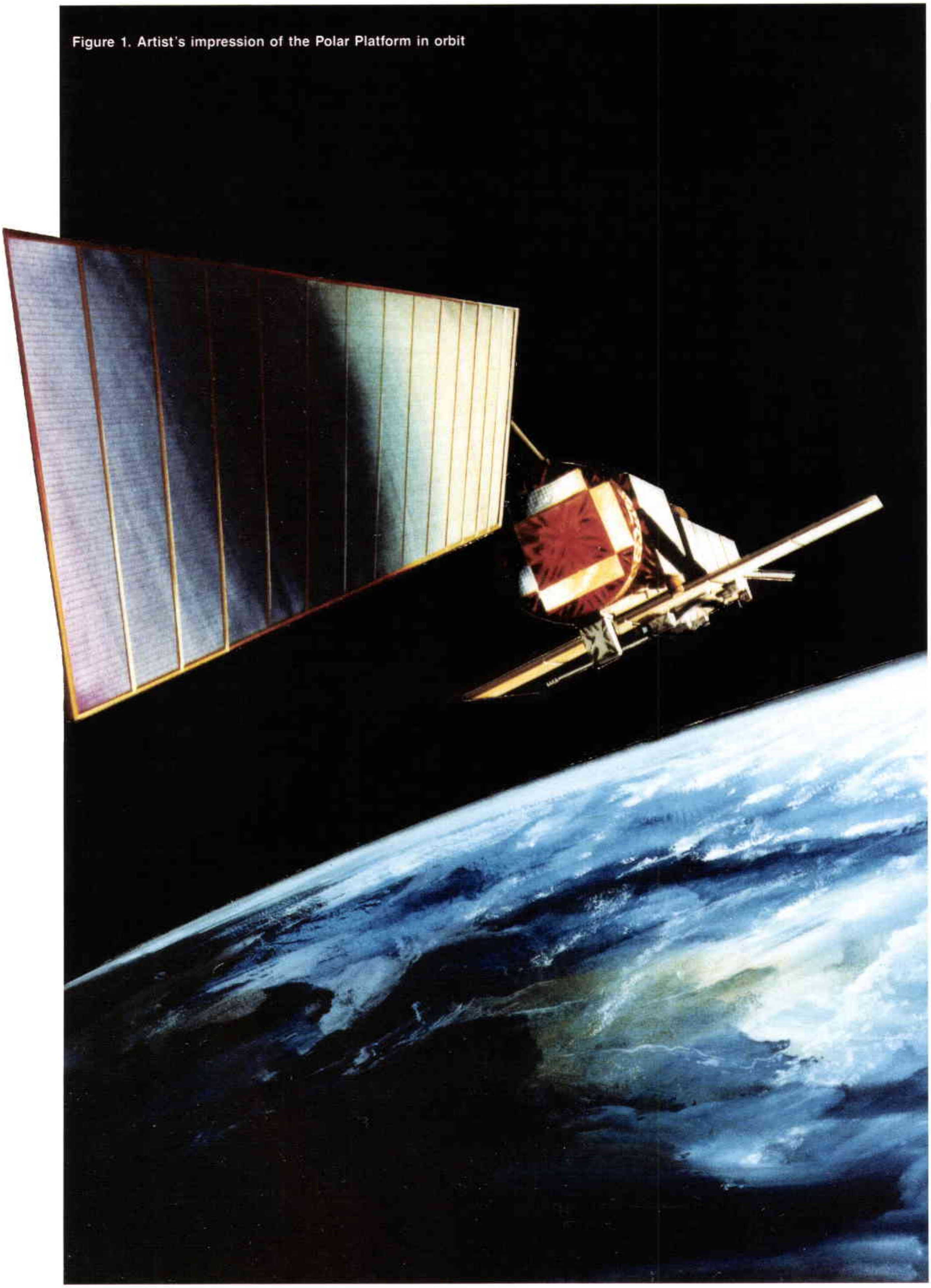

Figure 1. Artist's impression of the Polar Platform in orbit

The ESA Polar Platform

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There is growing concern about the increasing sensitivity of mankind to environmental and climatic change. Consequently, environmental issues are now very high on the international political agenda. A basic aim in Earth observation must therefore be to respond to this concern and contribute to the resolution of the issues involved by making use of the inherent capabilities and advantages that observing and monitoring our planet from space can provide.

Introduction

ESA has been active in the Earth-observation field since the 1970s. In addition to its long-running and highly successful Meteosat Programme of meteorological observation missions carried out with satellites positioned in geostationary orbit (GEO), the Agency is now making a major contribution to the observation of the globe from low Earth orbit (LEO) via its European Remote-Sensing Satellite (ERS) Programme. The first satellite of this series, ERS-1, launched in July 1991, carries a number of state of the art instruments (see ESA Bulletin No. 65) which are proving highly successful in orbital operation. A follow-on mission, ERS-2, with a more extensive payload complement, is under development for launch in 1994.

The Agency is now endeavouring to provide continuity of this effort for the future through the preparation of follow-on missions and generations of Earth-observation satellites operating in LEO. Comprehensive studies of various types of mission, instrument design and application, and the associated satellite technology, as well as the Agency's experience with ERS, have pointed to the need for versatile Earth-observation platforms able to meet the requirements of future observing instruments, such as flexible accommodation in terms of surface and volume, large power and mass resources, and extensive instrument onboard data-gathering and transmission capabilities.

The ESA Polar Platform presently under development responds to these objectives and will support the Agency's future polar-orbiting missions, starting with POEM-1 which is due to be launched in mid-1998. In addition to forming part of the infrastructure for future European Earth-observation missions, the Polar Platform will also contribute to the worldwide effort, being undertaken together with USA and Japan, to establish a polar-orbiting monitoring system.

Background to the Programme

The ESA Polar Platform is being developed within the framework of the Columbus Programme. Initiated after the ESA Council Meeting at Ministerial Level in Rome in January 1985, it was approved for development at the Hague Ministerial Council in November 1987.

Since then, the essential requirements and design concept have evolved considerably. In particular, earlier Polar-Platform requirements called for serviceability in orbit for the replacement of payload and platform units. The mission and payload-complement requirements were also more ambitious: 30 years in orbit and 4 tons of instruments. Through a series of studies, cost evaluations and iterations with potential users, these requirements were reduced, and during 1989 the Agency performed more detailed design analyses and trade-offs, converging on an implementation relying on maximum re-use of the Spot-4 spacecraft bus design in order to minimise Programme development schedules and cost. Implementation of this design concept, and the associated payload requirements, were agreed by the ESA Council at the end of 1989.

Following a consolidation of requirements in early 1990, and the acceptance by ESA of the industrial proposal for the Platform's main development phase (Phase-C/D), received in October 1990, the development effort has gained momentum and has proceeded smoothly.

The ESA Council Meeting at Ministerial Level in Munich in November 1991 confirmed the continuation of the Programme within the framework of the Columbus Development Programme, consistent with a launch date for the POEM-1 mission based on the Polar Platform in mid-1998.

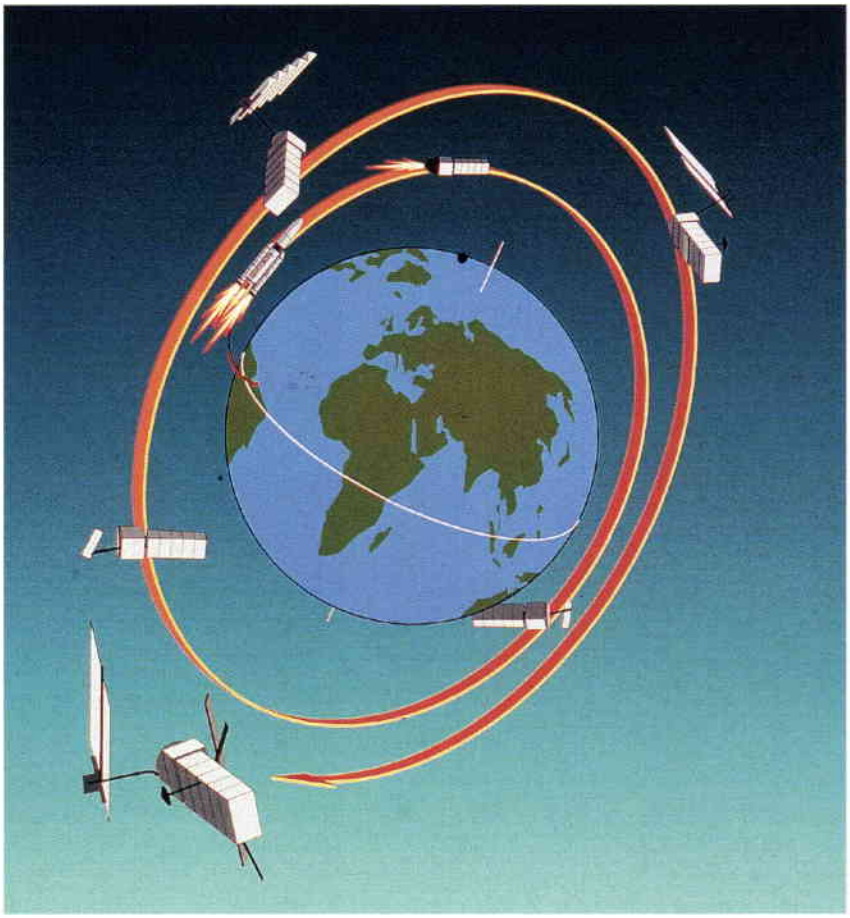

Figure 2. Polar Platform launch and orbital-injection scenario

Mission capabilities and requirements

The ESA Polar Platform (Fig. 1) is intended primarily as a 'workhorse' for future Earth-observation missions in polar orbits. As such, it has to provide a wide range of services and resources to different payload complements for Earth-observation, meteorological and scientific applications.

The Platform will be able to operate in Sun-synchronous polar Earth orbits with altitudes in the range 700–850 km. The phasing of the orbit with respect to the Sun is determined by the local hour at the equator crossing, which can be selected in the range 09:30 to 10:30 for the descending node (so-called 'morning orbits') or 13:30 to 14:30 for the ascending node ('afternoon orbits').

The coverage obtained from this type of orbit allows an instrument to map the entire surface of the Earth in periods ranging from a few days to several weeks, depending on the instrument's swath width (typically 3 days for an instrument having a 900 km swath width).

The Polar Platform's on-board system design and the ground segment used for orbit restitution and control will allow the ground track of the nominal orbit to be maintained to within 1 km and the node local hour to within 5 min.

The Polar Platform will be launched as the sole payload on an Ariane-5 vehicle and injected directly into its nominal orbit (Fig. 2). Launches in the upper position of an Ariane-5 dual launch or as the sole passenger on an Ariane-4 are also feasible for the smaller versions of the Platform (two or three payload-module sections; see below).

The Platform's design lifetime is 4 years, but its degradable materials (thermal coatings) and hydrazine capacity are compatible with a 6 year mission. The current plan is to raise the Platform into a higher 'parking orbit' at the end of its useful life, in order to free its nominal orbit for other missions. This has the added benefit of maximising the decay time to the low Earth orbits that are intensively used by manned missions (around 500 km). The minimum decay time foreseen from this 'parking orbit' down to 500 km altitude is about 100 years.

Payload capability and requirements

A wide range of resources can be provided by the Platform to the payload instruments by exploiting the modularity of its design (Table 1). In general, the payload requirements identified for future Earth-observation missions foresee the combination of a wide range of instruments representing various disciplines and technologies (optical, active and passive microwave). These requirements have been consolidated by ESA based on mission-definition (Phase-A) studies carried out as part of the Earth-Observation Preparatory Programme (EOPP).

In addition to POEM-1, which is presently baselined as the first polar mission, 'Envisat' and 'Metop' are two other possible missions – dedicated environmental and meteorological satellite missions, respectively – which could replace or follow-on from POEM-1. The payload masses and power requirements for all three missions are compared with the Polar Platform's capabilities in Figure 3.

Missions concentrating on operational meteorology as envisaged by the European Meteorological Satellite Organisation (Eumetsat) are also within the Polar Platform's capabilities: the so-called 'Complementary Polar Satellites' (or 'CPSs') in Figure 3. Other possible future European customers include the Western European Union (WEU in Fig. 3), which is also defining a satellite system that could be used to monitor arms-control agreements. The payload requirements for ESA's ERS-1/2, CNES's Spot-1/4, and for Metoc and Globsat, two other possible future missions presently under study by CNES, have been included in the same figure for comparison purposes.

Thanks to its modularity, the Polar Platform can cope efficiently with a wide variety of possible future payloads in polar orbits, as Table 1 and Figure 3 show.

Table 1 — Polar Platform services to the payload

Mounting Surface
Up to 54 m^2 (Ariane-5 configuration)
From 12 to 24 m^2 (Ariane-4 launch)

Mass
From 800 to 2400 kg with different payload carrier lengths

Power

Sunlight average	up to 2.4 kW
Eclipse average	up to 2.2 kW
Peak power	4.1 kW

Data Transmission
Up to 3 Ka-band channels, via DRS, each 50/100 Mbps
Up to 3 X-band channels, each 50/100 Mbps

Data Recording
Up to 4 tape recorders, capacity >25 Gbit
Recording rate 2–4.5 Mbps; replay rate 50 Mbps

Attitude
Pointing: better than 0.1° (3 σ)
Measurement: better than 0.03° (3 σ)

Data Interfaces
Up to 3 high-rate channels, each up to 100 Mbps
Plus 15 low/medium-rate channels, each up to 32 Mbps

Platform design

Overall concept

The Polar Platform concept and detailed design are the logical continuation and extension of the Spot and ERS designs, a heritage that is illustrated in Figure 4. In particular, the Platform's Service Module is derived from that of Spot-4, while its Payload Equipment Bay follows the basic concept and design features of ERS-1 and 2.

The Platform is made up of two major assemblies (Fig. 5): a Service Module (SM) providing the main-support functions, and a mission-specific Payload Module (PLM) on which the payload instruments and payload-support equipment are accommodated. Limited instrument accommodation on the Service Module's external panels is also foreseen.

The Service and Payload Modules are being developed separately, enabling mission-specific payload configurations to be developed as required. Such an architecture allows separate and parallel development and integration of the Platform and instru-

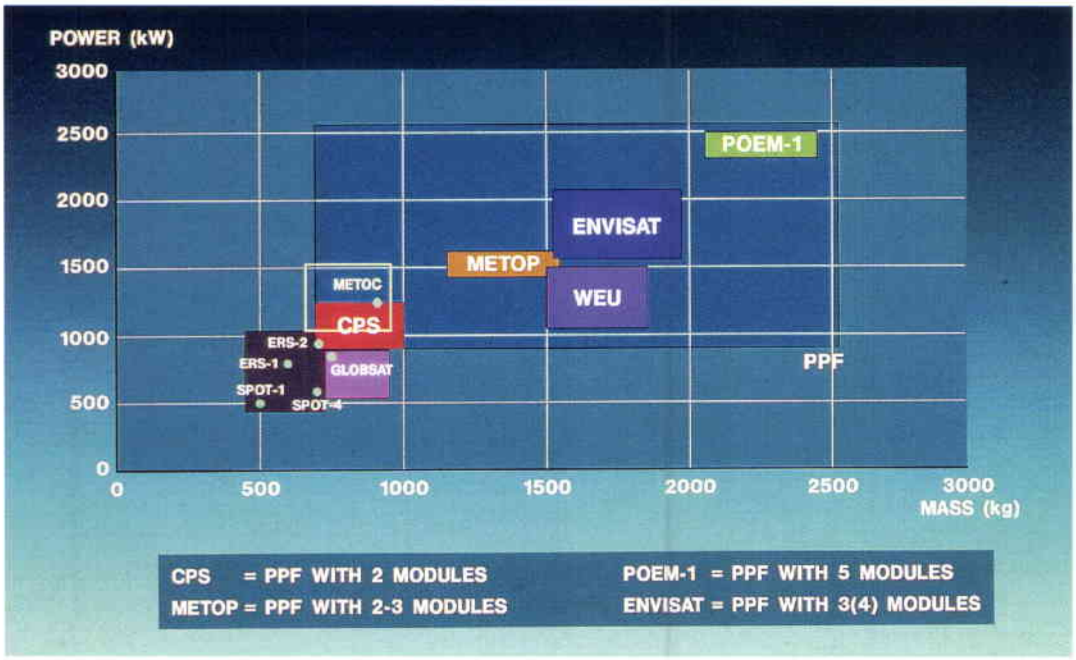

Figure 3. Past and future Earth-observation payload requirements

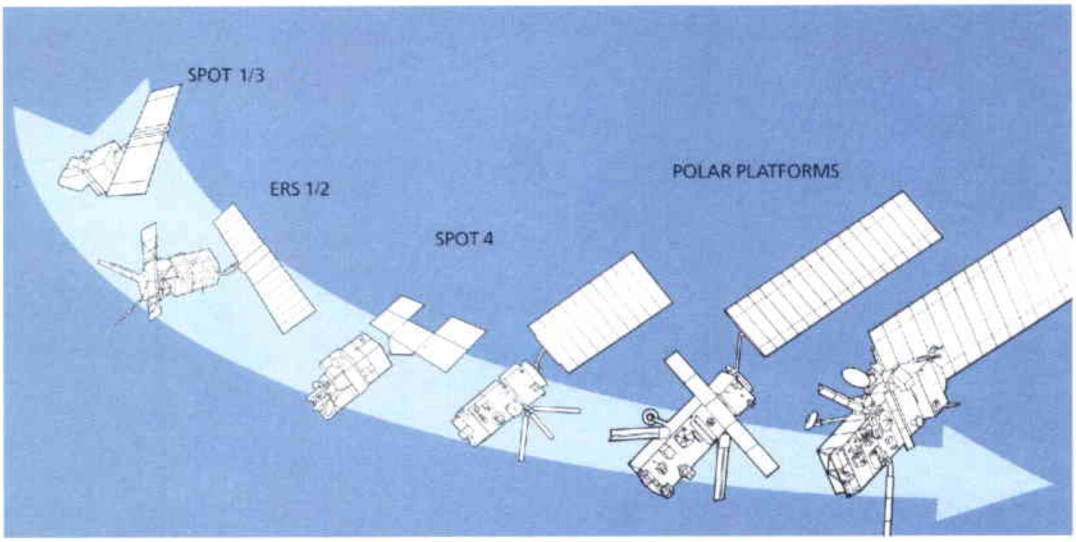

Figure 4. Polar Platform's design heritage

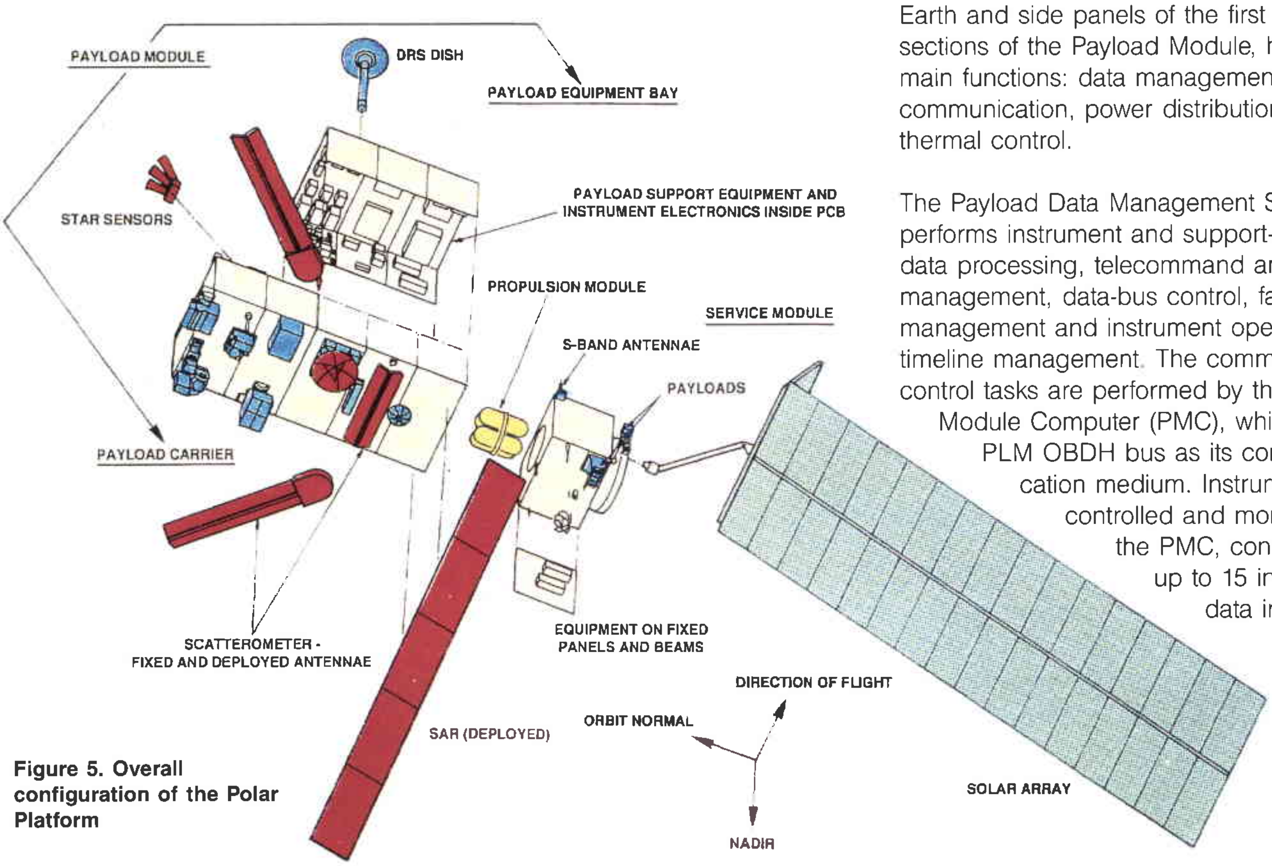

Figure 5. Overall configuration of the Polar Platform

ments, and the interface decoupling between the two results in a shortening of the final spacecraft integration programme. In particular, and in contrast to ERS, the Payload Module has its own computer for instrument monitoring and control.

Payload Module

Physically, the Payload Module can be configured to consist of between two and five sections, depending upon the specific mission requirements (Fig. 6). It is composed of two subassemblies in addition to the payload instruments: the Payload Equipment Bay (PEB) and the Payload Carrier (PLC).

The PEB equipment, installed on the anti-Earth and side panels of the first three sections of the Payload Module, has four main functions: data management, data communication, power distribution and thermal control.

The Payload Data Management Subsytem performs instrument and support-subsystems data processing, telecommand and telemetry management, data-bus control, failure management and instrument operations timeline management. The command and control tasks are performed by the Payload Module Computer (PMC), which uses the PLM OBDH bus as its communication medium. Instruments are controlled and monitored by the PMC, connected by up to 15 instrument data interfaces.

Scientific data generated by the instruments are processed by the High-Speed Multiplexer (HSM) for recording or transmission to the ground. Low-rate scientific data (0–32 Mbps) are routed from the instruments to the HSM to create data streams which are passed on to the recorders or to the Encoding and Switching Unit (ESU) prior to transmission. Up to 15 such low-rate inputs can be accommodated. High-rate scientific data for some instruments (50 to 100 Mbps) are routed directly to the ESU.

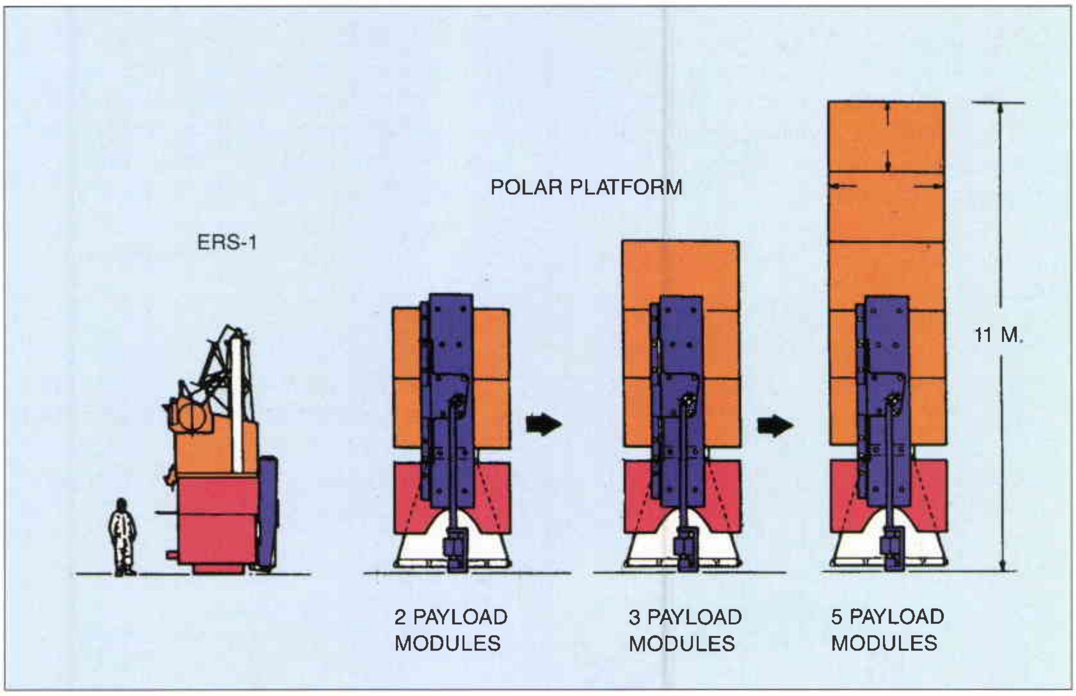

Figure 6. Modularity of the Polar Platform

A bank of up to four tape recorders is provided, each with a recording speed of 2 to 4 Mbps, a replay rate of 50 Mbps and a capacity of at least 25 Gbits.

The communication subsystem for the transmission of instrument-parameter or scientific data comprises an X-band link direct to ground and a Ka-band bi-directional link via ESA's Data Relay Satellite (DRS) or Artemis. The Ka-band communication assembly is a sophisticated system containing both the transmit and receive sections and the antenna tracking assembly. The payload downlinking concept is shown in Figure 7.

There are two Payload Power Distribution Units (PPDUs) and up to 16 redundant unregulated power outlets can be provided for the payload instruments, with ratings of between 200 and 1500 W.

The Thermal-Control Subsystem consists of a Heater Switching Unit (HSU), heaters, thermistors and thermostats operating under PMC control. Instruments mounted on the outside of the Platform are thermally isolated from it and will provide their own thermal control when operating. Instruments mounted inside the PEB and the payload support subsystems are thermally controlled by the Platform's Thermal Control Subsystem.

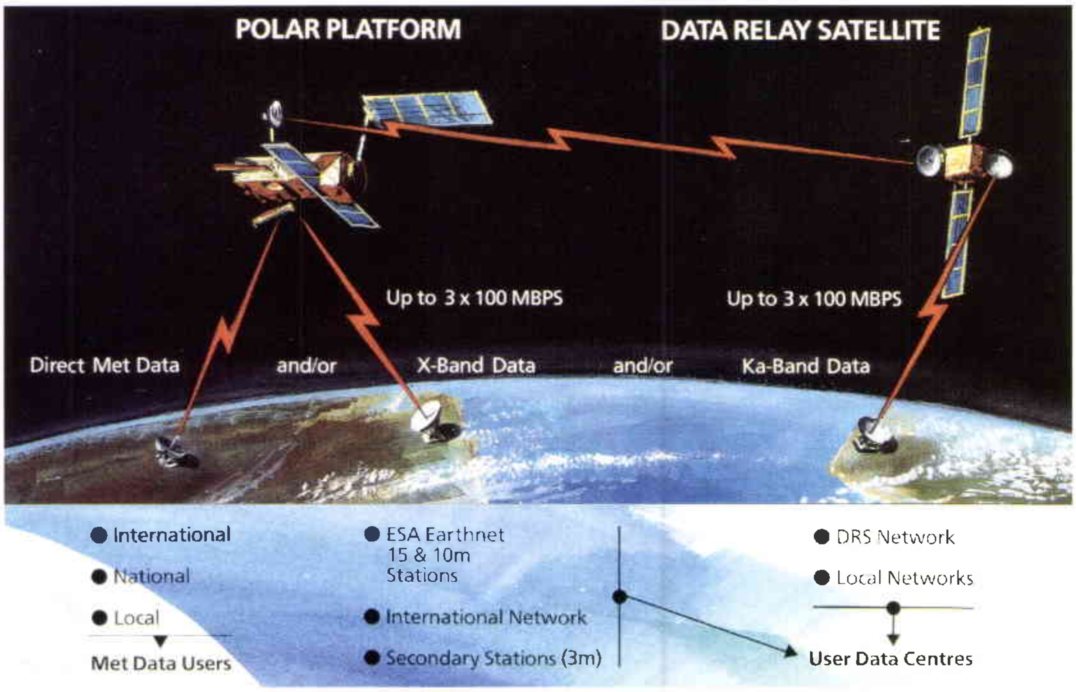

Figure 7. Payload data-downlinking concept

The PLC provides: accommodation and mechanical support to instruments and PEB equipment, the mechanical interface between the PLM and Service Module, and mechanical support for attitude and orbit control sensors and thrusters.

The primary structure of the Payload Module consists of:
- a 1.2 m diameter tube formed by up to five stacked cylinders, each 1.6 m high, giving a maximum height of 8 m; each cylinder is made of a CFRP (carbon-fibre-reinforced plastic) sandwich with metallic honeycomb case (Fig. 15)
- a set of CFRP sandwich panels forming the webs and external faces of the PLM box.

central cone. The external walls are used as a radiative area, the thermal control being essentially passive and complemented by heating elements mainly for the hydrazine system and the batteries.

The propulsion module on top of the cone contains four tanks, which can hold up to 300 kg of hydrazine.

The power subsystem uses up to eight nickel-cadmium batteries (each 40 Ah), and a modular solar array, the most powerful version of which delivers more than 7.5 kW at end of life. Figure 9 shows various stages in the deployment sequence of this solar array.

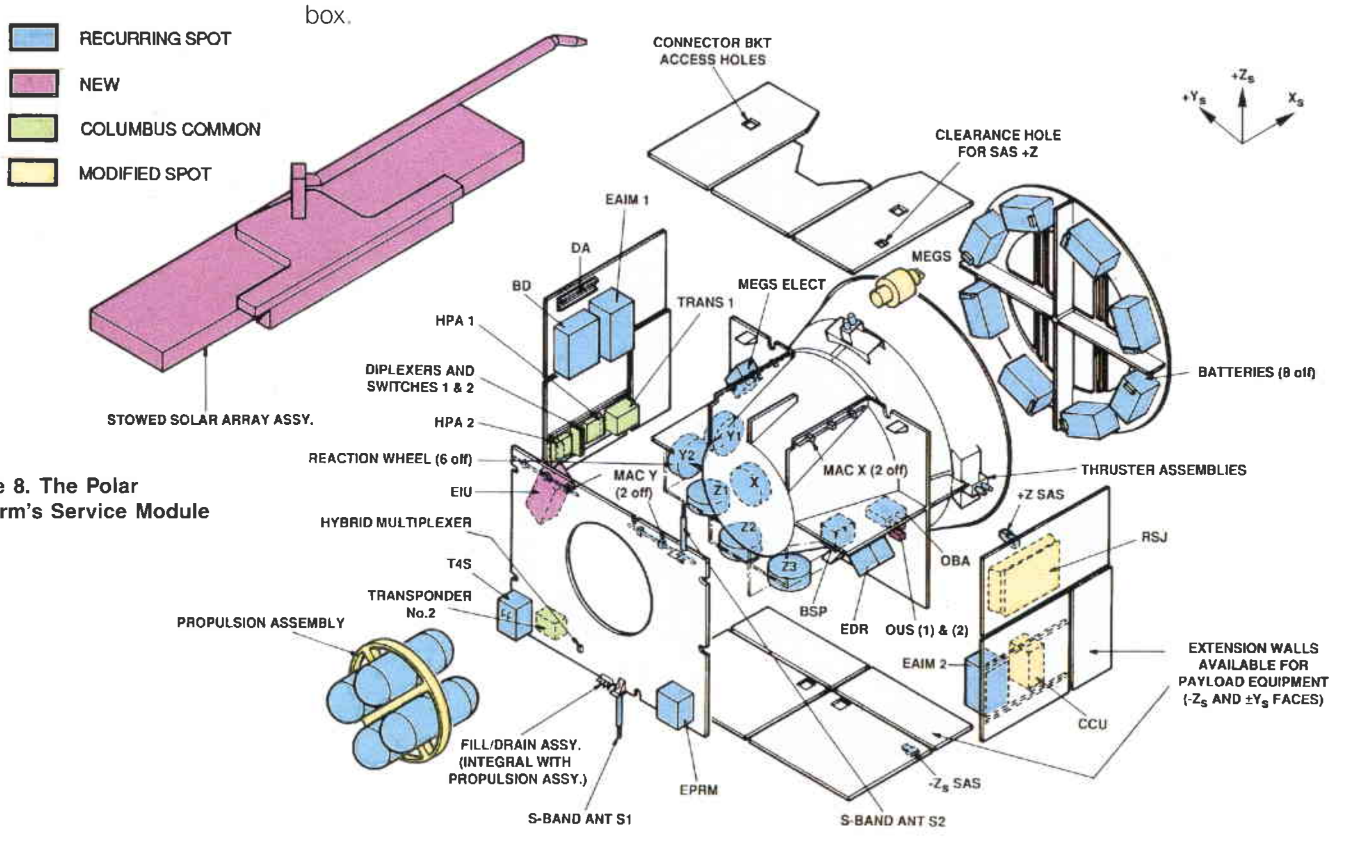

Figure 8. The Polar Platform's Service Module

Service Module

The Service Module's concept and detailed design are based largely on Spot-4. In broad terms, it combines a newly designed structure, thermal-control system and solar array with Spot-4 recurrent or modified hardware, used for the electronic equipment and propulsion subsystem (Fig. 8).

The Service Module is built around a CFRP cone as the primary structure, with the launcher interface at one end and the propulsion module at the other. Both interfaces are made of aluminium. A box-shaped metallic structure, supporting the electronic equipment, surrounds the Service Module's

The Service Module's on-board data management is performed by a Central Computer Unit (CCU) operating through a serial data bus (OBDH-type). Its software handles ground-command processing, telemetry reporting, equipment monitoring and control, time management, attitude and orbit control functions, and interfaces with the Payload Module Computer. The commanding and control functions are performed via S-band communication direct to ground or via the DRS.

The Attitude and Orbit Control Subsystem (AOCS) provides three-axis stabilisation of the Polar Platform body, which remains fixed in

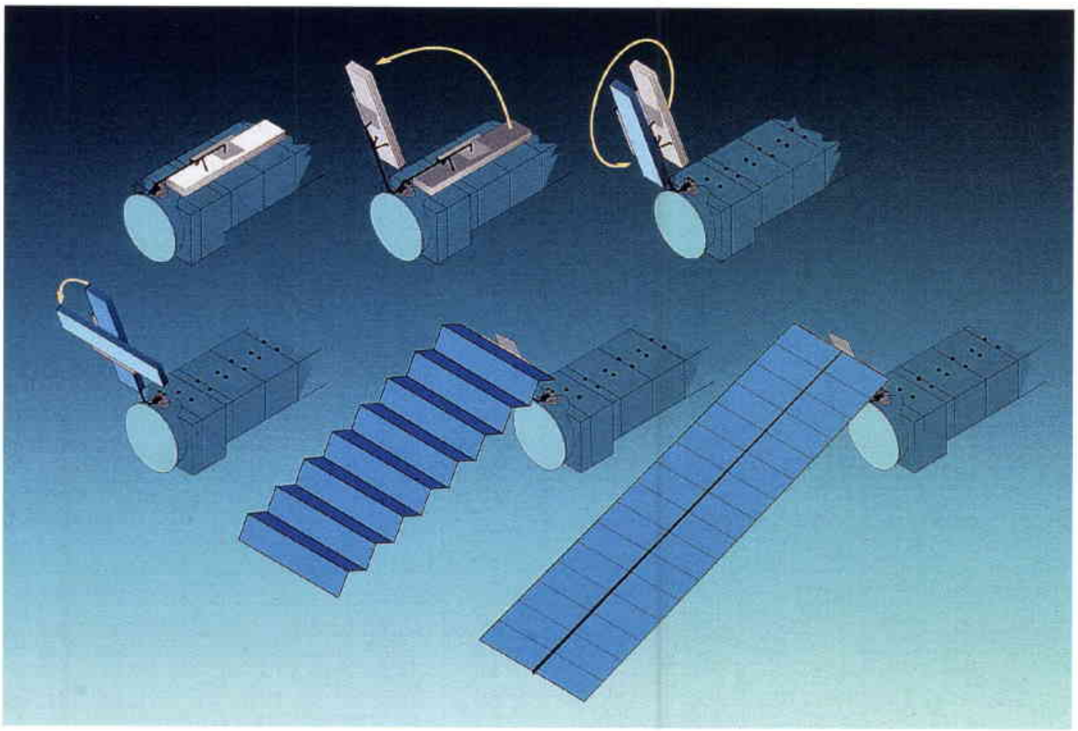

Figure 9. The solar-array deployment sequence

the local orbital reference frame. During initial acquisition, orbit control and back-up modes, attitude measurement is provided by digital Sun sensors, Earth-horizon sensors and gyroscopes, while monopropellant thrusters are used for attitude control. In fine-pointing mode, measurements from star sensors and gyroscopes are used to generate commands to the reaction wheels and magneto-torquers. In the case of moderate instrument pointing-performance requirements, the Earth and Sun sensors can be used instead of star sensors.

To cope with critical failures, the AOCS has a microprocessor-based unit (the so-called 'safe-mode electronics') which uses information from Sun acquisition sensors and gyroscopes to bring the Polar Platform into a safe mode in which the nominal zenith face is pointed towards the Sun.

Design modularity

A modular approach has been used in the Polar Platform's design to enable a wide range of payload requirements to be accommodated within specified basic payload system resource limits (mass, power, data output streams, etc.). This modularity, in turn, allows the Platform's payload resources and physical size to be matched to a specific mission's requirements without recourse to new development and qualification work.

The modular approach also ensures an adequate design margin for each mission. An implied drawback in terms of slightly increased mass and power consumption, because the overall design is not re-optimised for each particular mission, is largely compensated for by the flexibility of response to each particular mission, which results in shortened development times and reduced hardware costs. The greater mounting area offered for payload instruments is also a quantifiable benefit.

The modular approach has also been designed-in at both subsystem and unit level, so that so that a range of performances can be achieved by modifying the number of components rather than changing the basic design.

The propulsion and attitude control subsystem's modularity is driven by the size of the payload. The number of reaction wheels to be flown can be varied as a function of altitude and spacecraft mass properties. The mass of hydrazine is also adaptable through the use of two or four tanks and by varying the fill ratios. The reference attitude measurement system uses star sensors, but if a reduced attitude measurement accuracy is adequate for a specific payload complement a system relying on Earth and Sun sensors only can be flown.

The power subsystem's solar array is designed for the full range of payload power requirements, allowing for growth in discrete steps of two panels (minimum configuration 8 panels; largest configuration 16), to suit the particular payload configuration. The number of batteries and the associated electronics can also be varied from mission to mission (from 4 to 8), and the number and type of power outlets available to the payloads can be changed.

In the payload data-management and communications domain, the number of data-acquisition channels, time/frequency distribution interfaces, tape recorders, and Ka- and X-band downlink channels are all variable within set limits.

The thermal-control subsystem is designed to cope with the full range of orbits, but can also be trimmed for each particular mission.

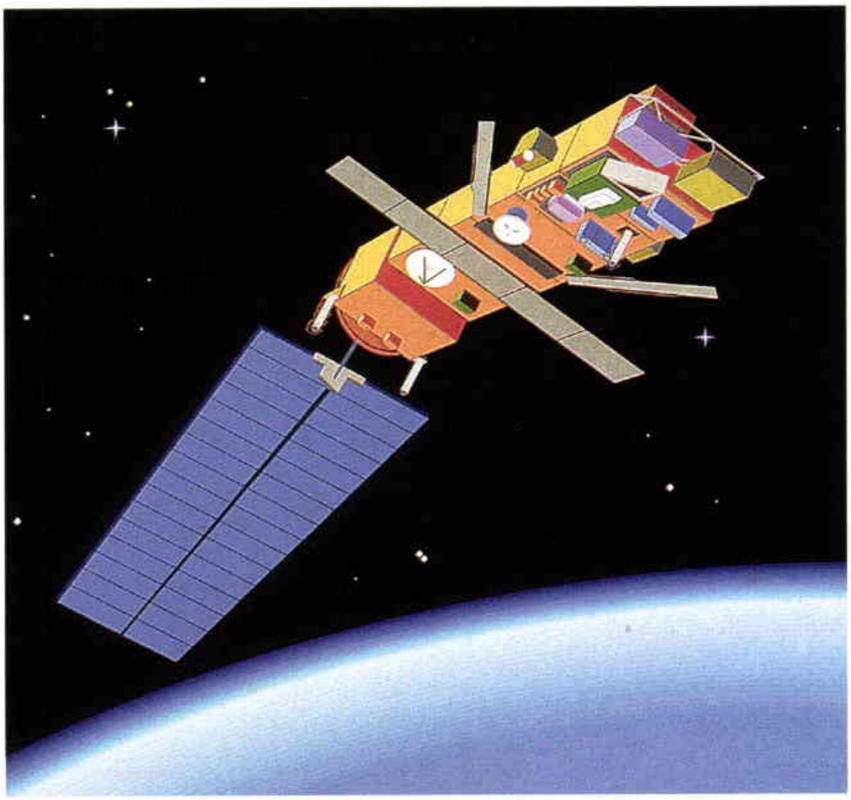

Figure 10. Current POEM-1 concept based on the Polar Platform

Figure 10 shows the most demanding configuration corresponding to the present concept for the POEM-1 mission.

Operations concept

The operations concept for Polar Platform missions is broadly similar to that for ERS-1 and 2, with the addition of the Data-Relay Satellite (DRS) capability primarily for payload data acquisition, but also for telecommanding in specific cases, using Ka- or S-band links.

The Polar Platform will be monitored in real-time within the constraints of visibility through the S-band direct-to-ground link and the DRS Ka-band link whenever the DRS system is used. The S-band link via DRS will also be used. During nominal operations, the Polar Platform will autonomously execute a Master Time Line (MTL) uplinked from the ground approximately once every 24 h, to provide the necessary instrument mode transitions. Orbit maintenance manoeuvres will be initiated from the ground and carried out autonomously.

The Polar Platform ground segment for command and control is derived directly from that used for ERS, and maximum re-use will be made of the hardware and software developed for ERS-1 and 2 and the experience gained with it. The Kiruna (Salmijaervi) S-band ground station in Sweden, elements of the Mission Management and Control Centre (MMCC) at ESOC in Darmstadt (D), and other established interfaces will all be re-used.

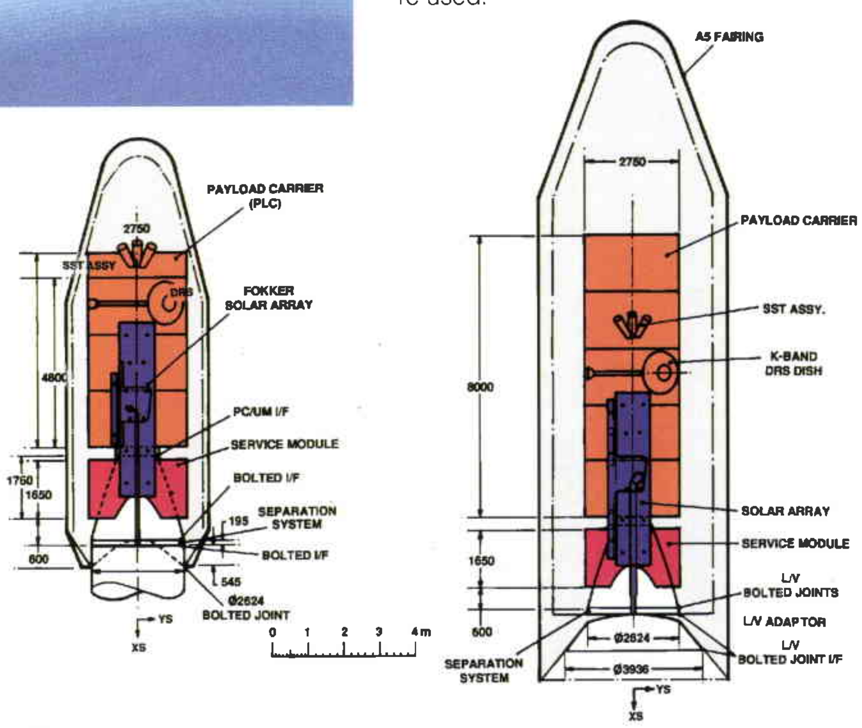

Figure 11. Comparison of Ariane-4 and Ariane-5 launch capacities for Polar Platforms

Launcher interface

The Polar Platform is primarily designed for launch as an Ariane-5 vehicle's sole passenger. However, its modularity offers configurations compatible with a dual launch as the upper passenger on Ariane-5, or with an Ariane-4 launch (Fig. 11).

The Platform interfaces with the launcher via a Launch Vehicle Adaptor (LVA, 2624 mm diameter). The Platform will be bolted to the upper flange of the LVA, which will have a linear charged cord or Marmon clamp-band release device (the final choice will be made later this year), with springs to induce the necessary separation force.

Development and verification

The Polar Platform Programme includes all the development, assembly and test activities necessary to deliver a fully-qualified Platform and payload ready for launch. It also includes a number of features intended to reduce the risks and costs of the development effort:

- The Service and Payload Modules are being developed, integrated and tested in parallel, thanks to their physical and functional decoupling.
- In view of the re-use of Spot-4 developments in the Service Module, several electrical units are already flight-qualified or need only limited modification. This has allowed the Service Module's development to be based on a 'proto-flight-model' philosophy.

The Polar Platform's overall qualification and acceptance is based on three models: two development models, namely a Structural and an Engineering Model, and the Flight Model.

Industrial organisation

The Platform is under development by a consortium of European industrial companies (Fig. 12), led by British Aerospace (UK) as Prime Contractor, with major delegation of development responsibility to Dornier (D) for the Payload Equipment Bay (circa 39% of the work) and Matra (F) for the Service Module (circa 35%). Some 46 major companies are currently actively working on the Polar Platform development programme, corresponding to a work force of about 800.

Current status

The Polar Platform's main development phase (Phase-C/D) has been under way, based on a launch date of October 1997, for the last two years. The Platform has therefore already reached an advanced stage of development, which remains compatible with the revised POEM-1 launch date of mid-1998. In particular, the Agency's requirements have been finalised and the top-level industrial requirements derived from them have been defined and approved. All lower-level specifications have also been issued. A number of Preliminary Design Reviews (PDRs) have been held in preparation for the System Preliminary Design Review foreseen for October.

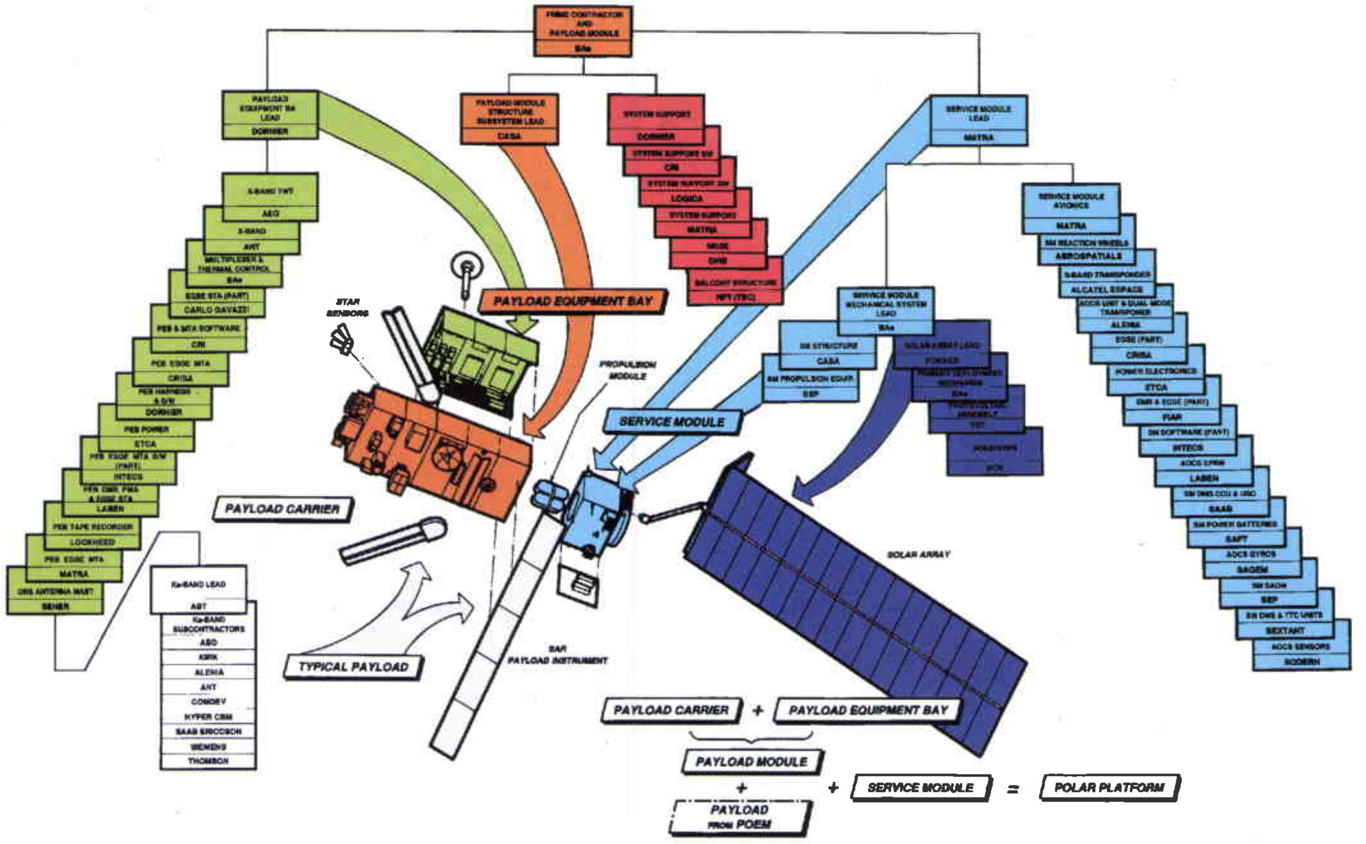

Figure 12. Industrial organisation for Polar Platform development

Figure 13 a-c. Three different Polar Platform configuration models
(a) 5 sections
(b) 3 sections
(c) 2 sections

(a)

A full-scale configuration model has been manufactured for harness routing, handling practice as well as payload-accommodation activities. It is also modular and can be used for smaller versions of the Platform (Figs. 13 a-c). A radio-frequency (RF) model of the complete Polar Platform is currently in final assembly and will be used in the coming weeks for antennae coupling factor measurements.

Because of the solar array's complex mechanical design, a breadboard programme has been started to test its Primary Deployment Mechanism (PDM). A one-third scale model of the complete array has also been manufactured to establish confidence in the secondary deployment system and to test the zero-gravity device concept (Fig. 14).

Sections of the Platform's central cylindrical structure have been manufactured (Fig. 15) to verify the production process. This was considered necessary in view of the size and complexity of the Payload Module structure. The Payload Module panels have also been manufactured to verify thermal-doubler characteristics, including the bonding process, and to check RF shielding effectiveness. The critical attachment joint between the Service and Payload Modules

(b)

(c)

has been successfully tested. Manufacture of the Service Module Structural Model has started.

The design of the breadboard unit for the High-Speed Multiplexer is at an advanced stage and the critical high-speed areas are currently being tested. The results of these tests will be incorporated into the final design for the engineering model, manufacture of which is imminent.

In order to cope with the different utilisation cycles of Spot-4 thrusters on the Polar Platform, a delta-qualification programme has been initiated. A first test phase involving characterisation at 22 bar pressure has already been completed without major problem. Manufacture of the flight tanks has started and procurement of long-lead-time flight thruster items is also in process.

A breadboard of the X-band antenna has been manufactured and tested (Fig. 16) to verify its complex radio-frequency pattern.

Because of the complex packaging of electronics in the Polar Platform, detailed harness routing has been defined using a Service Module mock-up (Fig. 17). Breadboarding of the Payload Power Distribution Unit (PPDU) has also been carried out.

Components have been ordered for the Service Module equipment items and procurement activities are in progress for the Payload Module Equipment.

Figure 14. One-third scale model of the solar-array

Figure 15. Section of the Polar Platform's central cylindrical structure

The status of the Mechanical Ground-Support Equipment (MGSE) is generally well advanced, since it will be required for handling the protoflight Service Module and the Platform's Structural Model. Several Critical Design Reviews have already been held and some items have been released for manufacture.

Given the existing funding limitations, activities throughout the remainder of 1992 will focus on the Structural Model

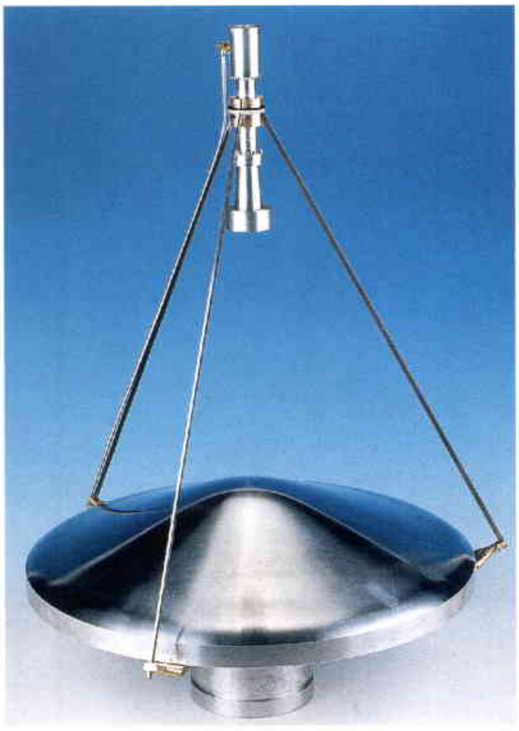

Figure 16. Breadboard model of the X-band antenna feed for Polar Platform

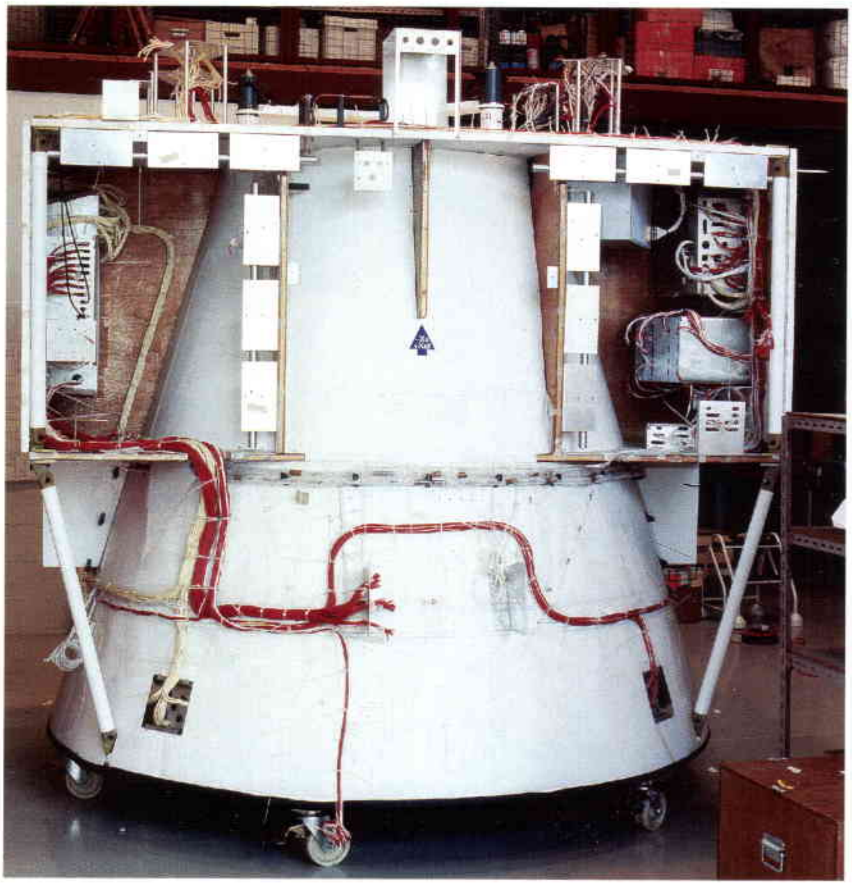

Figure 17. Mock-up of the Service Module, used for harness routing

(manufacture of structure and MGSE) and the flight-model equipment for the Service Module (finalisation of detailed design and start of manufacture of electronic circuitry). The detailed design of the Payload Module equipment will also be finalised in order to initiate engineering-model manufacture.

Payload-related activities

Several payload complements have been studied since 1990 and their feasibility assessed. One such configuration (Fig. 18) includes an Advanced Synthetic-Aperture Radar (ASAR) and Advanced Scatterometer (ASCAT), while another includes ERS-type Active Microwave Instrumentation (AMI). Currently, a configuration including the Microwave Imaging Radiometer (MIMR) is also under assessment.

A Payload Accommodation Handbook has been issued to provide complete interface information to the instrument developers. Considerable effort has been devoted to refining the induced mechanical and electrical environments for payloads. Substantial improvements have been achieved compared with the original specifications.

Conclusions

The ESA Polar Platform requirements and design have converged towards a baseline that represents the outcome of experience acquired throughout Europe in terms of the satellite buses to be used in the future for Earth-observation missions. Its modular design offers ample payload resources for a wide range of Earth-observation missions and can constitute the infrastructural backbone for Europe's future Earth-observation activities, thereby allowing future efforts to focus on the development of payloads rather than on satellite-bus upgrades or redesign.

The re-use of Spot-4 design and equipment elements for the Service Module and the ERS design approach for the Payload Module has ensured a cost-efficient and minimum-risk development approach. Given the Programme's already well-advanced development status and the good results obtained to date with breadboard-model and developmental testing, there is every confidence that the 1998 launch date, compatible with the POEM-1 mission, can be met within the financial envelope foreseen.

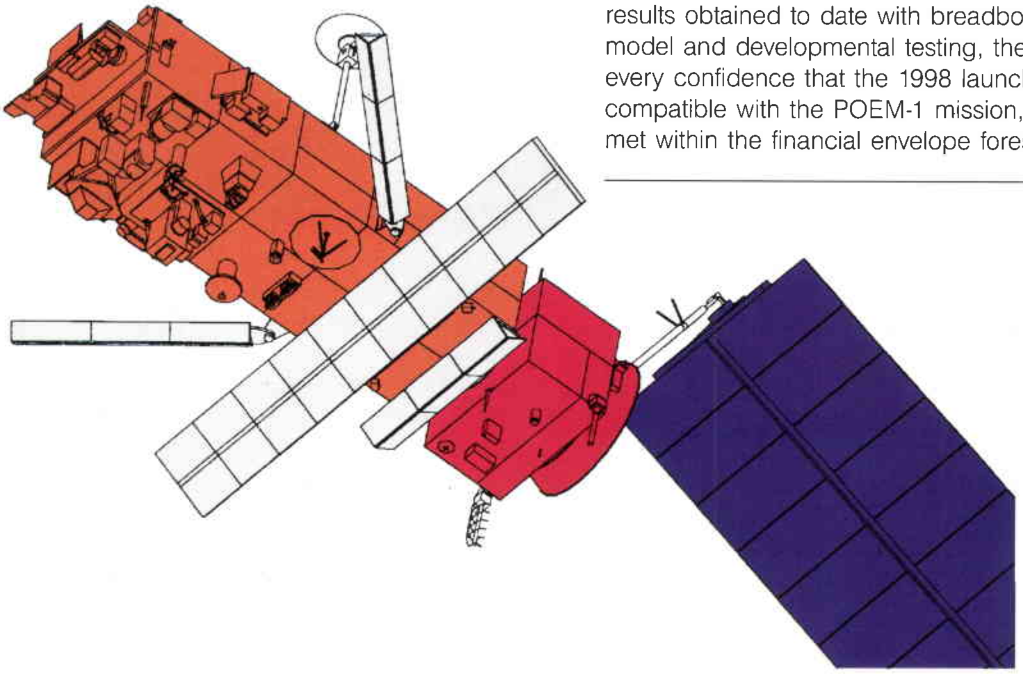

Figure 18. One possible Polar Platform configuration including ASAR and ASCAT instruments

A New Generation of Astronauts in Space – The Astronaut Selection Process

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Introduction

The European Astronauts Selection Board (EASB) met for the first time in June 1989. Its main responsibilities and tasks, as laid down in its Terms of Reference, are to advise the ESA Director General on all matters concerning astronaut selection. The EASB supervised the overall planning and procedures for the present selection and recruitment of astronauts, initiating the Announcement of Opportunity, recommending the selection criteria for the Director General's approval, and finally proposing a list of suitable European Candidate Astronaut applicants to him.

ESA's Council approved the setting-up of a single European Astronauts Corps in June 1989 and as a result the Agency initiated a selection campaign for European Candidate Astronauts. Considerable experience has been gained in the process of this campaign and many lessons have been learnt which will be of great value for future similar selection exercises.

An Evaluation and Interviewing Committee (EVINCO) was then set up by the EASB to conduct and assess the professional interviews. The European Astronaut Medical and Psychological Advisory Group (EAMPAG) was to advise ESA on medical and psychological matters related to the selection process. This group is made up of thirteen specialists in medicine and psychology, appointed by the Member-State Delegations.

EVINCO also appointed three working groups – medical, psychological and 'professional' – to develop the selection criteria. The latter were then reviewed, together with the Announcement of Opportunity, by the Ariane and Columbus Programme Boards, and approved by ESA's Director General.

The pre-selection process

The selection process started officially on 1 June 1990 with a letter being sent by ESA's Director General, inviting each of the 13 Member States and Canada to initiate a pre-selection campaign. In the Announcement of Opportunity, ESA strongly recommended to the Member States that they should use the ESA selection criteria (Table 1).

Although ESA was not itself participating in the pre-selection process, EAC was on call to assist the Member States during this phase. Typical requests for assistance involved detailed interpretation of the ESA selection criteria and provision of information on the availability of special medical facilities, such as the centrifuge or the lower-body negative-pressure device, required to perform the space-specific medical tests.

5494 valid applications were received by the 13 Member States (Canada did not participate in this selection process), reflecting the strong interest on the part of young Europeans in ESA's manned space programmes. 12% of these European Candidate Astronaut applicants were women. 23% were pilots, and the remaining 77% were scientists, medical doctors or engineers.

By 30 April 1991, this number had been distilled to the sixty applicants who were presented to ESA. They included five applicants each from Austria, Belgium, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden and Switzerland, four from Ireland and three each from Denmark and the United Kingdom. Shortly thereafter, one of the UK applicants withdrew and so the final number entering the ESA selection process was fifty-nine.

A questionnaire was sent to each Delegation for two purposes: to collect basic statistics on the pre-selection and to gather comments and recommendations in order to improve future selection procedures.

The ESA selection process

The first part of the ESA selection process was divided into two phases:

- A first phase, from 5 June to 20 July, dedicated to psychological assessment and professional evaluation of the applicants. They were called, in three groups, for the psychological tests at DLR in Hamburg (D) and for the professional/ psychological interviews at EAC in Cologne.
- A second phase, in September and early October 1991, dedicated to general and to space-specific medical evaluations.

The general medical evaluation was performed by:

- DAMEC, Copenhagen (DK), for the candidates from Denmark, Ireland, Norway, Sweden and the United Kingdom
- DLR, Cologne (D), for the candidates from Austria, Belgium, Germany and The Netherlands
- MEDES, Toulouse, for the candidates from France, Italy, Spain and Switzerland, using the CNEMPN facilities in Paris.

This geographical split allowed a good balance to be struck in terms of the number of applicants processed at each location, containment of travel costs, and good harmonisation of results.

For the space-specific medical evaluation, all applicants visited DLR in Cologne. The tests performed there included: centrifuge, lower-body negative-pressure and vestibular-system investigations, and altitude-chamber exposure. The benefits of the centralised solution in this case included well-established investigation protocols, integrated medical support, and proximity to EAC.

Table 1. Summary of selection criteria

General requirements

Applicants may be male or female. They must be nationals of an ESA Member State or of an ESA Associate State involved in an ESA manned space programme. For the present selection, the preferred age range is 27 to 37. Applicants must be between 153 to 190 cm tall. They should speak and read English. Applicants must possess a University Degree (or equivalent) in the Natural Sciences, Engineering, or Medicine, and preferably have at least three years post-graduate related professional experience (for Laboratory Specialist), or possess a test-, military- or commercial-pilot's licence and have at least three years of professional experience (for Spaceplane Specialist).

Medical requirements

Compliance with medical criteria is mandatory. Applicants should have a satisfactory medical history and be in a sound state of health, have a normal weight, and be of normal psychiatric disposition. A severe history of motion- or air-sickness may result in disqualification.

Abnormally high dosages of any medication may be considered a disqualifying factor.

Applicants must be prepared to provide a full family and personal history and permit the collection of further information if deemed necessary by the examining medical body. They must also be prepared to participate in extensive medical screening, including internal examinations. In addition, certain tests will be performed to evaluate the applicant's bodily system (muscular, cardiovascular and vestibular). These tests will employ such facilties as: centrifuges, rotating chairs, pressure chambers, and aircraft. All information provided will be treated as confidential.

Psychological requirements

The objective of the psychological tests is to ensure that the Candidate Astronaut will be able to cope with the expected occupational demands (which they may not have faced previously in their careers) in an efficient and reliable manner. Their activities, during the extensive training phase and during spaceflight, will have to be conducted under a certain degree of stress and in co-operation with other crew members (male and female).

General characteristics expected of the applicant include good reasoning capability and memory, good concentration, and good aptitude for spatial orientation and manual dexterity. The applicant's personality should be characterised by high motivation, good flexibility, gregariousness, empathy with fellow workers, low level of or disposition towards aggressiveness, and sound emotional stability.

Professional requirements

The applicant's scientific and technical background and ability will be scrutinised by the ESA Evaluation and Interview Committee. The Candidate Astronaut must be well versed in the scientific disciplines and have demonstrated superior capability in applicable fields, preferably including operational skills.

NAME	Mr Maurizio CHELI
DATE & PLACE OF BIRTH	4 May 1959 in Modena, Italy
EDUCATION	Studied physics at the University of Rome (La Sapienza). Graduated from the Empire Test Pilots' School in the United Kingdom in 1988
MARITAL STATUS	Single
EXPERIENCE	Since 1978, Mr. Cheli has been with the Italian Air Force where he is currently a professional military test pilot, carrying out operational evaluation of new aircraft and equipment Mr Cheli has logged more than 2200 flying hours, mostly on jet aircraft
HOBBIES	Sports, travel and cycling

NAME	Mr Jean-François CLERVOY
DATE & PLACE OF BIRTH	19 November 1958 in Longeville Les Metz, France
EDUCATION	Engineering degrees: 'Ingénieur Polytechnicien' (Ecole Polytechnique, Palaiseau, France), 'Ingénieur Aéronautique' (ENSAE) and 'Ingénieur Navigant d'Essai' (EPNER)
MARITAL STATUS	Married
EXPERIENCE	Mr Clervoy joined the French Space Agency (CNES) in 1983 as a Systems Engineer. In 1985, he was appointed as an astronaut by CNES. He is currently Head of the Parabolic Flights Programme at the 'Centre d'Essais en Vol'
HOBBIES	Sports, travel, diving, parachuting and flying

NAME	Mr Pedro DUQUE
DATE & PLACE OF BIRTH	14 March 1963 in Madrid, Spain
EDUCATION	Degree in Aeronautical Engineering from Madrid Polytechnic University
MARITAL STATUS	Married, one child
EXPERIENCE	Mr Duque is currently employed as a Software Engineer with 'Grupo de Mecanica de Vuelo' (GMV) at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, in charge of orbit determination for Earth-orbiting satellites; he is a member of the flight-dynamics team
HOBBIES	Diving, cycling and reading

NAME	Mr. Christer FUGLESANG
DATE & PLACE OF BIRTH	18 March 1957 in Nacka, Sweden
EDUCATION	Has a Masters in Physics, Mathematics and Engineering from the Royal Institute of Technology (KTH) in Stockholm and a Doctorate in Experimental Particle Physics from Stockholm University
MARITAL STATUS	Married, two children
EXPERIENCE	Mr Fuglesang worked as graduate student in Experimental Particle Physics at Stockholm University. In 1988, he joined the European Organisation for Nuclear Research (CERN) in Geneva, Switzerland, where he worked until 1990 as a project leader on the particle sub-detector of the CPLEAR experiment. He is curently a Research Assistant at the 'Manne Siegbahn Institutet' in Stockholm, Sweden.
HOBBIES	Sports, sailing, skiing, travel and reading

NAME	Ms Marianne MERCHEZ
DATE & PLACE OF BIRTH	25 October 1960 in Uccle, Belgium
EDUCATION	Doctor of Medicine from the Catholic University of Louvain, Belgium, and has also taken specialised courses in aeronautical, aerospace and industrial medicine. Has a Belgian Air Transport Pilot Licence from the Civil Aviation School in Belgium.
MARITAL STATUS	Single
EXPERIENCE	Ms Merchez has been a General Practitioner since 1985. In parallel, she has co-piloted Falcon 20s and Boeing 737s. She has also worked as a consultant for the European Aviation Training Center (EATC) Ms Merchez has logged more than 1200 flying hours
HOBBIES	Classical music, walking and ballet

NAME	Mr Thomas REITER
DATE & PLACE OF BIRTH	23 May 1958 in Frankfurt am Main, Germany
EDUCATION	Masters Degree in Aerospace Technology (Dipl. Ing.) from the Armed Forces University in Munich. He has undergone test-pilot training at the German Military Flight Test Centre in Manching, Germany
MARITAL STATUS	Married, one child
EXPERIENCE	Mr Reiter trained as a military jet pilot with the US and German Airforces. He is currently at the Empire Test Pilots' School in the United Kingdom Mr Reiter has logged more than 1300 flying hours as an operational military jet pilot
HOBBIES	Sports, playing the guitar and cooking

In the second part of the ESA selection process, the EASB drew up a list of twenty-five applicants for the final interviews, which took place in February and April 1992.

The evaluation

The professional evaluation provided the means for ranking all fifty-nine applicants based on the Interview Evaluation Form by scoring the ESA Professional Criteria, applying the weightings according to applicant category (Laboratory or Spaceplane Specialist), and taking into account the expert advice. The psychological assessment provided additional input for assessing an applicant's suitability.

The mandatory compliance with the ESA medical criteria, assessed during the medical evaluation, reduced the original list of fifty-nine applicants to thirty-two: twenty-seven men and five women.

EVINCO was responsible for the final evaluation, integrating the results from the individual evaluations – professional interviews, psychological interviews and tests, and medical tests – and this was completed on 15 November 1991.

From the list of thirty-two applicants meeting the ESA medical criteria, the EASB pre-selected twenty-five for the final interview. Aspects taken into consideration here included professional suitability and trainability, age and career prognosis, and a fair distribution among Member-State nationals.

The results

The end result of this whole process has been the selection of six European Candidate Astronauts, five of whom are currently having an introductory two months of training at EAC. In August, two of them will be joining the First International Cadre of Astronauts for the International Space Station 'Freedom' and will subsequently undergo the requisite Mission Specialist training for Shuttle missions at Johnson Space Center (JSC) in Houston. The other four Candidate Astronauts will follow one year of classical basic training at EAC in 1993. Thereafter, they will be assigned to future missions such as the Columbus Precursor Flights or possible European MIR missions.

The ESA selection campaign has resulted in a 'European Procedure' for selecting Candidate Astronauts. This procedure has turned out to be thorough but somewhat protracted for several reasons, the two most important being that it represents a first attempt to create a European approach, and the complex nature of the environment in which ESA has to operate. ESA had run an earlier selection process in 1977 for the Spacelab Payload Specialists, but that selection was for a unique purpose and was based on NASA selection criteria. At that time ESA had no intention of repeating the procedure on a regular basis. With some improvements here and there, the newly established procedure should be valid for many years to come.

Another important aspect to be considered is that the new selection was not for Payload Specialists only, but for candidates aspiring to be career astronauts. In other words, the previous selection process concentrated on the candidate's scientific background, while the new procedure is much broader since it must take into account scientific, piloting and operations skills. A further complicating factor is that the selection criteria must be acceptable for manned US and CIS space missions, as well as European. The result is a very stringent set of requirements, especially in terms of anthropometric parameters.

As noted earlier, the European Astronauts Policy respects the wish of the Member States to participate in the selection process by performing a pre-selection in each country. Each Member State was free to conduct its pre-selection in accordance with its own criteria, although the Announcement of Opportunity strongly recommended use of the 'ESA Criteria'. In the event, this pre-selection process took one year (June 1990 to May 1991). Four countries – Austria, France, Germany and the UK – decided not to conduct a special pre-selection exercise, but rather to put forward candidates who had been identified in previous national selection processes.

Table 2 shows some statistics compiled from the responses by the Member States to a questionnaire. The first striking fact is the number of young European professionals interested in space research, with some 23 000 applications being received. This figure includes the Austrian selection in 1988, the German selection in 1986, the selections in France in 1985 and 1990 (not the one in 1980), and the 1989 UK selection. Even the 5494 valid applications after the firt screening is large as compared with the total of 2054 received by NASA for its last selection of 19 astronaut candidates. The distribution between male and female applicants varies

Table 2. Best estimates of applicant preselection

Member State	A	B	CH	D	DK	E	F		I	IRL	N	NL	S	UK	
Preselection in	1988			1986			84/85	89/90						1989	Total
Number of Applicants	230	526	447	3800	250	700	1100	297	406	700	180	400	600	13000	22636
Applicable Files	220	323	117	1799	90	658	715	157	330	352	49	240	294	150	5494
Females	20	27	5	350	7	76	79	4	35	56	10		17		686
Pilots	1	65	29	13	40	124	570	157	106	46			107		1258
Remaining after															
Eval. of Prof. + Med. Files	110	101	39	321	12	150	161	110	242	250	49	90	22	35	1692
Final Interviews	5	7	9	13	3	10	15	18	10	4	5	5	8	4	116
Remaining Applicants	5	7	5	13	3	10	20		10	4	5	5	8	11	106
Females	2	1	0	6	1	0	1		0	1	1	1	1	1	16
Pilots	0	2	1	2	2	4	14		5	2	1	1	3	1	38
Proposed Applicants	5	5	5	5	3	5	5		5	4	5	5	5	3	60
Females	2	1	0	0	1	0	1		0	1	1	1	1	1	10
Pilots	0	1	1	2	2	1	3		1	2	1	1	1	1	17

from country to country, with Swiss females accounting for 4%, and German females 19% (between 10 and 15% in the USA). On average, however, the figure is around 13%.

Table 3 shows the breakdown of the 60 applicants by profession.

Table 3. National applicants grouped by discipline

Country	Pilots	Engin.	Phys.	Info/El.	Med./Bio.	Others	M/F
Austria	0	1	1	2	1	0	3/2
Belgium	1	2	1	0	1	0	4/1
Denmark	2	1	0	0	0	0	2/1
France	3	1	0	0	1	0	4/1
Germany	2	0	2	0	0	1	5/0
Ireland	2	0	0	0	2	0	3/1
Italy	1	2	0	0	2	0	5/0
Netherlands	1	0	2	0	2	0	4/1
Norway	1	1	1	0	2	0	4/1
Spain	2	2	0	0	1	0	5/0
Sweden	1	1	1	2	0	0	4/1
Switzerland	1	1	3	0	0	0	5/0
United Kingdom	1	0	0	0	0	1	1/1
Total	18	12	11	4	12	2	

Total number of applicants: 59 (49 male & 10 female)

Lessons learnt and possible future improvements

In the questionnaire circulated to the Member States, the last two questions were:

- What experience gained during the pre-selection process could be applied in future astronaut selection processes?
- What further suggestions do you have?

The number and variety of responses do not permit a full analysis here, but we can highlight some conclusions drawn from the most relevant ones for future ESA selection procedures, under the three classical headings of medical, psychological and professional:

Medical

There is a general feeling that the anthropometric parameters (mainly imposed for the Hermes seating/environment) are currently too stringent, as they have excluded some professionally good candidates.

Ophthalmology has also been considered very severely by Member States, some of whom have suggested including visual-acuity questions in the medical questionnaire to save time during the pre-selection process.

An important recommendation is that medical tests requiring ionising radiation and/or invasive procedures should not be repeated during the ESA selection if they have already been performed during the Member State's pre-selection processing. To save time and avoid unnecessary tests for candidates, it is suggested also that the selection process start with the most demanding test, namely the 'Coriolis stress test'. Other Member States have suggested starting with an initial medical test such as that for a private pilot's licence.

Psychological
Some Member States have suggested that the standard tests used for the ESA selection process should be made available for their pre-selection process, with the individual countries free to decide on whether or not to use them.

Special psychological tests were used by some Member States which proved to be very effective. As some psychological tests are on the boundaries of psychiatry, it is also recommended that psychiatrists and pschologists be included on the same board.

Professional
In most non-English-mother-tongue countries, the applicant's command of English was tested, but these tests were not highly discriminatory. Some Member States have suggested a clear distribution in the type of candidates sought, in terms of, for example, educational background, experience and, if possible, distribution foreseen in the European Astronaut Corps.

It is strongly suggested that experienced astronauts be included in the selection boards.

Some of the suggestions and recommendations were of a general nature, such as that more time be allowed for the pre-selection and if at all possible the tests should be of a 'go/no go' nature, in order to avoid further questions. A clear distinction between mandatory and optional tests for the pre-selection process was also suggested.

In the original Announcement of Opportunity, the Agency strongly recommended use of the ESA Selection Criteria for the pre-selection process, although each Member State was free to use its own procedures and criteria. The non-adherence to the ESA Criteria by a number of Member States, some of whom made no pre-selection at all, is probably one of the prime reasons for the high percentage of medical rejections (46%) among the fifty-nine 'pre-selected' applicants, reported by the EAMPAG to EVINCO.

The present selection process (preparation, pre-selection by Member States and ESA selection) has also proved too time-consuming, taking in the order of three years from start to finish. By comparison, NASDA's and NASA's last astronaut selection processes each took about eight months.

For future selections, the preparatory process will not be required or can be reduced to a minimum, i.e. a few weeks instead of a year, but even two years is a long time to ask applicants to wait for an answer. Improvements to reduce the combined period of pre-selection and selection could focus on combined or overlapping medical pre-selection and selection, with possibly just one psychological assessment and two professional interviews (one national and one by ESA). Success in this respect would depend on greater overall transparency and better coordination in the selection process between the Member States and ESA, as some overlapping of activities would be required. Ideally, the combined pre-selection and selection process should not take longer than one year.

Conclusion
With the selection of six European Candidate Astronauts, the Agency has given credance to the dreams of thousands of young Europeans who are interested in participating in manned space flight. In a joint Europe-wide endeavour, groups of professionals in medicine, psychology, engineering, space sciences and other disciplines have striven to compile a considered set of criteria, tests and questionnaires based upon many years of professional experience, in order to ensure the selection of the best European Candidate Astronauts.

It is now the European Astronauts Centre's responsibility to prepare and train the six European Candidate Astronauts who have been selected for their future careers, working together with the space scientists and engineers to maximise the return from the European space research and development and operations activities of tomorrow.

Suction-Cup Shoes for Astronauts — A New Method of Foot Restraint

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The search for the ideal type of foot restraint for astronauts to use when performing tasks within a space vehicle has been underway since space vehicles became large enough to give an astronaut room to 'float' away from the job at hand. Several solutions have been tried, including clamp-type devices and foot loops at strategic locations, but each type has drawbacks. ESA has developed an alternative, a running shoe with suction cups attached to the sole. It has been tested successfully during parabolic flights and on the IML-1 mission. It is well suited to short-duration tasks or delicate tasks during which astronauts must be confident that they will remain firmly in place. When an improved type of suction cup has been found, NASA will test the shoes again on a future Shuttle flight.

The search for the ideal type of foot restraint for astronauts to use when performing tasks within a space vehicle has been underway, essentially without interruption, since space vehicles became large enough to give an astronaut room to 'float' away from the job at hand.

For extra-vehicular activities (EVA), the nature of the astronaut's EVA suit, the precise tasks to be performed, and the grave consequences if the astronaut became detached accidently, have resulted in the development of clamp-type devices to attach the astronaut very securely to the exterior of the spacecraft. A similar approach was used for intra-vehicular activities in the Skylab programme: crew members wore special shoes with a triangular, metal cleat on each sole, and the cleats fitted into an open-grid floor which was used throughout the vehicle (Fig. 1). Even though the shoes could be used anywhere on the floor, there were many situations where either the astronaut's preferred orientation or the short time spent at one location made a rigid fixation unsuitable. In addition, the metal cleats could inadvertently cause damage to equipment.

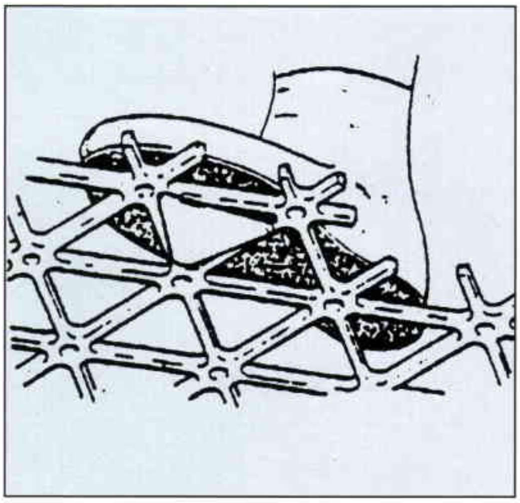

Figure 1. The shoe used on Skylab missions, with a triangular cleat that fits into an open-grid floor

For Space Shuttle and Spacelab missions, the standard approach to foot restraints has been to place foot loops (which are similar to those used on surfboards) on the floor at all locations most frequently used on a specific mission (Fig. 2). The crew is not required to wear any special footwear. This approach has worked reasonably well given the confined space of the Shuttle's mid- and aft-flight decks. However, it is evident from video recordings that the location of foot loops is never ideal because of the differences in the crew members' height and reach. As a result, the crew members tend to use any convenient object to restrain themselves while performing tasks. They grasp the object or hook themselves onto it using any part of the body that is not required for the task, such as a toe, an elbow or a knee, and appear to be able to do so without mental distraction from the task.

The same approach is taken further in the Commonwealth of Independent States' Mir Space Station, where very few foot restraints are provided. Instead, the crew uses anything available as a body restraint. Although this approach works well in the Mir station, it requires having equipment on

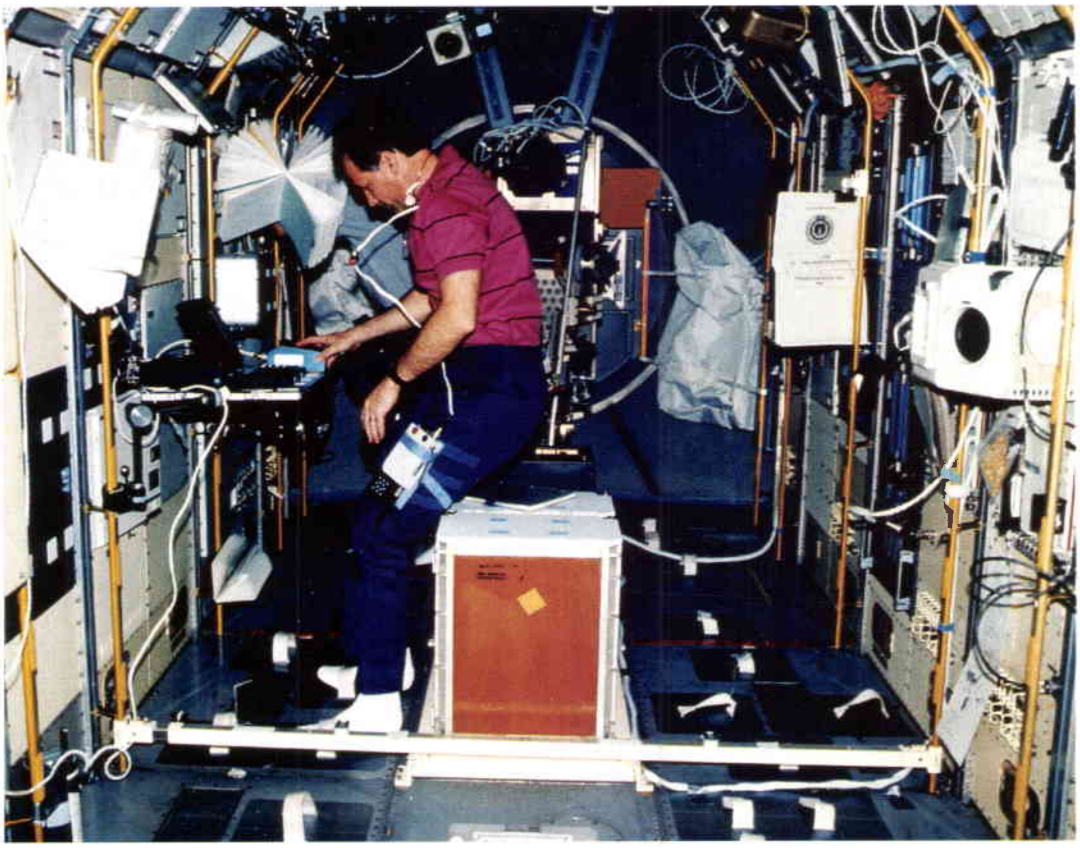

Figure 2. Ronald Grabe, commander of the IML-1 mission, working with his feet in foot loops

Figure 3. A crew member wearing a prototype of the suction-cup shoe hangs from the ceiling of an aircraft during a parabolic flight

board that is very heavy and can resist the force that a body can exert, and a flexible approach to the location of payload equipment. The consequence is the accessible but cluttered interior of the Mir station.

For the international Space Station Freedom, it is envisaged that each of the laboratory modules on board will be similar in size and positioning to those in the Spacelab, with a relatively spacious central aisle, lined on both sides with flat-fronted racks of experiment equipment. To allow rapid egress in the case of an emergency, and the removal of large objects such as a rack, the central aisle cannot contain a lot of equipment, which would otherwise be convenient for the crew to use as restraints. However, foot loops are also not suitable for all crew members and for all work locations, especially short-duration work locations. Therefore, the search for the optimal type of restraint continues.

During ESA's parabolic flight test programme, conducted in October 1990 using a Caravelle aircraft belonging to the French national space agency CNES, a similar problem arose. The members of the support team on board the flights had similar requirements for foot restraints: the team members must be 'fixed' during the flight's 20 seconds of zero-gravity in order to record events on

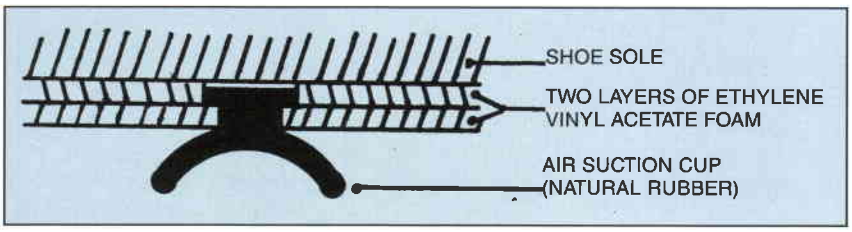

Figure 4. The running shoe with the suction-cup sole, tested on the IML-1 mission, and its construction

videotape or to make notes, but must be able to free themselves rapidly before the 2-g recovery period. As a solution, 'Spiderman' shoes — shoes with many small suction cups on the soles — were suggested. It would only be necessary for a few of the suction cups to stick to a smooth surface with sufficient force to hold a 'weightless' person in place. Such shoes were constructed and tested during the parabolic flights. The interior of the Caravelle proved to be ideal: the shoes readily gripped and remained attached to the smooth, padded walls and ceiling (Fig. 3). But, could the same shoes work in a spacecraft, with different floor, ceiling and equipment surfaces, and while astronauts perform actual tasks?

In August 1991, the ESA team presented its design and the results from the parabolic flights at a Crew Station Review meeting at which the astronaut activities for the Space Station Freedom were being planned. The NASA astronauts were interested immediately, and the Johnson Space Center (JSC) Astronaut Office, the office in charge of crew activities, requested that the shoes be tested on board the International Microgravity Laboratory (IML-1)/Space Shuttle Discovery (STS 42) mission (which occurred in January 1992). To do so, ESA had to provide flight-qualified shoes within six weeks.

To meet such a tight deadline, the shoes had to be prepared within ESTEC. The selection of materials and the testing to meet the Space Shuttle requirements were performed in ESTEC's Materials and Processes Laboratory, and all manufacturing was done in the Testing Division's workshops except for the stitching operations — a specialty of the local surf shop. As a result of the great effort made by all involved, the shoes were delivered to JSC in Houston in October 1991, as scheduled, and were stored in ESA astronaut Ulf Merbold's locker on board the spacecraft in preparation for the mission.

Off-the-shelf running shoes were selected based on their materials content and construction. The profile on the sole was scoured off and two layers of ethylene vinyl acetate foam material were glued in its place. Twenty-four natural rubber suction cups, each of which had been tested to hold 1.5 kg, were arranged uniformly over the sole and glued in place (Fig. 4).

During the IML-1 flight, both ESA astronaut Ulf Merbold and NASA astronaut Steve Oswald (who has approximately the same size feet as Merbold) tested the shoes by performing several kinds of tasks at various locations. The shoes worked equally well on the floor, the walls and the front of the racks. The astronauts found it easy to 'attach' themselves to a surface from a free-floating position, and to free themselves again by rolling the foot forward or sideways. They were also able to 'walk' down the aisle of the Spacelab, although this is not desirable because of the microgravity disturbances that it creates.

For short tasks or for delicate two-handed tasks, the astronauts felt that they could rely on the shoes to keep them securely in place. However, for prolonged work at one location, the shoes are not ideal because they eventually become detached as each suction cup allows a very small amount of air leakage. However, the results from the initial flight test were sufficiently good and, when a suction cup with an improved surface has been found, NASA will test the shoes again on a future Shuttle flight.

Acknowledgement
The authors would like to thank Dwight Blair and Monica Hughes at the JSC Astronaut Office for their efforts in arranging the stowage of the suction-cup shoes in the Space Shuttle.

The ESA Packet Utilisation Standard – A Validation Prototype

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The Committee for Operations and EGSE* Standardisation has produced a draft Packet Utilisation Standard which recommends a practical way of using CCSDS Telemetry and Telecommand Packets between on-board applications and ground-control systems. This document was produced in draft form about a year ago, and a validation prototype was developed in order to check the correctness of the standard, its operational suitability and the feasibility of its implementation.**

Background

The ESA Telemetry and Telecommand Packet Standards, which are derived from the Recommendations of the Consultative Committee for Space Data Systems (CCSDS), provide the space-to-ground communication mechanism that enables an end-to-end exchange of 'data units' between spacecraft on-board systems and ground systems.

The nature of 'packets' makes it possible to generate data in a very flexible manner. A 'packet' is an envelope containing data, which could be of any structure, generated asynchronously and exchanged according to any kind of application protocol. This sudden increase in flexibility compared to the old ESA Telemetry and Telecommand Standards could be used in different ways by different projects. A consequence of this would be that there would be very little re-use of on-board and ground software between projects. Aside from the cost impacts, mission-specific implementations carry a significant risk element.

It is therefore vital that recommendations be made quickly, at least within the Agency, on how packets should be used in monitoring and controling a space segment. This is necessary to enable on-board and ground infrastructures to be developed and used systematically by the next generation of ESA missions. This is the so-called 'horizontal commonality'.

*Electrical Ground Support Equipment
**Consultative Committee for Space Data Systems

Role of COES

The Committee for Operations and EGSE Standardisation (COES) was created in 1987 in order to establish ESA standards that would lead to the implementation of ground infrastructure systems that would be usable during the checkout phase as well as during the operational phase of a mission. This represents so-called 'vertical commonality' within a given project.

From the knowledge that the architecture of software systems is closely related to the data structures they manipulate (in this case telemetry and telecommand data), COES decided to start with the definition of standards governing the use of telemetry and telecommand packets. Only thereafter could the generic functions of a common EGSE and Mission Control System (MCS) be specified.

In February 1991, the COES issued a draft version of the Packet Utilisation Standard (PUS), which was widely distributed to the ESA Directorates and to space industry for comment. At the same time, the development of a prototype to validate the technical specifications contained in the PUS was initiated by the COES . The PUS Validation Prototype (PUSV) was delivered in February 1992 and installed at both ESTEC and ESOC.

The Packet Utilisation Standard (PUS)

The objectives of the PUS are primarily to complement the ESA Packet Standards by defining an application layer using the packet communication layer. Secondly the PUS should respond to the known requirements of current and future ESA missions, whilst retaining sufficient flexibility so that:

- mission-specific requirements can be readily accommodated

- it can be extended to 'standardise' new functionalities, as and when they become better defined.

The PUS is composed of two major parts:

Part 1: Operational Requirements
- routine and contingency operations
- traditional (hardware) and process-control techniques
- definition of generic on-board functions.

Part 2: Packet Content Definitions
- standards for the data field header
- standards for packet 'types' and 'subtypes
- parameter types
- data-field-structure rules.

Operational requirements
The PUS defines different classes of missions (geostationary, low-orbiting and deep-space) and proposes a common operational concept that could be equally applied to all of them. The fact that on-board systems tend to be largely driven by software reduces the need for real-time closed-loop control between space and ground. The nominal mode of operation should become of a more offline nature, and this principle could also be applied to geostationary missions.

Whereas in the past on-board devices were directly controlled from the ground via an on-board bus interface, the tendency today is to have on-board software device controllers which translate high-level telecommands received from the ground into the proper sequence of bus commands to the device.

Because the space-to-ground CCSDS communication protocol guarantees reliable transmission between ground and space, the on-board applications (which perform device controller functions, etc.) do not need to worry about the correctness of the data and can proceed directly with the execution of a telecommand. They should inform the ground (through telemetry reporting packets) about the correct progress of the execution (positive-acknowledgement principle) or about problems detected on-board.

For nominal operations, therefore, the data traffic between ground and space should be considerably reduced. However, sufficient link-budget margins should be foreseen in case of on-board anomalies, to allow more data to be sampled more frequently. Also, in the event that an on-board software logic error is suspected, direct access to the device data should always be possible for diagnostic purposes.

Following this logic, a number of functional domains have been identified with specific operational requirements:
- telecommanding, including telecommand verification
- process control and communication
- memory loading and dumping
- telemetry content and timing information
- telemetry generation and transmission
- diagnostic mode
- master schedule
- on-board monitoring
- on-board software management
- testability.

Packet content definition
In response to the above functional requirements, a number of packet types corresponding to the various types of functions have been defined. Within each type, subtypes have been defined that specify subfunctions within a particular function type.

An on-board application could in principle generate a number of different packet types/subtypes, and thus a general data-field header was created for this purpose.

Common data-field structure and formatting rules are defined and applied to all packet types/subtypes. These rules allow for complex data structures supported by high-order languages (e.g. ADA, etc.), but simple structures such as time-division-multiplexed (TDM) channels are also covered.

The PUS should be seen as a catalogue of standard on-board functions and data structure/formats. This means that a particular mission would merely take the subset of functions and structures/formats appropriate to its requirements.

The PUS validation prototype
The PUS can be viewed as a technical specification of an on-board/ground data-exchange interface. Thus, an important and essential task is to check it thoroughly before formally releasing it. Immediately after the release of the present PUS draft version in February 1991, the COES decided to initiate a validation exercise in the form of a validation prototype, known as the 'PUSV'.

Objectives
The PUSV was intended to be a tool for validating the PUS in order to verify several aspects:

– Does it enable practical and reliable operations of a remote application?
– Is it easily implementable on-board as well as on the ground?

and to
– have an extensible tool which can be used to experiment with the PUS and model different on-board architectures
– ensure that the packets defined are logically self-consistent and unambiguous
– use it as a demonstration vehicle for projects and operations teams.

However, the communication of packets between space and ground and on-board is not addressed. The former has already been demonstrated, and for the latter it is assumed that there will be a proper packet-oriented on-board communication mechanism.

What is the PUSV?
The PUSV can be described functionally as follows:

– It is a simple emulation of a ground segment and a space segment (Fig. 1).
– Ground and space communicate via PUS packets.
– The space segment consists of a number of on-board applications.
– On-board application behaviour is configurable.
– The ground segment is controlled by a script.
– Mimic-diagram displays provide visibility of actions on-board and as reported to ground via telemetry.

Architecture
The PUSV runs on two Sun work stations, one emulating the space segment, the other the ground segment (Fig. 2), which are themselves decomposed into a number of basic elements.

The ground emulation enables the inter-active generation of telecommand packets with the 'packet generator' and the

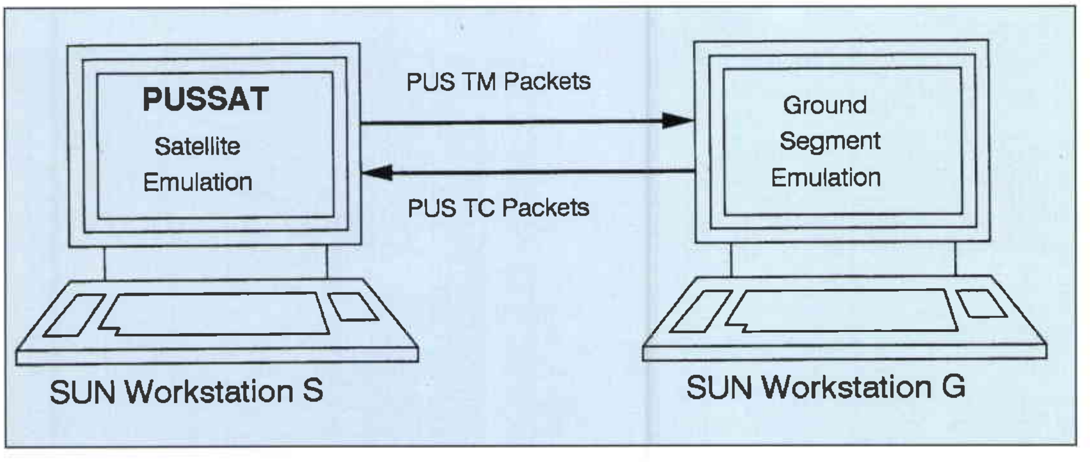


Figure 1. PUS validation prototype setup

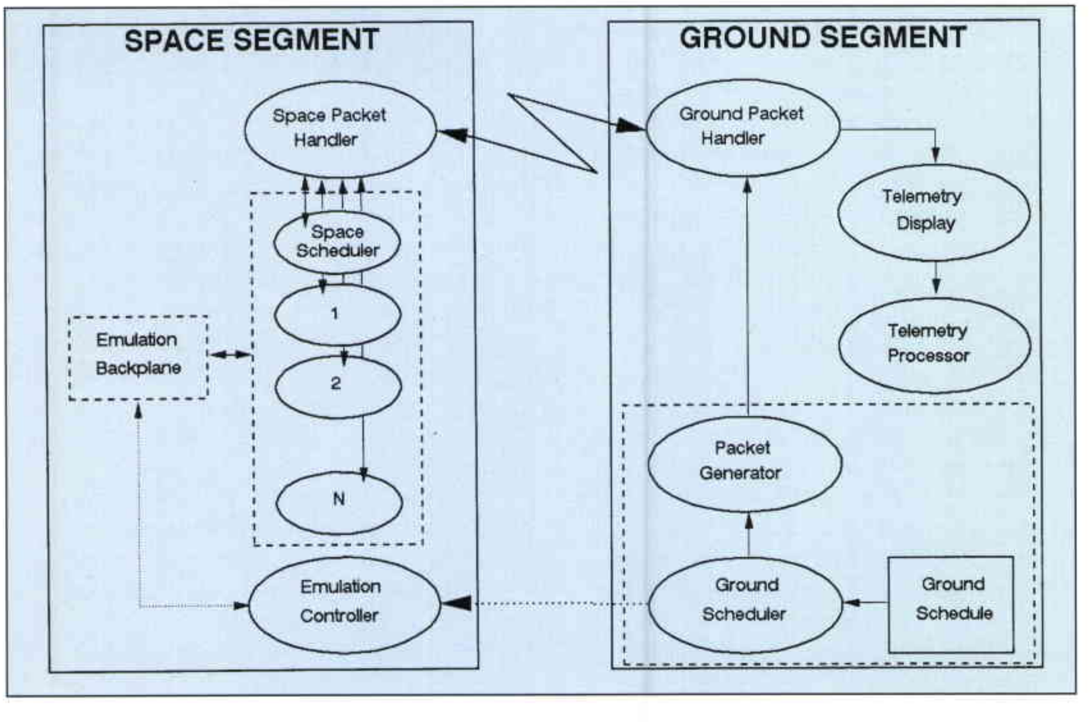


Figure 2. PUSV architecture

```
WHEN TIMER (300)
     UPDATE ("HouseKeeping", 0);
     SEND NEW (OUR_APPID, PUS_TM_FLAG, 4, 1)
          Rate := TELEMETRY_FRAME_CYCLE;
          Status := TIME_MANAGEMENT_STATUS;
          CUCTime := CURRENT_TIME;
     ENDSEND;
ENDWHEN;

WHEN UPDATED (TIME_MANAGEMENT_STATUS)
     IF (TIME_MANAGEMENT_STATUS != OK) THEN
          SEND NEW (OUR_APPID, PUS_TM_FLAG, 2, 1)
               RID := 2;
               FailureID := 1;
          ENDSEND;
     ENDIF;
ENDWHEN;

WHEN PACKET (Type == 2, SubType == 1)
     IF ("DIAG" == PACKET(ProcessName)) THEN
          M002 := ACTIVE;
     ENDIF;
     IF ("TIME" == PACKET(ProcessName)) THEN
          M001 := ACTIVE;
     ENDIF;
ENDWHEN;
```

Figure 3. Example of application emulation script

construction of sequences of telecommand packets (optionally time-tagged) constituting a test scenario which can be automatically executed through a 'ground scheduler'. Telemetry is sent to the 'telemetry processor'; parameters are extracted and then displayed by the 'telemetry display' element.

The space emulation provides a general infrastructure to emulate on-board applications. An 'emulation controller' provides visibility into what actually happens within the applications.

The PUSV, written in C++, is designed in an object-oriented manner. It uses a windowing interface based on XView, DevGuide and DataViews. It is largely configurable and is driven by files. Two areas provide interesting extension possibilities:
- New packet types and subtypes can be easily introduced. This feature will be used to adapt the PUSV to what will be the final standard, and later whenever new functionalities are introduced in subsequent issues of the standard.
- On-board applications can be emulated by using a script file which drives the behaviour of the application. A script language was defined which allows (Fig. 3):
  - Flow control
  - Performing of actions (modification of on-board parameters, generation of telemetry packets with specified values, calling of an external function not supported by the language, etc.)
  - Response to events (expiry of timers, arrival of specified packet types/subtypes, updating of the value of a specified parameter, etc.).

The PUS test satellite PUSSAT

All features of the PUSV were thoroughly tested. However, in order to ensure a realistic demonstration of its capability, a number of typical on-board applications were emulated to represent typical on-board functions and a typical on-board architecture. This particular satellite model uses all varieties of functions and packet types/subtypes offered by the PUS (hence the name 'PUSSAT').

The overall architecture of the PUSSAT is shown in Figure 4; it is composed of:
- a time-management application
- a Data-Handling Subsystem (Fig. 5) able to control a number of subsystems (e.g. thermal control; Fig. 6). This application also holds the Master Scheduler, which is able to schedule telecommand packets to itself or to other applications
- an AOCS intelligent application (Fig. 7)
- an intelligent 'Payload Z' application (Fig. 8).

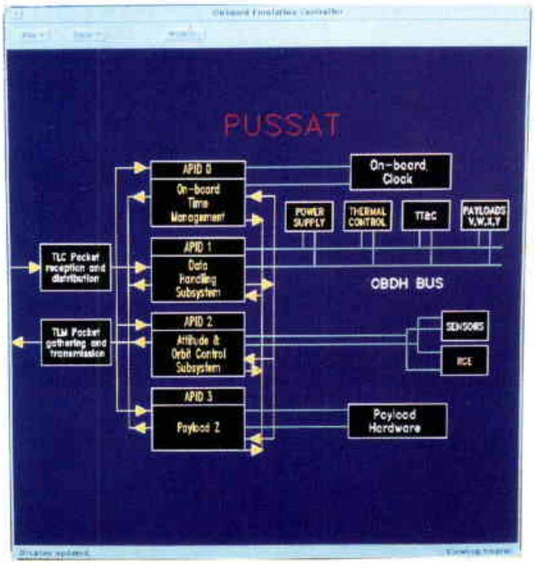


Figure 4. The PUSSAT satellite model

The emulated PUSSAT model can be fully operated through the emulated ground-control system. One can always see that the ground perception of the satellite status corresponds to what actually happens on-board. At all stages, there is full visibility via mimic telemetry displays, as well as the possibility to inspect either the telecommand or telemetry content in detail.

Conclusions

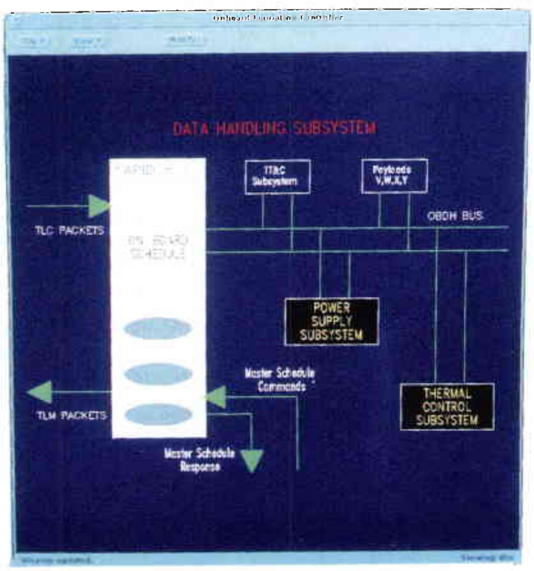
During the last twelve months, there has been a marked increase in interest in the new Packet Utilisation Standard. This may be linked to the fact that more and more projects are considering the use of the CCSDS Telemetry and Telecommand Standards, and at some stage of the on-board design consideration must be given to the concept of how they should be used at application level. It is perhaps being recognised that the PUS is an attempt to provide answers to these questions.

In this respect the PUSV is a useful tool which could help in the process of introducing the Packet Utilisation Standard in several ways:
- familiarisation with the underlying operating concept
- understanding of the on-board-design implications
- enabling of different models for an on-board application's architecture.

Based on the experienced gained to date with the PUSV, it is intended to subject the PUS to a formal review process and to submit a new issue for Agency approval during the second half of 1992.

Thereafter the PUSV will be upgraded to take into account the latest modifications made to the standard. It is also planned to specify and implement a more open communications interface between the space and ground emulators, in order to allow remote connections and to constitute a reference tool for the validation of specific on-board implementations based on realistic platforms.

Acknowledgement
The author would like to thank A. Pidgeon and R. Melvin from the company VEGA, who have successfully developed the PUSV. They also produced the diagrams included in this article.



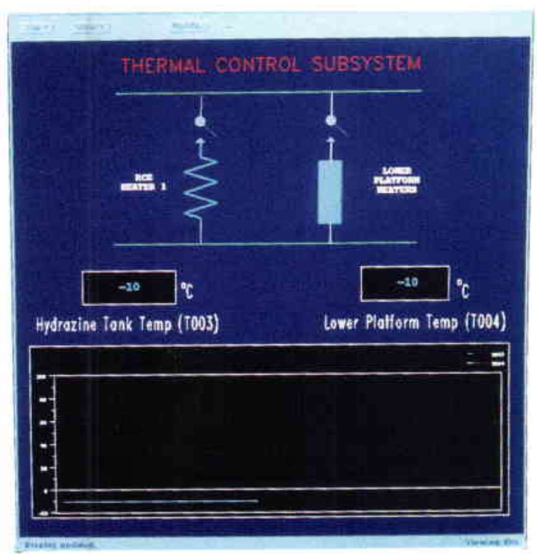
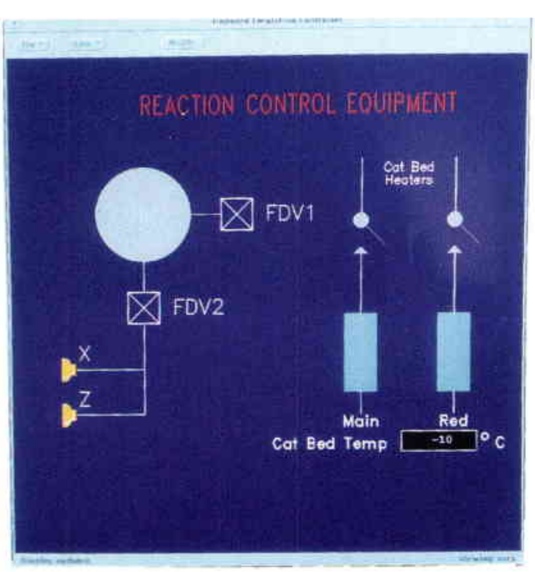


Figure 5. The data-handling subsystem

Figure 6. The thermal-control subsystem



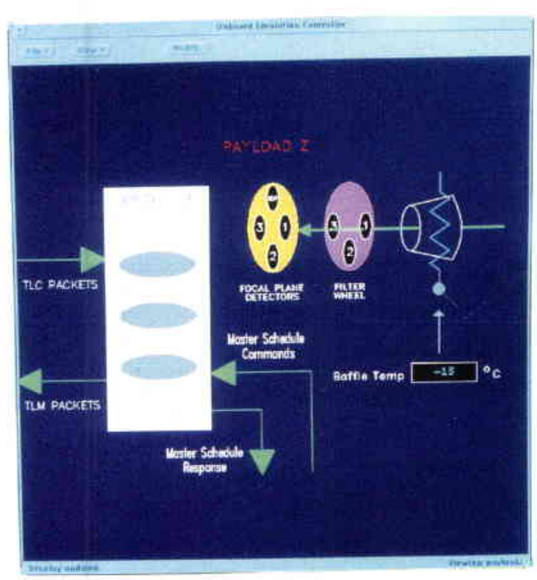


Figure 7. Element of the AOCS subsystem

Figure 8. Dummy payload: 'Payload Z'

The World Administrative Radio Conference 1992 and Its Impact on ESA's Programmes

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The World Administrative Radio Conference 1992, known familiarly as WARC-92, was held in Malaga-Torremolinos between 3 February and 3 March this year. This WARC, attended by more than 1400 delegates from 127 Member Countries of the International Telecommunications Union (ITU) and numerous observer organisations such as ESA, may well have been the last of the large WARCs of recent decades.

Introduction

As is customary for WARCs held away from Geneva (CH), the seat of the ITU, the 1992 Conference was chaired by a national of the host country, in this case D. Jose Barrionuevo Peña, a member of the Spanish Parliament. In December of this year, when an Extraordinary Plenipotentiary Conference of the ITU will decide on the new structure for the Union, it may also be decided to hold smaller Radioconferences with less ambitious agendas biannually in future.

The agenda for WARC-92, although far less exhaustive than that for the general WARC of 1979 (.....to review and, where required, revise the [entire] Radio Regulations...), still contained items as diverse as high-frequency (HF) broadcasting, certification of ship-station personnel, broadcast satellite HDTV, and new applications for space services above 20 GHz! However, the heart of the agenda was the 1–3 GHz band, to which not only mobile and satellite mobile services and the broadcast satellite/sound services, but also the space-science services in the 2 GHz bands sought access. There was deadlock between the various parties regarding this band and a 'compromise solution' could only be found late into the last night of the Conference, when Europe, i.e. the CEPT, in a gesture of ultimate flexibility, decided to abandon some of its initial positions and thereby made way for WARC-92 to be a last-minute success.

The political environment

Politically speaking, this 'last large WARC' was markedly different from its predecessors. Historically there had always been the big power blocks: the USA and their allies, the former USSR and its allies, and the group of non-aligned nations, usually led by India, with China playing a powerful outsider role. WARC-92 saw a fundamental change; with virtually all of the former USSR allies now members of the CEPT, the new Commonwealth of Independent States leaned strongly towards the European positions represented by the rather well orchestrated 30-member group of CEPT countries. The group of non-aligned countries missed its usually strong leader, India, which currently seems to be less actively involved in the politics of the non-aligned movement. No other African, Asian or South American country seemed prepared to assume the leadership role. The Kingdom of Morocco stood out due to its keen and competent interventions, while China and Japan adopted very low-key approaches.

Finally, the USA – with a delegation in which private sector interests were well represented – was adamant in its insistence on its initial positions and held out on several occasions for 'US-only solutions'. Europe, demonstrated much more of a conciliatory position, not least by making possible the compromise on the last night of the Conference without which WARC-92 would have been something of a failure.

The preparatory cycle

Compared to the time-consuming and tedious preparations for past conferences, such as for WARC-79, where ESA had to seek support for its positions from each individual Member State PTT Administration, recent developments in Europe rendered

ESA's preparatory activities for WARC-92 much more efficient. The apparent change in the CEPT in the wake of increasing deregulation of the European telecommunications market, its new representation by the 'European Radiocommunications Committee (ERC)', together with its greater openness towards the 'users', considerably facilitated ESA's simultaneous access to all of the Member-State regulatory authorities as a group.

Almost from the outset ESA was invited to participate, as an observer, in the work of the CEPT's Ad Hoc Working Group WARC-92, which had been set up by the ERC with the mandate of preparing for the Conference and developing 'European Common Positions (ECPs)' for all major agenda items. Many of the Agency's contributions to the work of several of the technico-regulatory Drafting Groups supporting the Ad Hoc Group were readily accepted.

Another valuable asset in the preparations for WARC-92, at least in such areas as the Space Research, Earth Exploration Satellite, Meteorological Satellite and Space Operation Services, was the Space Frequency Coordination Group (SFCG), which was created in 1980 by ESA as a result of the ad-hoc coordination among space agencies at WARC-79. The SFCG, which now counts among its members all of the world's major space agencies, reached prior agreement on all major issues regarding the above services, and succeeded in a great number of cases in convincing national regulatory authorities to support SFCG views at WARC-92. The upgrading of the 2 GHz bands for space research/operation and the allocation near 26 GHz of the return link band for data-relay satellites were among the goals achieved in this way.

The WARC-92 logo

The results

The science services

The so-called 'science services' – i.e. the space research, space operation, Earth exploration and meteorological satellite services – had an interest in two agenda items: (i) frequency allocations to new space service applications above 20 GHz, including allocations in lower frequency bands for manned spaceflight, and (ii) upgrading of the allocation status of the 2 GHz bands assigned to the science services.

The science-service allocations above 20 GHz

During the early preparatory stages of its data-relay satellite programme, in 1982/83, ESA had already identified the 25.25–27.5 GHz band as a particularly attractive one for both the forward and return links between the data-relay and user satellites. However, with the increasing demands on return-link capacity, it was decided to reserve this band exclusively for the wideband return link and to assign the forward link to an existing inter-satellite-service allocation near 23 GHz. Later, both NASDA and NASA followed ESA's lead and also decided to use the 26 GHz band for their future data-relay satellites' return links.

The crucial problem of the 26 GHz band was its unsatisfactory allocation status in the

Table of Frequencies of the ITU Radio Regulations (ITU/RR). The band had been allocated with a secondary status to the Earth-exploration satellite service (space-to-space) at WARC-79. This was clearly an unnecessarily limiting situation for the much wider use envisaged by data-relay satellites, serving not only Earth-exploration but also scientific satellites and – last but not least – Space Station 'Freedom' with its variety of requirements for numerous radio--communication services. After thorough discussion, the SFCG called for a new allocation of the band either to the inter-satellite service or to the space-research plus Earth-exploration satellite service. The US and Japanese administrations preferred the first alternative, the CEPT countries the second.

Nevertheless, the deliberations at WARC-92 resulted rather quickly in a very acceptable compromise between the differing national proposals: it was agreed to allocate the 25.25–27.5 GHz band, with primary status, to the inter-satellite service, but with the proviso that its use would be limited to space-research and Earth-exploration applications and the transmission of data originating from industrial and medical activities in space. Despite the limitations, this compromise meets the needs of space agencies perfectly whilst excluding other, potentially non-compatible, users.

Future space-science programmes, particularly NASA's ambitious Lunar/Mars Exploratory Programme, will require bandwidths that cannot be satisfied in the currently allocated frequency bands. Consequently, the SFCFG also developed a position for the allocation of new bands above 20 GHz to cater not only for these needs, but also those of spaceborne radioastronomy observations, such as Very Long Baseline Interferometry (VLBI). Although there may currently be no programmes under development in these areas within ESA, there are in other space agencies. The new frequency bands that WARC-92 allocated to the space-research service, 37–38 GHz space–Earth, coupled with 40–40.5 GHz Earth–space, should meet scientific needs for at least the next decade or two.

At the initiative of the Commonwealth of Independent States, and with the support of numerous other administrations, an additional frequency allocation was made by the Conference to the Earth- exploration satellite service. This new allocation provides for a bandwidth of 3 GHz in the space–Earth direction from 37.5 to 40.5 GHz, together with 1.5 GHz in the Earth–space direction from 28.5 to 30 GHz. Both allocations have only a secondary allocation status.

Since their earliest days in space, astronauts have had to rely on frequencies borrowed from other users, e.g. the military, in order to communicate with one another and their base stations, such as the Shuttle or MIR. Although this situation was marginally acceptable as long as the extravehicular activities (EVAs) were quite limited in number, the expected increase in EVAs in the future justifies a dedicated frequency band for communications between manned space vehicles. The choice of a suitable band was not straightforward given the current use of attractive candidate bands by other, mostly terrestrial users on the one hand, and technological requirements, such as antenna size and transmitter power, on the other.

After considerable iteration within the SFCG, the band around 400 MHz seemed to offer the best compromise, despite its heavy occupation by terrestrial users. The Conference considered two proposals, one for a relatively minor amendment to an existing allocation to the space-research service in the 400.15–401 MHz band, the adoption of which involved no problems, and another more controversial one for the 410–420 MHz band. While the first proposal was accepted without major discussion, the second met with significant opposition. A compromise was eventually reached by allocating the 410–420 MHz band to manned spaceflight activities, but with only secondary allocation status, which does not meet the protection requirements of the space services.

The 2 GHz bands of the science services

The story of the allocation of the 2025–2120 and 2200–2300 MHz bands – the so-called '2 GHz bands' – to the science services is one of a long uphill fight involving the space agencies and established terrestrial users, such as the fixed service. First allocated, at least partially, at Space WARC-71, with the proviso 'subject to agreement by administrations having services in the bands', the bands were 'upgraded' to a somewhat uncomfortable status under the provisions of the onerous coordination procedure of Article 14 of the ITU/RR. This Article, which was designed to protect the terrestrial services, turned out, in its day-to-day application, to be so cumbersome that administrations shied away from its use.

Although having to cope with an unsatisfactory allocation status, space agencies made increasing use of the 2 GHz bands, and by the time of WARC-92 the SFCG Satellite Frequency Data Base contained 250 entries for the Earth–space band and 280 for the space–Earth one. Despite the heavy use being made of the 2 GHz bands by the space-science services, no complaint of interference was ever filed by the fixed services. Based on this day-to-day experience, the terrestrial fixed services gradually admitted that they and the space-science services could indeed co-exist in the same band.

By the time the fixed services had tacitly accepted the co-existence with the space services, another user declared an interest in the 2 GHz bands: the terrestrial mobile service was actively searching for a bandwidth of at least 230 MHz below 3 GHz for its Future Public Land Mobile Telecommunications System (FPLMTS). Backed by the solid market forces of what is at times referred to as 'the market of the century', the mobile service earmarked the 2 GHz bands for its quite loosely defined future needs. Technical studies carried out by ESA soon showed that sharing with high-density terrestrial mobiles such as the FPLMTS or similar mobile systems could not be envisaged, since these would inevitably cause harmful interference to the space services, particularly the data-relay satellites operating in these bands. Likewise, ESA had evaluated the budgetary impact of having to vacate the 2 GHz bands and move all projects already using them, or planning to use them, to as yet unknown bands, to be of the order of 1300 Million Accounting Units.

In long negotiations prior to the WARC, it was possible to convince the terrestrial mobile service not to envisage implementing the FPLMTS in the 2 GHz bands, but rather to use these bands for other applications, such as Electronic News Gathering* (ENG), which could co-exist with the space services. The result of these formidable pre-WARC discussions, which were efficiently supported by the SFCG, was that many administrations arrived at the WARC with proposals for a primary allocation of the 2 GHz bands to the space-science services, some – like the CEPT countries – even going a step further and proposing a limitation to terrestrial mobile activities in order to afford the space-science services the protection they need.

Deliberations at WARC-92 on the topic of the 2 GHz bands were quite arduous and time-consuming, but resulted finally in the allocation of the 2 GHz bands to the space-science services, with a primary status in the Table of Frequencies. This allocation is accompanied, however, by two Resolutions, one of them inviting the CCIR to urgently study the bandwidth requirements of both the mobile and space-science services in the 2 GHz bands, and the second asking for a study by the CCIR of protection criteria for the space services.

The mobile satellite services

Given that Resolution 208 of WARC-Mobile 1987, which stipulates the revision of the 1–3 GHz band with a view to allocating additional bandwidth to the mobile and mobile satellite services, was one of the main drivers for holding WARC-92, it is hardly surprising that this agenda item should have consumed much Conference time.

In this particularly sensitive band the WARC was faced with many controversial issues, including:

- Extension of the present allocations to the various mobile satellite services near 1.5/1.6 GHz, or alternatively an allocation somewhat higher in the band but still below 3 GHz, as proposed by Europe.

Example of a mobile satellite service for road hauliers (Prodat)

* ENG typically uses RF links between TV cameras and their base stations for covering major sports or other news events

The USA favoured a re-allocation of all mobile satellite bands to the generic mobile satellite service, whereas Europe insisted on keeping the current allocations to the aeronautical, land and maritime mobile satellite services, at least in the existing allocations near 1.5/1.6 GHz.

- Many administrations were eager to allocate the largest piece of the spectrum (at least 230 MHz and preferably more) to the Future Public Land Mobile Telecommunication System (FPLMTS), it being understood that part of this band would be available to satellite links complementing the terrestrial ones of the FPLMTS. The urgency of such an allocation was not perceived in at all the same way, however, by Europe and the United States. While Europe favoured an early identification of certain bands for the FPLMTS, the USA did not see any urgent need for such an action at WARC-92.
- The USA rather put emphasis on frequency allocations to the so-called 'Low-Earth-Orbit Satellite Systems', or 'LEOs' for short. LEOs became one of the key Conference issues, being further amplified by ferocious competition between several potential satellite systems.

  In fact, two different types of LEO systems were looking for frequency spectrum: the 'small LEOs', designed to provide a messaging-type service, not necessarily in real time but rather on a 'store-and-forward' basis, and the 'large LEOs', such as Globalstar, Iridium and Odyssey, aiming at establishing a worldwide communications system operating with small hand-held telephone terminals, serving in a way as a forerunner to systems like the FPLMTS.

Finally, some administrations were looking for spectrum with a generic 'multi-service' allocation in the 20/30 GHz bands to be used for implementing satellite communications systems operating with fixed, transportable or even mobile earth stations. This issue is further explained below.

Aside from the revision of the Table of Frequency Allocations, the LEO system discussions also resulted in a special regulatory procedure applicable to non-geostationary satellites operating in certain frequency bands of the mobile satellite service. These non-geostationary satellite networks can involve LEOs, HEOs (High-Eccentricity Orbits, such as envisaged for ESA's Archimedes satellite), or both.

In summary, for LEO systems worldwide allocations could be found for both the 'small LEOs' in the 136/148/400 MHz bands and for the 'big LEOs' a 16 MHz-wide band in each direction near 1.6 and 2.4 GHz, respectively. Moreover, a small but significant addition of 5 MHz was made to the existing band of the maritime satellite service near 1500 MHz, thereby balancing the available bandwidths in the up- and down links. However, as in many other cases where no worldwide consensus could be reached, the unresolvable difference of views between the USA and Europe on the issue of a generic allocation to the mobile satellite service resulted in different allocations in Regions 1 and 3 (Europe, Africa, Asia and Australia) and in Region 2 (the Americas). For the FPLMTS also, the only solution possible was a regional one, again differing for Regions 1/3 and Region 2.

In the event, therefore, the overall results of WARC-92 for the mobile satellite services, apart from the allocations to the small and big LEOs, have fallen short of even modest expectations.

The broadcasting satellite/HDTV service

High-Definition Television (HDTV) broadcasting is seen as the next logical step in the evolution of home entertainment and information services. HDTV will allow the delivery of pictures of cinema quality in cinema format. This requires more information to be processed and transmitted and early concepts developed in the late 1970s to early 1980s arrived at transmission bandwidth requirements well in excess of 100 MHz for a single HDTV programme.

Such bandwidths were regarded as excessive for terrestrial broadcasting operations, and consequently a search for alternative solutions was initiated. Satellite broadcasting was quickly identified as the most attractive solution, particularly as it provides immediate wide-area coverage at reasonable cost. However, the frequency allocations then available were not wide enough to support the number of HDTV programmes that can eventually be expected. The 20 GHz region of the spectrum was identified as the only practical solution, since it offers sufficient bandwidth, while propagation conditions are still acceptable. With the exception of Europe and Africa (ITU Region 1), there was already an allocation to the broadcasting satellite service near 23 GHz in the 1982 version of the Radio Regulations.

accomplishing a very high percentage of the tasks that had been assigned to them, and even carrying out unplanned repairs to malfunctioning equipment (e.g. an echo-cardiograph) inside the chambers using the most rudimentary tools, and on-line assistance from a specialist at a remote location. The effective workload on the crew turned out to be rather high, peaking at 12 h per day, with some problems being generated by the length and cumbersome nature of certain procedures (e.g. waste water draining, urine collection).

In fact, there were no severe emotional or social conflicts, and no signs of physical or psychological strain, among the EMSInauts during the experiment. The studies on subjective state and Autonomic Nervous System (ANS) showed that the perceived load imposed by the working conditions and prolonged isolation and confinement, was mostly in the middle range. This was also apparent from the very few psychosomatic and anxiety/stress-related symptoms reported, and was also confirmed by psycho-endocrinological analyses (stress hormones in blood, urine and saliva) and psycho-physiology indicators (heart rate, heart-rate variability).

The study of sleep rhythms conducted using the wrist-worn activity monitors (a promising non-invasive technique which was also able to detect increasing tiredness during the course of the isolation) did not reveal major sleep disturbances. However, the monitors did provide a clear picture of the strong adherence of the EMSInauts to their imposed daily and weekly schedule. Figure 1 shows a typical recording pattern for one EMSInaut, covering the complete period of isolation.

The studies of crew performance and cognitive demand showed no changes in performance for simple tasks, but some impairment was detected with an increased level of complication of the task to be performed. This is evident from the Evoked Potential recordings, shown in Figure 2, where the N100 wave (linked to the state of the central nervous system) is unchanged throughout the isolation, while the P300 wave, which represents the response to a cognitive event, shows altered patterns during the second and fourth weeks.

Recorded data suggest that subjects tend to modify their strategy for accomplishing a cognitive task, as has recently been found for other stress conditions also. There are also suggestions that the subject's behaviour becomes more variable and unpredictable as time passes, rather than steadily more impaired. This is evident from Figure 3, which shows one EMSInaut's response times to a memory-exercising task.

The studies of social interaction and communication showed a strong tendency towards increased centralisation within the team over the four-week period. The Commander's importance increased with

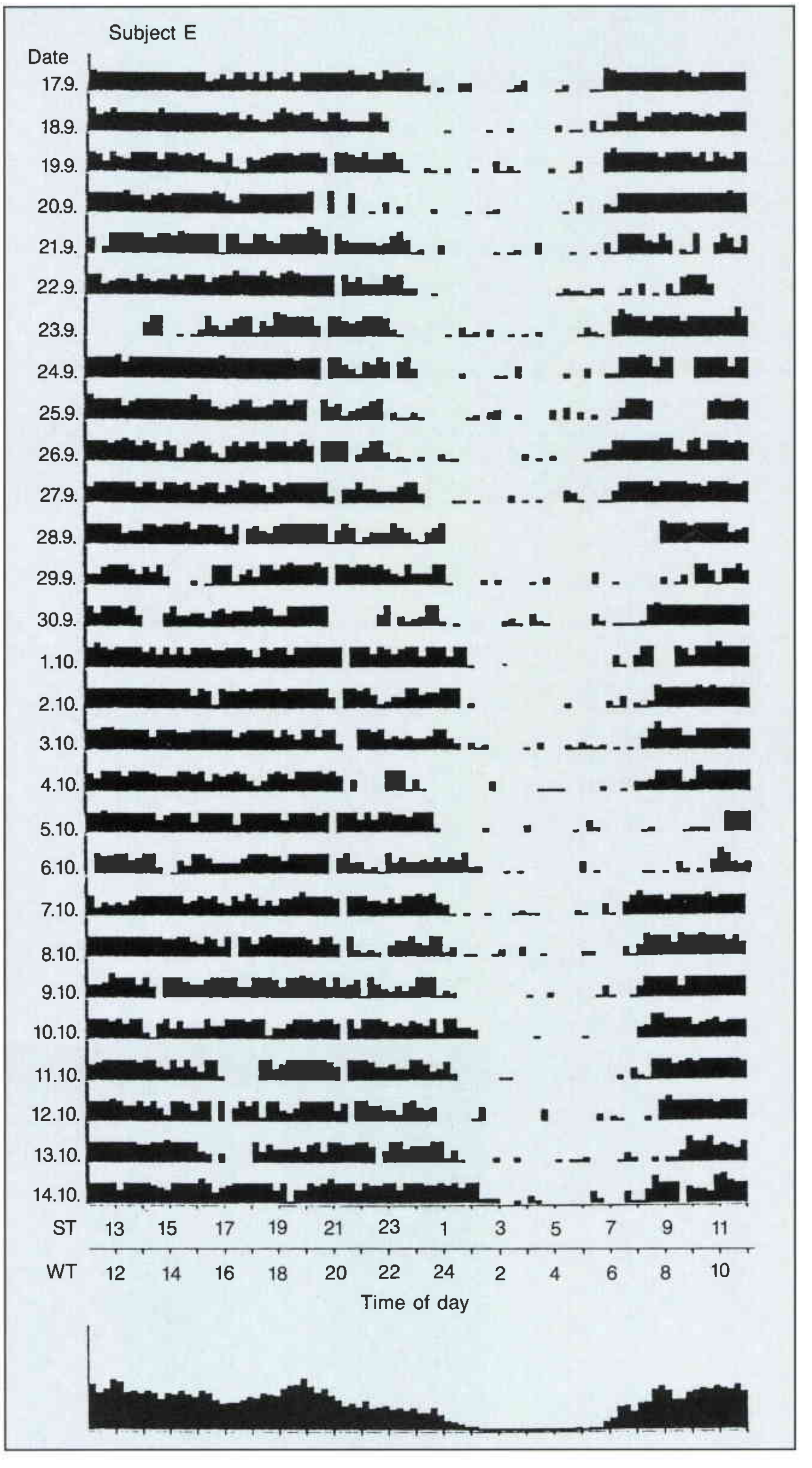


Figure 1. Recording pattern from an activity monitor worn on the wrist by an EMSInaut during his 28 days of isolation. Both summer (ST) and winter (WT) time is given as the switch-over occurred during the experiment. The sum total of all recorded activity is plotted at the bottom of the figure.

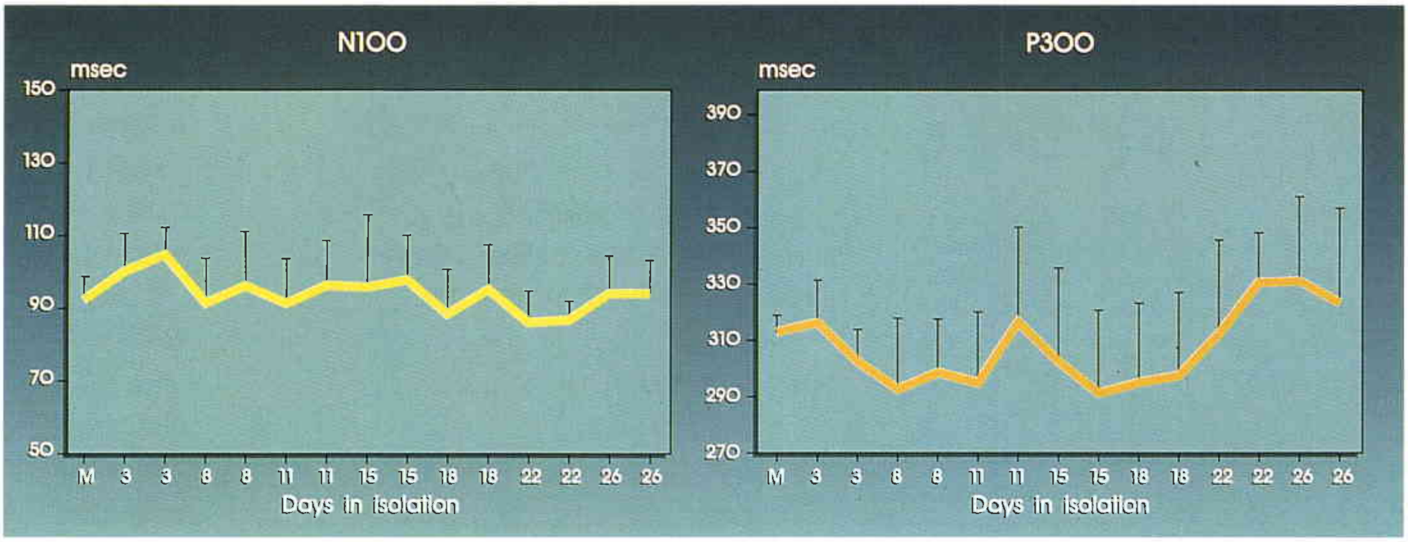


Figure 2. State of the central nervous system (N100 wave) and the response to cognitive events (P300 wave) recorded over the isolation period, averaged over the six-man crew. Note the change in the P300 pattern during the second and fourth weeks.

time, as well as the communication flow to and from him. At the same time, he got gradually less positive evaluations from other team members in terms of how 'well' he was performing as a leader. His popularity increased again after the end of the isolation period, as did that of the other EMSInauts. There was therefore a clear increase in mutual acceptance within the group after completion of the mission.

Figure 4 shows the network of communications established among the crew during 3 days of the isolation period; the thickness of the arrows highlights the process of centralisation.

Generally speaking, the EMSInauts seemed to be closer to each other in interests, background, social habits and skills, and even culture, than a random sample of young men of a particular nationality would normally be.

A significant increase in emotional expression, particularly negative emotions, was evident among the EMSInauts towards the end of the experiment. The crew as a whole felt less goal-oriented and satisfied during the last week of their ordeal. The present hypothesis is that such variations in emotional content are not linked to any particular length of time spent under unusual living conditions, but rather to the dynamics

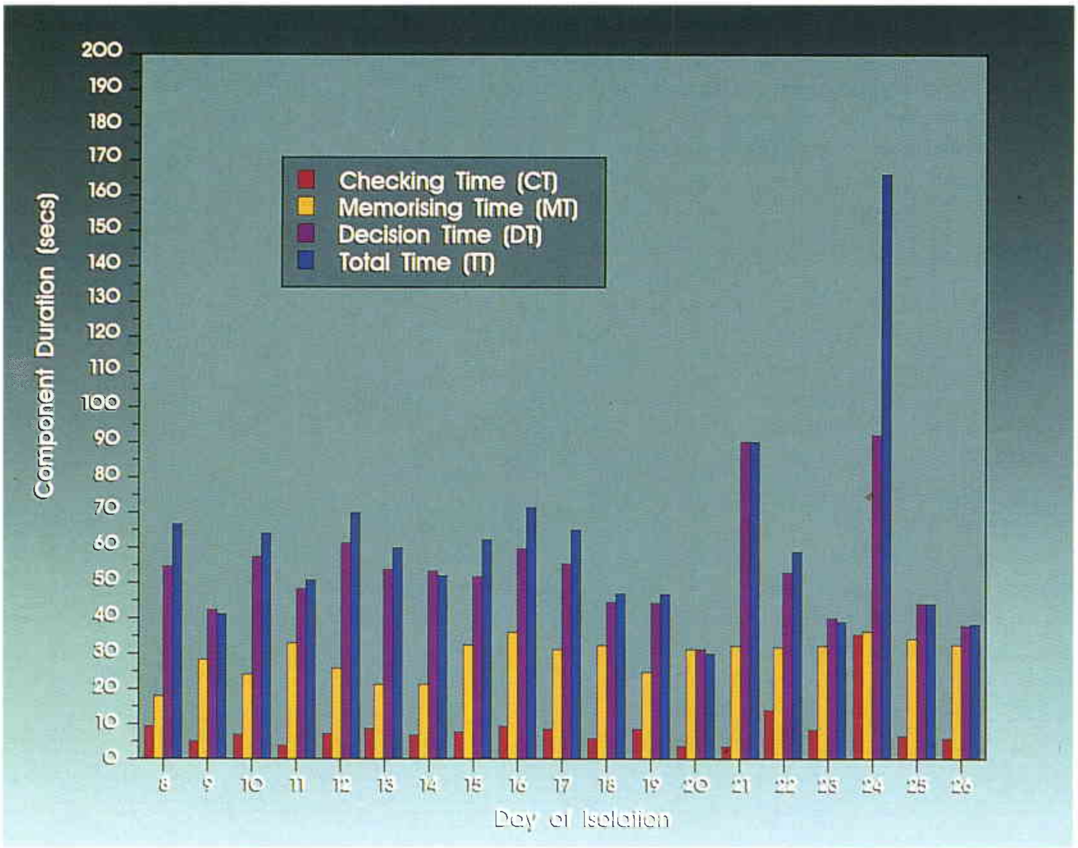


Figure 3. Response times to a memory-exercising task for one EMSInaut over the isolation period. Note the more variable/unpredictable pattern during the fourth week.

of the mission. Thus, they would occur only towards the end of even a significantly longer period of isolation ('light at the end of the tunnel'). This finding may well be the most important single result of the study, and is supported by observations of other groups confined in analogous environments. As a 'hypothesis' it remains to be verified in future studies.

Language was not found to be a problem within the group, which had little or no difficulty in communicating with the outside world. English was used by EMSInauts throughout the experiment, although there were no native English speakers, so that everyone had a comparable 'handicap'. An interesting observation was the clear preference for using the mother tongue in communications with the Experimenters.

The EMSInauts showed high motivation for individual and group success, with an 'esprit de corps' developing among them, and even an 'us-and-them' syndrome ('us' being the crew on board, and 'them' the ground control staff, the two parties frequently having contrasting views and interests). While the crew gradually reported fewer difficulties with ground control as time passed, problems of the 'them' variety were evident again at the very end of the isolation period.

Indeed, some difficulties experienced within the ISEMSI Operations Support Team (IOST) with the management of Experimenter interfaces and with the day-to-day schedule maintenance did create stressful situations for the crew members, who were obliged to act independently from the IOST. This meant, for instance, that the EMSInauts had to contact Experimenters directly in the event of difficulties with their instruments, or had to rearrange their own time allocations. How much such occurrences deviated from a comparable space mission scenario is a matter for further verification.

The physiology-experiment results

The study of endrocrine parameters showed that peak levels of stress hormones occurred during the second week of isolation. This result could be well correlated with other parameters such as the cardiovascular data (heart rate and its variability), as well as with the results of skin-evaporation-rate and skin-lipids measurements. One promising aspect is that the non-invasive measurement techniques (such as evaporation rate) proved their merit in reproducing the same reaction patterns recorded by invasive techniques, and are therefore excellent candidates for space-applied monitoring devices. Further studies to confirm this approach are needed.

Another interesting result, although one that also needs further confirmation, concerns the blood-volume-regulating hormone levels observed during ISEMSI, which may be related to the forced prolonged inactivity to which the crew members were subjected for 28 days. Similar modifications are induced in space by the microgravity environment, which causes a shift in fluids towards the upper part of the body. Consequently, the experimenters believe that long-duration confinement may become a valuable analogue for the simulation of some physiological aspects of spaceflight.

The special environmental features of the ISEMSI study allowed measurement of the total water turnover of the crew, since both the water intake (log book) and water output (urine, evaporation) could be monitored. Under these conditions, the water intake

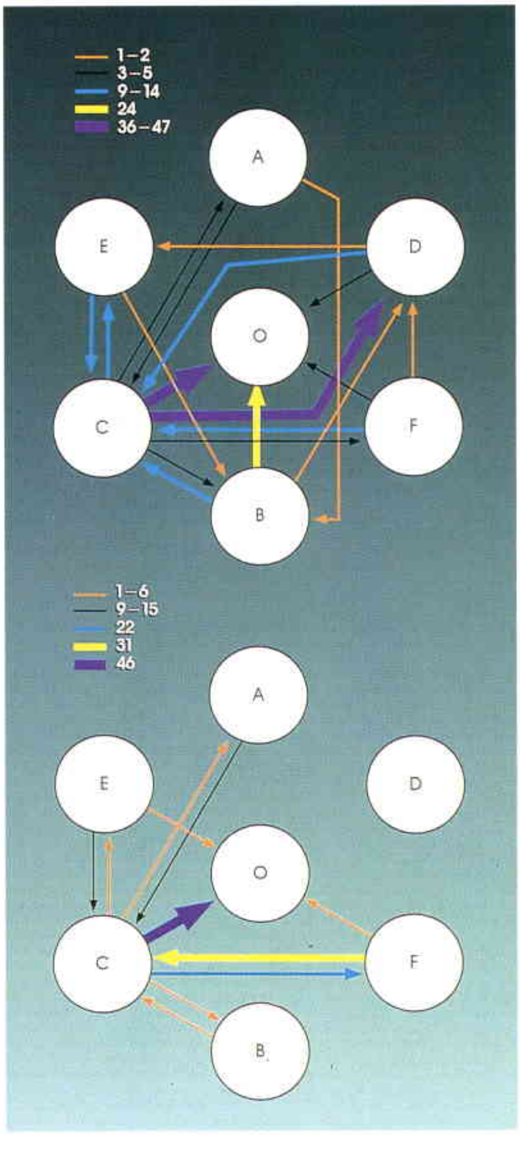


Figure 4. Evolution in the pattern of communications between EMSInauts for Day 2 (top) and Day 26 (bottom) of the isolation period. The increasing tendency for the Commander (C) to address the whole group (O) rather than a particular individual, and the reduced number of communications between individuals, are both apparent here.

correlated very well with the total water output (r=0.81 n <0.05), but evaporative fluid losses, for instance, went hand in hand with low urine outputs and vice versa. A circaseptan rhythm in the water intake, urine output, and sodium and potassium excretion was observed. These rhythms disappeared during the fourth week. This means that physiological data elaborated on Monday/Tuesday differ from the Thursday/Friday values, which could have a considerable impact as far as similar future ground- and space-based studies are concerned.

A Lower-Body Negative Pressure (LBNP) experiment was adopted for ISEMSI on the basis that inactivity and hypokinesia during confinement could be expected to cause some cardiovascular de-conditioning in the subjects and, in particular, orthostatic intolerance. In fact, the results did not show any significant variation in cardiovascular parameters during sessions of LBNP exposure. This was mainly attributed to the fact that the subject's life in the confined habitat did not actually impose a significant drop in their physical activities; even the limited exercise possibilities available in the chambers were sufficient to avoid cardiovascular-deconditioning symptoms.

More difficult was the interpretation of the immunology study results, which were affected by a delay in the blood sampling after the end of the isolation period. Some modifications were indeed noticeable, such as a slight trend towards immune-system activation, with some increase in the lymphocyte count. However, further studies are required before any firm conclusions can be drawn.

Conclusion

In general terms, the goal of autonomy set for Europe pre-supposes the latter's mastery of a number of human-related problems, which are currently only being addressed in the USSR and, to a lesser extent, in the USA.

Already some conclusions can be drawn for Europe:

- Such mastery cannot be gained via theoretical as opposed to experimental study. Human factors can only be studied conclusively by conducting investigations with human subjects in the loop.
- The necessary studies can only proceed at a rate commensurate with the slow adaptive processes inherent in living organisms; in other words, studies of human factors of this nature take time.
- Human-factor studies involve a large spectrum of disciplines, thereby making an interdisciplinary approach mandatory.
- Statistical data are essential where humans are involved.

Studies such as those performed in the framework of ISEMSI are a very rich source of information and help us to begin to establish the database that Europe must have if it is to embark safely on manned system operations in space.

The limitations encountered during ISEMSI as far as the statistical validity of results and their straightforward applicability to space scenarios is concerned have been outlined above. The need to continue and further expand the research is therefore quite clear, and planning has already started of future simulation campaigns, exploiting such diverse analogous environments as undersea habitats and polar expeditions. These will also help to filter out the 'background noise' from the data sets for a particular environment when comparing results from small groups in different settings. It is essential to repeat this kind of study, in order to build up the database, varying different parameters (duration, number and sex of crew members, stress factors, etc.) according to a well-defined study programme over a period of several years.

Many more simulation studies involving humans are necessary in order to model successfully the conditions that our astronauts embarking on future space missions in a European-designed space system will encounter. Some of these simulations should be international endeavours, bearing in mind such exploratory initiatives as a manned mission to Mars. In this respect, the planned 'Arctic Drift', to celebrate the one hundredth anniversary of Fridtjof Nansen's trip across the ice pack, during which a crew will be left isolated for two years in an extremely hostile environment, will provide an ideal analogy for such a flight to Mars.

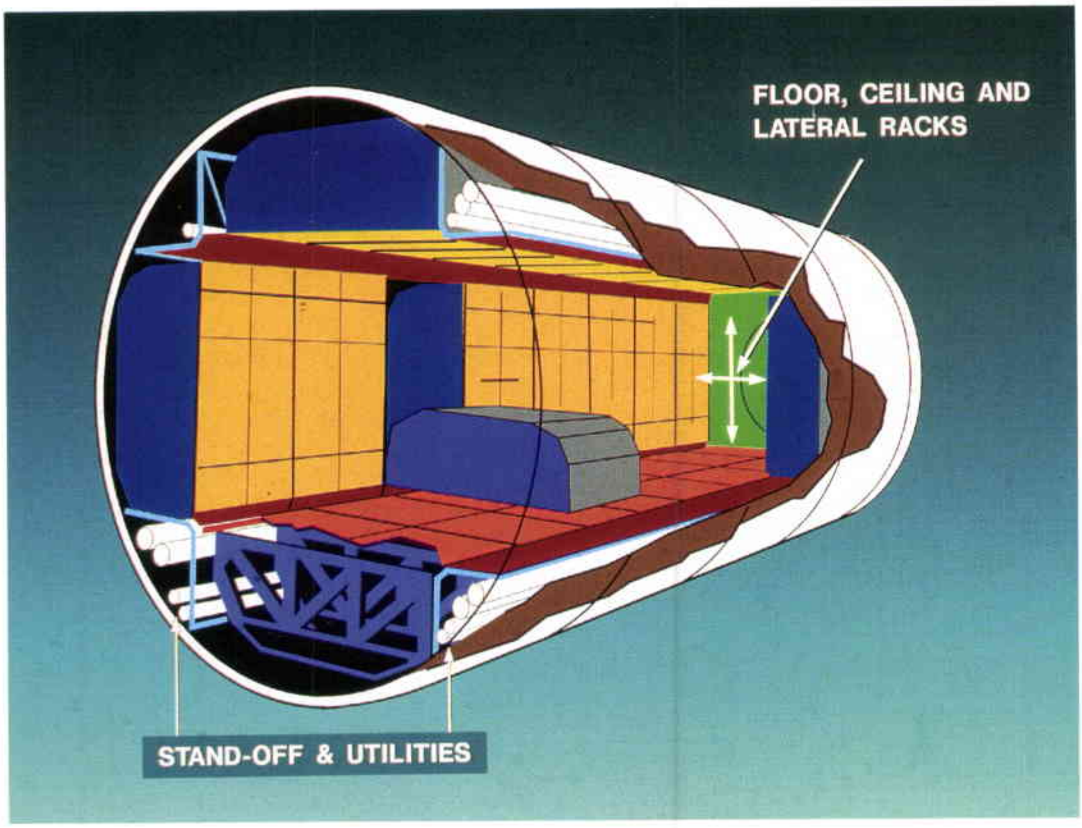


Figure 1. Layout of the interior of the Columbus Attached Laboratory

activities involved in in-orbit rack handling and transportation by the crew, and to evaluate crew support aids used to move within the Attached Laboratory's work areas. The main goal of this so-called Columbus IVA Underwater Testing (CIUT) campaign was to test those IVA tasks and to establish the importance of zero-gravity underwater simulation for future routine crew training and engineering design, development and verification. In the initial phase, the principal goal was to establish a set of procedures and a design that allow the Space Station flight crew to safely perform the on-board tasks that relate to handling, installing and removing massive payload and system racks under full control and with minimum impact on the microgravity level.

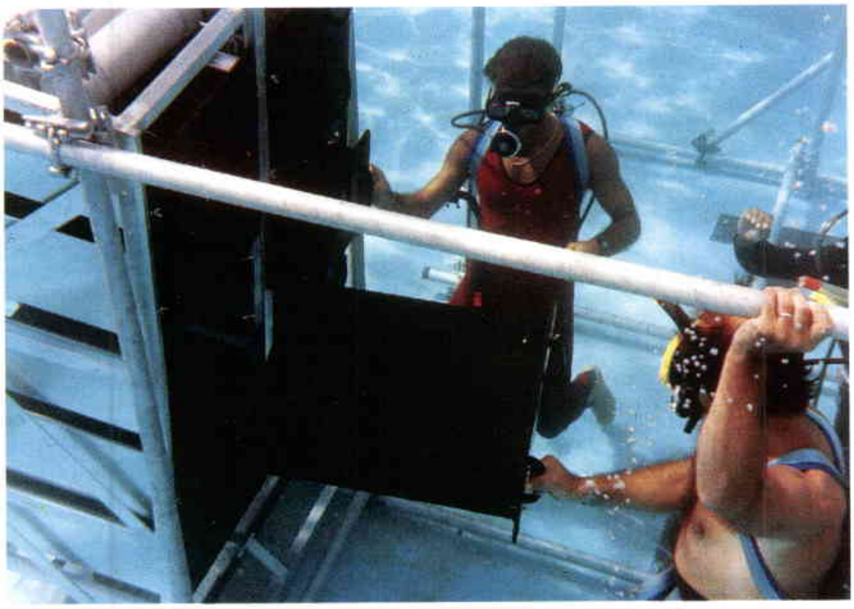


Figure 2. Team members remove a drawer from a lateral rack, while underwater as part of CIUT-1. The rack is installed in a scaffold that represents the central aisle of the Attached Laboratory

The initial test (CIUT-1)

To support the testing, the Crew Activities Office designed a submersible mock-up of the Attached Laboratory. That model incorporates only those portions of the Attached Laboratory that are relevant to the test objectives from both an engineering and a crew performance evaluation standpoint.

In August 1991, while that mock-up was being built, an initial test was carried out with a much simpler version of the Attached Laboratory, consisting of a scaffold of the type used in the construction industry to represent the module's central aisle, with a lateral rack housing. The test was conducted in a public swimming pool near ESTEC in Noordwijk, The Netherlands (Figs. 2, 3).

Objectives of CIUT-1

The following two aspects of IVA-related tasks were investigated:

- crew work-related mobility using crew support equipment such as handles, hand-rails, foot restraints, and central aisle support structures
- rack installation, maneuvering and transportation within the module's central aisle, using one or two crew members.

Four subjects participated in the test: a Spacelab D-1 astronaut, a crew systems and neutral buoyancy simulation expert, a crew operations engineer and a crew systems engineer.

Outcome of CIUT-1

Despite the very low fidelity of the mock-up used in the test, the campaign triggered some fruitful brainstorming and resulted in the refinement of objectives for future campaigns and the definition of more comprehensive tests on the Columbus design and crew operational scenario.

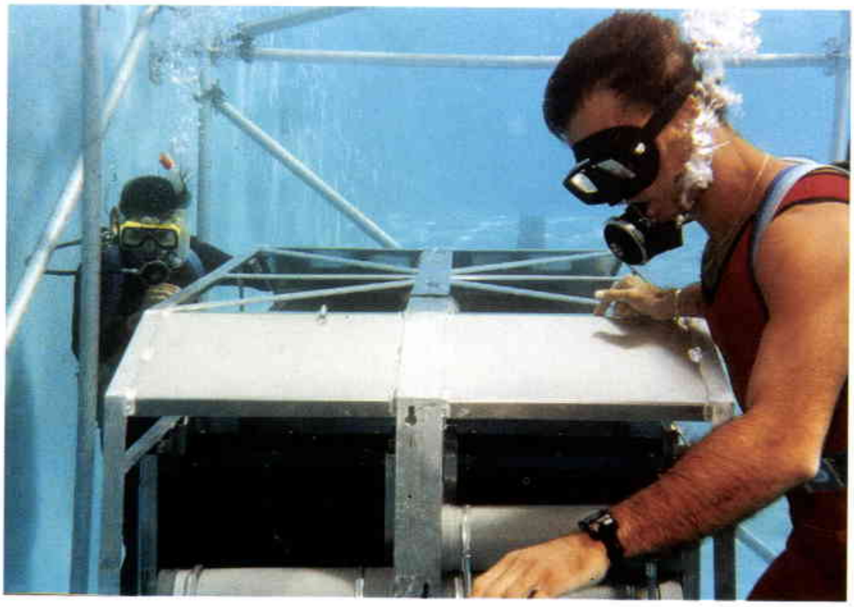


Figure 3. Team members test a rack transportation procedure as part of CIUT-1. The 500 kg mock-up of a rack is lying front-down, and parallel with the central aisle. At the bottom of the photo, three flotation tubes are visible

The following points were demonstrated:

— Since air density and dynamic viscosity are respectively approximately three and two orders of magnitude lower than water density and viscosity, water helps to both dampen out movements and perturbations, and propel the test subjects. Test subjects need to be trained to work underwater in the same way as they would work in zero-gravity: by pushing off, gliding, gently stopping and restraining themselves, but not swimming.
— Neutral buoyancy in water is always relative for the test subjects, with different parts of the body having different specific masses. Test subjects need to be trimmed as much as possible using air bags or lead weights. Breathing in and out also affects the test subject's neutrality.
— The test subject's scuba equipment can be a hindrance when the subject is working in a confined location such as a stand-off. Both the volume and the mass of the equipment must be minimised.
— Methods of hardware neutralisation, such as the use of plastic flotation tanks or polyurethane foam, need to be carefully designed with consideration given to the depth at which the underwater simulation will occur.

The above points imply that the outcome of any underwater simulation must be carefully weighed against the potential distortion factors caused by that test environment. With the inherent experience of the test subjects, proper training, and appropriate trimming of both the subject's equipment and the test hardware, acceptable test results can be obtained.

This preliminary effort confirmed the validity of and the need for such a testing exercise: this campaign can be considered as a benchmark in the Columbus development, verification and crew training programme.

The second campaign (CIUT-2)

The second test campaign was successfully conducted at Marseille (France) in the Comex company's outdoor neutral buoyancy facility, in mid-September 1991, using the mock-up of the Attached Laboratory.

A Skylab astronaut, with 84 days of experience in orbit, joined the ESA team. Alenia and MBB/ERNO witnessed the test as engineering observers from industry.

The mock-up of the Attached Laboratory consists of a stainless steel structure that represents only the necessary Attached Laboratory geometry to meet the test objectives and to provide a basis for future updating of the configuration.

This mock-up (Fig. 4) includes:

— a simulation of the Attached Laboratory corridor, approximately 6.5 m long or three-quarters of the length of the actual Attached Laboratory, i.e. six double-racks long
— a simulated end cone and hatch aperture at one end, with the other end remaining open
— a section of the external shell which is two-racks long, with a support structure (stand-off) to accommodate two racks and dummy utilities.

The walls and floor of the mock-up are made of stainless steel sheets, the ceiling of a stainless steel grid. Together they simulate the Attached Laboratory's central aisle. Wall and ceiling handrails are provided together with a floor-mounted 'banister' which runs the length of the mock-up.

The mock-up of a typical half-ton double payload rack (Fig. 2) was outfitted with 10 dummy equipment drawers, which represent the dimensions and mass of typical payload drawers. The mock-up rack must be neutralised to best simulate zero-gravity conditions: both the rack's mass must be ballasted and the rack's centre of gravity must coincide with its centre of flotation. The neutralisation process requires careful analysis and much expertise. Preliminary tests are necessary to eliminate in both rack and rack drawers any strong tendency to float or sink, by respectively adding lead bars or flotation pipes filled with air (Figs. 2 & 3), and/or polyurethane foam at appropriate locations on the structure. (NASA has been successfully using this method in other applications for the past 25 years).

To obtain neutral-buoyant dummy drawers, hollow polyethylene 'boxes' were manufactured, with a few holes measuring a half-centimetre in diameter to allow the box to fill with water thereby bringing its overall density very close to that of water and retaining at the same time the representative mass (approximately 40 kg per drawer) and inertia.

Objectives of CIUT-2

The crew tasks simulated in the CIUT-2 campaign were the following:

- transportation of a rack along the module's central aisle, from the hatch to the rack's assigned location in the Attached Laboratory, using various mobility and fixation aids, such as foot restraints, handrails and the longitudinal foot banister
- rotation, insertion, securing and tilting of a rack to install it in its housing
- insertion and removal of rack drawers
- de-installation and removal of the rack (the reverse of the first two points).

In addition, the crew members tested the lateral and rear accessibility to the rack, and accessibility to the stand-off and the shell, for maintenance purposes.

Outcome of CIUT-2

During the testing, both the engineers and the astronauts involved experienced a very steep learning curve.

The following crew-mobility-related results were obtained:

- Two central aisle longitudinal banisters (one 40 to 60 cm above the floor and the other a few centimetres below the ceiling racks) offer good support for generic crew mobility, and during work station utilisation and rack handling and transportation. They provide a fundamental 'guideline' for the crew, in particular for:
  - 'short' crewmembers (typically less than 1.85 m tall)
  - asymmetric mass transportation along the central aisle.
- Footloops are good fixation aids for stationary activities (e.g. experiment analysis or troubleshooting activities, and rack securing and release operations) but are not useful when crew movement is required (e.g. for transportation of a rack along the module's central aisle).
- Handrails installed vertically, i.e. from a ceiling corner to a floor corner at double rack pitch (parallel to the reference z-axis) provide crew members with upper body stability during local and semi-stationary activities (such as when providing one-hand 'assistance' during rack insertion or extraction, or when using equipment accommodated near a given work site). Such handrails should be connected to the stand-off (at the module quadrant corners) and not directly attached to the racks, in order to reduce microgravity disturbances.
- In addition to using different surface colours to distinguish between the floor and ceiling, orientation markings or labelling should be established to differentiate between port (left) and starboard (right) to allow crew members to orient themselves quickly, without having to rely on equipment-given clues.

Figure 4. The mock-up of the Attached Laboratory being placed in a swimming pool

The following rack-handling-related results were obtained:

- Handles and hand-grip points are necessary on various parts of the rack envelope to allow proper handling of the rack during installation and removal.
- An in-orbit rack attachment or hinge mechanism that requires the tilting of a rack to the horizontal position before rack extraction is recommended rather than the hinge-pin release mechanism and vertical method of rack extraction recommended in the baseline design document.
- When the rack is tilted outward but still hinged at the pivot point, there is adequate crew access to both the pressure shell, the stand-off and the base of the rack for all servicing and maintenance operations (Fig. 5). Crew restraints are necessary on the pressure shell to properly restrain the crew member during the tasks.
- Insertion and extraction of the rack drawers are basically easy tasks and require little training.

Figure 5. A crew member works in the 'head-down position' between a rack tilted forward and the pressure shell. His feet are restrained by footloops on the shell skin

Preparing for a campaign with the international partners (CIUT-3)

The third CIUT campaign was conducted in February 1992 in a public swimming pool near ESTEC. It was a pre-test for the first international Space Station Freedom development campaign to be conducted several months later at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, USA, with the participation of ESA, NASA and the Japanese space agency NASDA.

CIUT-3 was a follow-on to the two previous simulations. The team grew to nine members, with representation from both ESA and industry, and with experience in various engineering disciplines supported by astronaut zero-gravity experience.

The mock-up of the Attached Laboratory and the rack that were used in CIUT-2, were also used in this test. In addition, a fully equipped stand-off and a new rack reflecting the baseline design envelope and, more importantly, the launch and in-orbit rack attachment fittings, were used. The prime contractor for the Attached Laboratory, Alenia Spazio (Italy), supplied this other hardware.

Objectives of CIUT-3

In the previous tests, the method of rack installation and removal was established, however the hinge point hardware did not reflect the industrial baseline design for the Attached Laboratory or the draft procedure for rack handling. Three different, interchangeable hinge mechanisms were therefore designed and manufactured, and tested as part of CIUT-3; the most suitable one was to be selected based on the results of the test. In addition, further rack attachment fittings and access to the stand-off were to be evaluated. The goal was to establish a sound procedure for rack installation and removal, and to develop a well-trained team to support the test to be conducted at MSFC several months later.

The following are the characteristics of the three hinge mechanisms tested:

- Configuration A (Fig. 6)
  A hinge pin is mounted on the rack, on the inside of the rack post, and mates with a slotted, lockable hinge bracket that is mounted on the stand-off. This type of hinge is designed primarily for vertical rack installation from the central aisle.
- Configuration B (Fig. 7)
  A retractable hinge pin is mounted on the exterior of the rack envelope and mates with a removable hinge bracket that is mounted on the stand-off between two adjacent racks. The retractable hinge pin and removable bracket are necessary to provide sufficient clearance for the movement of the rack during the launch and landing phases. This type of hinge is also designed primarily for vertical rack installation from the central aisle.

6

7

— Configuration C (Fig. 8)
This type of hinge is a new mechanism derived from the CIUT-2 test. It consists of a hinge pin mounted on the stand-off (as opposed to on the rack as it is in Configurations A and B) and a slot in the rack. With this type of hinge, the rack is installed with the rack either partially tilted toward the floor or completely horizontal.

Outcome of CIUT-3

Two tests, the stand-off accessibility trials and the use of the rear attachment fitting, had to be deferred to the later MSFC test because of problems at the outset of CIUT-3 with the underwater assembly of the mock-up. The new test subjects required some training; three days were thus dedicated to bringing all team members to the same level of familiarity with both hardware and procedures.

The following occurred:
- Most results gathered during the CIUT-2 campaign were confirmed and validated.
- For this kind of experimental activity, a well equipped public swimming pool is sufficient to produce very valuable results, provided that representative test hardware and an experienced team are used.
- The Configuration C hinge mechanism was selected as the design baseline because it is more visible and the rack can be better controlled during insertion and extraction from the rack housing.
- The importance of having a continuous banister in order to support crew tasks along the module and possibly through the station node was again demonstrated and confirmed.

Immediately before all the hardware was shipped to the MSFC for further testing, a post-test fine tuning of the buoyancy of the Alenia rack was performed at the neutral buoyancy facility 'Valmessa' near Torino, Italy.

8

Figure 6. Configuration A hinge, with the hinge pin (behind crew member's head) on the rack and the slotted hinge bracket (in gold) on the stand-off

Figure 7. Configuration B hinge, with the retractable hinge pin on the exterior of the rack and the hinge bracket (in blue) on the stand-off

Figure 8. Configuration C hinge, with the hinge pin (in silver) on the stand-off and a slot in the rack

The first Space Station International Underwater Test: International Standard Payload Rack Neutral Buoyancy Simulation (ISPR NBS)

For the ISPR NBS test, a NASA module measuring the length of three double racks was connected to the ESA mock-up of the Attached Laboratory by a simple model of the Space Station node (Fig. 9). Such a configuration enabled ESA to add further value to the knowledge gained during the European CIUT campaigns.

The test was conducted at NASA/MSFC's 12-metre-deep Neutral Buoyancy Simulator, in May 1992. NASA and ESA engineers and astronauts, NASDA engineers, and industrial contractors participated. A long phase of data gathering and evaluation at the international level among the international partners in the Space Station project is currently underway.

Objectives of the ISPR NBS/ESA test
The team members for the European test were basically the same as for the CIUT-3 campaign. The design-related IVA operational objectives were:
— initial in-orbit set up of the configuration
— tilting up and down of the rack with utilities connected
— transport of the rack from the Attached Laboratory through the node to the NASA module and back
— two-rack traffic between the modules
— accessibility to the utilities packaging in the stand-off.

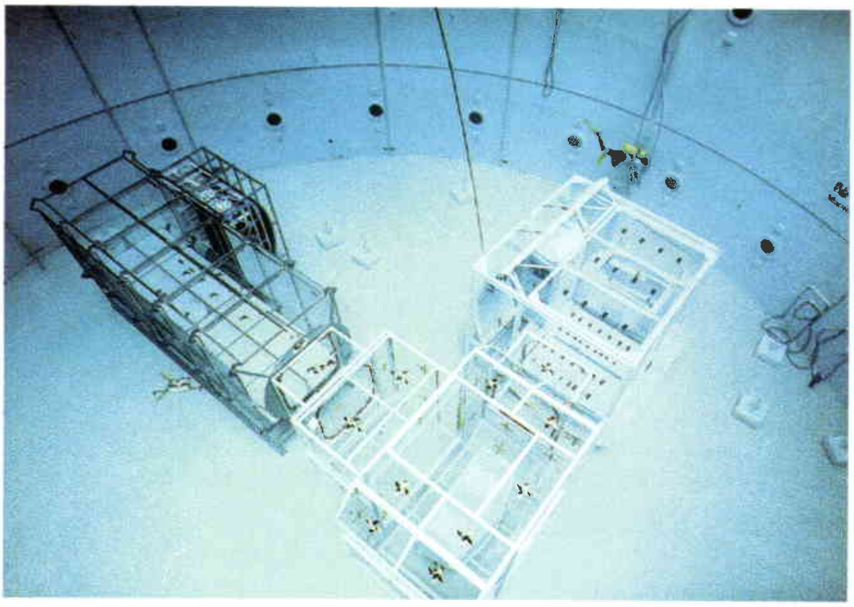


Figure 9. The mock-up of the Attached Laboratory (left) connected to the Space Station node and a mock-up of the NASA laboratory (right) for the first Space Station International Underwater Test in the NASA/MSFC Neutral Buoyancy Simulator

Similar operations were also performed using NASA hardware. Test results were to be used in the establishment of hardware standards to allow the partners (ESA, NASA and NASDA) to eventually develop intechangeable hardware, and to establish additional requirements for the Space Station crew mobility aids.

Outcome of ISPR NBS
The first international development test conducted underwater turned out to be a great success, confirming the majority of the results achieved during the ESA campaigns. In particular, the European rack hinge mechanism, the associated rack installation and removal procedure, and the crew restraint concept are to be incorporated in the overall station design.

Specific design requirements were established for the rack hinge and the rear and top attachments to allow for a large capture range, self alignment, ease of operation, good visibility and full compatibility with standard tools. It was also demonstrated that a collision of such massive racks against the pressure shell could occur during the installation procedure if the ESA-proposed hinge mechanism and the associated procedure were not implemented in all the relevant modules, including the logistics carriers.

Apart from such valuable technical input to the Space Station design and operations, this simulation helped ESA, NASA and NASDA to begin a process of joint development and verification in simulated zero-gravity conditions.

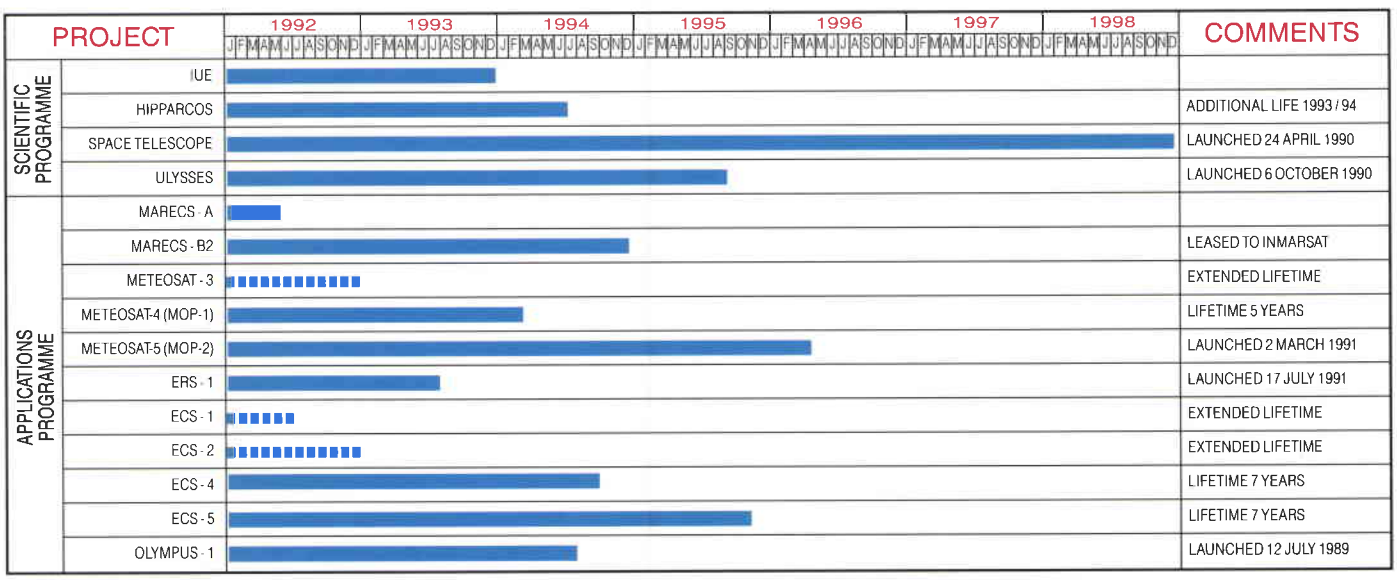
Conclusions

The test results and the valuable experience gained by ESA and European industry has clearly demonstrated that:

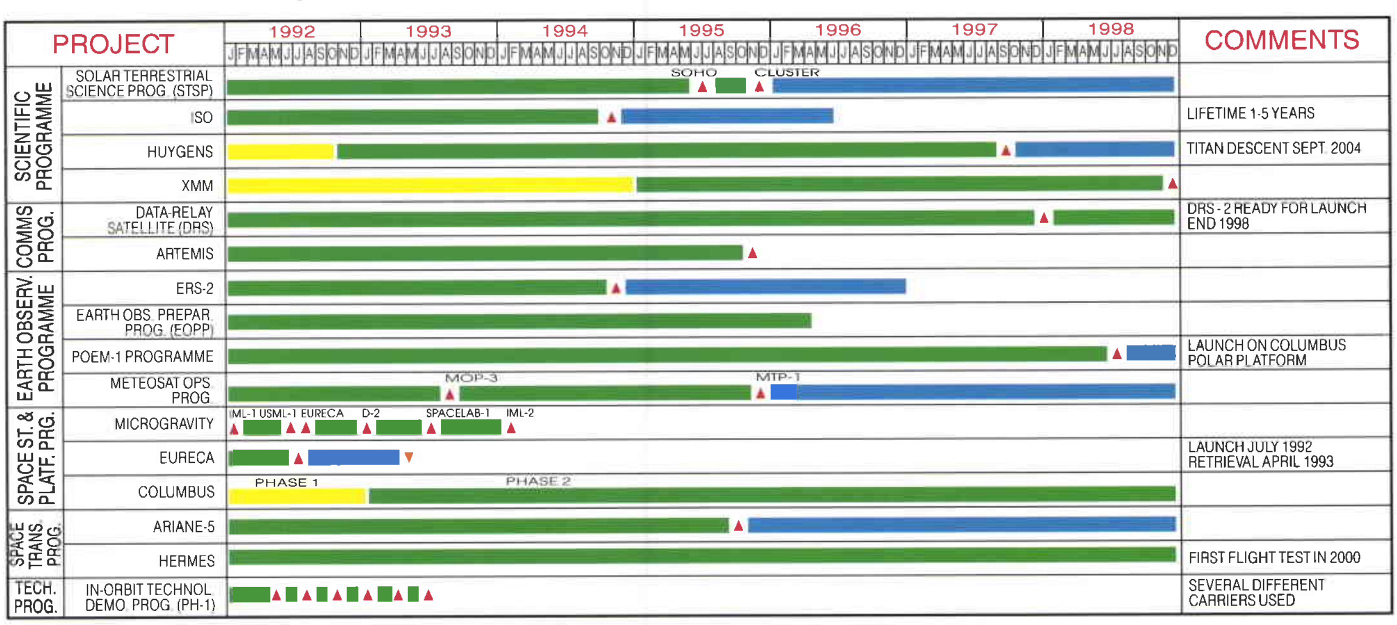
— A variety of Space Station/Columbus IVA-related design and operational aspects can be comprehensively tested in simulated zero-gravity environments, namely in underwater facilities.
— Experience in a zero-gravity environment is extremely beneficial to design engineers.
— A safe design and a fully controllable crew operation procedure for rack installation and handling with very limited zero-gravity disturbances can be achieved. A thorough understanding of the necessary crew mobility and restraint aids for the space station modules was attained during the test campaigns.
— Underwater IVA and EVA training is necessary for flight crews, particularly in support of station servicing and maintenance.
— Mission engineering support and troubleshooting during the Attached Laboratory's lifetime can be eased by performing underwater simulations (in line with the approach used in the Mir programme).
— The cost of neutral buoyancy testing can be dramatically reduced by the use of non-specialised facilities such as public swimming pools, as long as adequate test monitoring and control equipment is available.

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
OPERATIONS
MAIN DEVELOPMENT PHASE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
RETRIEVAL

Hipparcos

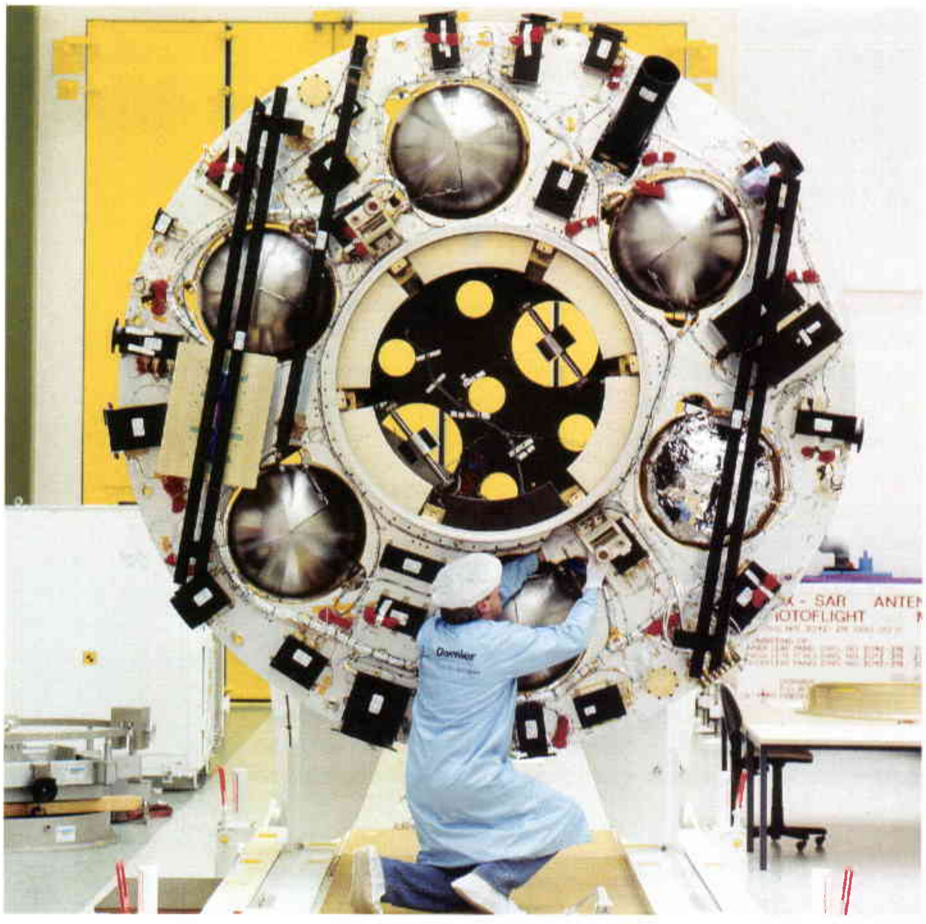
Hipparcos est parvenu au terme de deux années et demie de collecte de données scientifiques et est toujours en excellent état. Il dispose encore d'une charge utile entièrement redondante (détecteur compris). Au cours des trois derniers mois, la collecte des données est restée supérieure à 65%.

Les équipes chargées de la réduction de données ont terminé leur analyse des données de la première année de mission et ont procédé à des comparaisons croisées détaillées des résultats pris séparément; on constate une très bonne correspondance entre les deux réductions. L'analyse de la collecte des six mois suivants est en cours et devrait déboucher, fin 1992, sur un catalogue plus complet et plus précis de positions, parallaxes et mouvements propres.

Les premières communications scientifiques sur l'analyse des données ont été publiées en mai 1992 dans un numéro spécial de la revue scientifique européenne 'Astronomy & Astrophysics'.

En mai également, la Division des publications de l'ESA a publié le Catalogue d'entrée pour Hipparcos en 7 volumes (Hipparcos Input Catalogue, Réf. ESA SP-1136).

La justification scientifique d'une prolongation de l'exploitation du satellite au-delà du 31 décembre 1992, date envisagée pour la fin de la mission et à laquelle les objectifs visés devraient être atteints, a été réexaminée en mai par les instances consultatives scientifiques de l'Agence. A sa réunion de juin, le Comité du Programme scientifique a autorisé la poursuite de l'exploitation du satellite jusqu'à l'épuisement naturel des fluides qui est prévu pour la mi-1994. Avec cette prolongation, il devrait être possible d'affiner la précision des paramètres astronomiques de chacune des étoiles observées et, par conséquent, d'améliorer notablement la valeur scientifique du Catalogue Hipparcos.



Cluster structural-model spacecraft (top view)

Modèle de structure du véhicule spatial Cluster (Vu d'en haut)

ERS

ERS-1

Le fonctionnement du satellite sur le plan technique est excellent. La phase d'étude des glaces s'est terminée le 30 mars; en 4 jours, l'orbite d'ERS-1 a été modifiée pour que la récurrence du cycle passe à 35 jours en vue de la phase pluridisciplinaire. Le satellite devrait rester sur cette orbite jusqu'à fin 1993. Entre le 4 et le 13 avril 1992, on a mené à bien 40 manoeuvres de basculement en roulis du SAR; il s'agissait de faire basculer en roulis la plate-forme ERS-1 d'environ 10° pour obtenir des images sous un angle d'incidence d'environ 35°. En exploitation normale, les images SAR sont acquises sous un angle d'incidence de 23°.

Les opérations normales de la phase pluridisciplinaire ont été déclenchées le 14 avril. Depuis cette date, la mission assure notamment la couverture SAR complète des terres émergées et des zones glaciaires visibles du satellite dans le champ de réception de chaque station du réseau.

La mission globale à faible débit de transmission demeure inchangée sauf pour l'altimètre radar qui, tout en continuant à fonctionner en mode 'océan' au-dessus des mers, passe automatiquement en mode 'poursuite des glaces' au-dessus des terres émergées et des zones glaciaires. A la suite des campagnes de la phase de recette, on a modifié les algorithmes de traitement des produits à livraison rapide (FD) pour améliorer la qualité des produits 'vents' et 'vagues'. Le secteur sol d'ERS-1 continue de donner satisfaction. On constate l'excellente disponibilité de l'acquisition et du traitement des produits FD par les stations ESA d'où ils sont régulièrement transmis en temps quasi-réel à la communauté des utilisateurs.

L'installation de traitement et d'archivage (PAF) allemande et, plus récemment, la PAF britannique poursuivent le traitement en différé des images SAR. La PAF française assure la copie en mode différé et la distribution à la communauté scientifique des produits FD de l'altimètre radar et du diffusiomètre

Hipparcos

The Hipparcos satellite has now completed two and a half years of scientific data collection. It continues to be in a very healthy state, with full payload (including detector) redundancy still available. Data collection has remained at about 65 percent over the last three months.

The data-reduction teams have completed their analysis of the first year of mission data, and detailed intercomparisons of the separate results have been made, indicating a very good agreement between the two reductions. Analysis of the following six months of data is under way, and this should result in a larger, more precise catalogue of positions, parallaxes and proper motions, which is expected to be available by the end of 1992.

The first scientific papers resulting from the data analysis have appeared in a dedicated issue of the European scientific journal 'Astronomy & Astrophysics' in May 1992. The seven-volume Hipparcos Input Catalogue, ESA SP-1136, was also published by ESA Publications Division at the end of May.

The scientific case for extending the satellite operations beyond the foreseen date of 31 December 1992 (at which time the original target goals for the mission should have been achieved), was reviewed by the Agency's scientific advisory bodies in May. The Science Programme Committee, at its June meeting, authorised the continuation of mission operations until the natural exhaustion of the satellite consumables, expected around mid-1994. This continuation of operations is expected to yield an improvement in the accuracy of the astrometric parameters of each of the programme stars, with a correspondingly significant improvement in the scientific value of the resulting star catalogue.

ERS

ERS-1

The technical performance of the satellite has remained excellent. The ice phase was successfully completed on 30 March and the satellite was transferred within 4 days to the 35 day orbit repeat cycle of the multidisciplinary phase. It is planned to keep ERS-1 in this orbit repeat cycle until the end of 1993. In the period 4–13 April 1992, 40 SAR roll-tilt operations were successfully performed (i.e. a roll–tilt of the ERS-1 platform by about 10°, permitting the acquisition of SAR images at an incident angle of about 35°. In nominal operation, SAR images are acquired at 23° incidence angle).

Since 14 April, the nominal operations of the multi-disciplinary phase have been activated. In particular, complete SAR coverage of the land and ice zones within visibility of the ERS-1 station network is being acquired.

The global low-rate mission remains unchanged except for the Radar Altimeter which, whilst still operating in ocean mode over the oceans, is switched automatically to ice-tracking mode over land and ice zones. As a result of the Commissioning-Phase campaigns, the fast-delivery processing algorithms are being updated to improve wind and wave product quality. The ERS-1 ground segment has continued to operate nominally. There has been excellent availability of acquisition and fast-delivery processing at the ESA stations, with fast-delivery products being regularly disseminated in near-real-time to the user community from these stations.

SAR-image offline processing has continued to be provided by the German PAF (Processing and Archiving Facility) and, more recently, the UK-PAF also. The French PAF has supported offline copying and distribution of Radar Altimeter and Wind Scatterometer FD products to the scientific community, in parallel with the acceptance-testing of the offline processing chain.

All of the national and foreign stations have continued to acquire and archive SAR data within their coverage zones. SAR images have been produced at Tromsø, Fairbanks and the two Canadian stations.

The ERSC Consortium has started registering commercial orders, which are presently being processed through the ERS-1 ground segment.

ERS-2

ERS-2 continues to progress on schedule, with no major technical problems to report. Integration and testing of the instrument subsystems has started.

Development of GOME, the new ozone-monitoring experiment, is progressing satisfactorily, following consolidation of the technical baseline and agreement with industry on the framework for the main development (Phase-C/D) contract.

Negotiations with Arianespace regarding the launch of ERS-2 have been proceeding successfully, and the launch contract is expected to be signed in June/July.

Cluster

The structural-model spacecraft has undergone successful vibration and acoustic qualification testing at IABG in Munich (D), following static load tests at CESTA in Bordeaux (F). The remainder of the structural-model programme is dedicated to confirming the Ariane/Apex launch-configuration qualification as a stack of two spacecraft.

The engineering-model programme has commenced with the harness integration. Other subsystems are due for integration during July and August, and payload integration will commence in September. The schedule has slipped by some two months, but this is not expected to have an impact on the overall programme.

The engineering-model payload units are all on schedule and the overall payload is within its allocated mass and power resources.

The Cluster Science-Data System is progressing on schedule, with Hungary being accepted as the latest partner in the network. At the June meeting of ESA's Science Programme Committee (SPC), approval was given for manpower to staff the Joint Science Operations Centre and the Science 'vents'; simultanément, elle procède aux essais de recette de la chaîne de traitement en différé.

Toutes les stations nationales et étrangères ont continué à acquérir et archiver les données SAR dans leur zone de couverture. Tromsø, Fairbanks et les deux stations canadiennes ont produit des images SAR.

Le consortium ERSC a commencé à enregistrer des commandes commerciales qui sont actuellement traitées par le secteur sol ERS-1.

ERS-2

La réalisation d'ERS-2 se poursuit conformément au calendrier sans que l'on signale de difficulté technique majeure. L'intégration et les essais de sous-systèmes d'instruments ont commencé.

La mise au point de GOME, la nouvelle expérience de surveillance de l'ozone, progresse de manière satisfaisante après la consolidation de la référence technique et l'accord avec l'industrie sur le contrat principal de réalisation (phase-C/D).

Les négociations avec Arianespace sur le lancement d'ERS-2 se sont poursuivies de manière satisfaisante; le contrat de lancement devrait être signé en juin ou juillet.

Cluster

Le modèle structurel du véhicule spatial a subi avec succès, chez IABG à Munich (D), les essais de qualification acoustique et en vibration, qui ont été suivis par des essais de charge statique chez CESTA à Bordeaux (F). Le reste du programme de modèle structurel est destiné à confirmer la qualification de la configuration de lancement Ariane/Apex avec superposition des deux véhicules spatiaux.

Le programme du modèle d'identification a commencé par l'intégration des câblages. D'autres sous-systèmes doivent être intégrés pendant les mois de juillet et août et l'intégration de la charge utile commencera en septembre. Le calendrier a glissé d'environ deux mois mais ce retard ne devrait pas avoir d'incidence sur le programme dans son ensemble.

Les modèles d'identification des éléments de charge utile n'ont aucun retard sur le calendrier et l'ensemble de la charge utile reste dans les limites des ressources électriques et de la masse imparties.

Le système de données scientifiques de Cluster progresse conformément au calendrier, la Hongrie étant le dernier en date des partenaires accepté dans le réseau. Lors de sa réunion de juin, le Comité du Programme scientifique (SPC) a approuvé les effectifs nécessaires au fonctionnement du Centre conjoint d'opérations scientifiques et du Centre de soutien de l'analyse scientifique qui seront tous deux installés au RAL (Royaume-Uni). Les autres participants au réseau de données distribué sont la France, l'Allemagne, la Suède, l'Autriche et les Etats-Unis.

Dans le cadre de la coopération internationale, l'Agence met au point une unité de mémoire de masse de 1 Gbit à embarquer sur le véhicule spatial MARS-94 de la CEI. Ces unités de mémoire sont mises au point par Dornier en coopération avec l'Agence spatiale allemande (DARA), la gestion du projet étant assurée par l'équipe Cluster de l'ESA.

ISO

Instruments scientifiques

Après que la recette du modèle de vol de l'instrument scientifique ISOPHOT ait été menée à bien, celui-ci a été stocké. Le consortium ISOPHOT concentre maintenant ses efforts sur l'achèvement du modèle de vol de rechange, dont les caractéristiques seront meilleures.

Les modèles de vol d'ISOCAM, la caméra infrarouge, et du spectromètre ondes longues sont prêts à être livrés. Le détecteur du spectromètre ondes courtes rencontre des problèmes qui sont à l'étude. Les exemplaires de rechange des instruments sont tous en cours d'assemblage, à l'exception de celui d'ISOCAM: l'approvisionnement du rechange de vol requis est toujours à l'étude.

Satellite

Le modèle de développement du module de charge utile a été ouvert et on en a extrait le modèle de qualification du télescope. Le module de charge utile et le télescope sont en bon état, après avoir subi des essais mécaniques et thermiques approfondis l'an passé. L'intégrité du télescope reste encore à vérifier au moyen de mesures d'alignement et de qualité d'image. Le module de charge utile sera également utilisé pour des essais d'alimentation cryogénique à l'intérieur d'une maquette de la coiffe du lanceur Ariane.

Les travaux sur le matériel de vol du module de charge utile ont été retardés en raison de deux contretemps majeurs: d'une part, le télescope du modèle de vol a dû être refusé en raison de la contamination et des imperfections trop importantes du miroir primaire, et d'autre part, des anomalies ont été observées dans le comportement des vannes d'hélium liquide lors des essais de qualification. Le télescope du modèle de vol est réassemblé avec le miroir primaire de rechange et toutes les précautions possibles sont prises pour réduire le risque de contamination. La conception des vannes et les résultats des essais ont été revus en détail et les modifications nécessaires sont apportées avant de reprendre les essais. Compte tenu de la gravité du problème des vannes pour ce projet, plusieurs solutions sont envisagées, dont la préparation d'un modèle de remplacement et la recherche d'autres fournisseurs potentiels de vannes.

L'intégration du module de servitude de vol se déroule de façon satisfaisante, de même que les essais du sous-système de commande d'orientation. Les problèmes principaux se rapportent aux retards de livraison du calculateur de commande d'orientation, du suiveur d'étoiles et des gyroscopes.

Le calendrier du projet est totalement subordonné aux échéances relatives

Analysis Support Centre, both of which will be hosted by RAL in the UK. Other participants in the distributed data network are France, Germany, Sweden, Austria and the USA.

Within the framework of international co-operation, the Agency is developing a 1 Gbit mass memory unit to fly on the CIS's Mars 94 spacecraft. The units are being developed in co-operation with the German Space Agency (DARA) by Dornier, with project management from within ESA's Cluster team.

ISO

Scientific instruments

The flight model of the ISOPHOT scientific instrument has successfully completed its acceptance testing and is now in storage. The ISOPHOT Consortium is now concentrating its efforts on completing the flight-spare model, which will have better performance.

The flight models of ISOCAM, the infrared camera, and the Long-Wavelength Spectrometer are ready for delivery. The Short-Wavelength Spectrometer has detector problems which are currently being investigated. Instrument-spare units are all being assembled, with the exception of ISOCAM, where provision of the requisite spare is still being investigated.

Satellite

The payload-module development model has been opened and the qualification-model telescope removed. Both the payload module and the telescope are in good condition after extensive mechanical and thermal testing during the last year. The integrity of the telescope has still to be verified by measurements of its alignment and image quality. The payload module will be further used to perform cryogenic-servicing trials inside a mock-up of the Ariane launcher fairing.

Progress on the payload-module flight hardware has suffered two major setbacks: firstly, the flight-model telescope had to be rejected due to excessive contamination and blemishes on its primary mirror; and secondly the liquid-helium valves behaved anomalously during qualification testing. The flight-model telescope is being re-built using the spare primary mirror and all possible precautions are being taken to reduce the risk of contamination. The valve design and test results have been reviewed in detail and the necessary changes are being implemented prior to re-testing. In view of the very high criticality of the valve problem to the project, several alternatives are being pursued, including preparation of a back-up design and a search for other possible valve suppliers.

The flight-model service module integration is proceeding satisfactorily, as is the testing of the attitude-control subsystem. The main problems lie in the delays encountered with the attitude-control computer, star tracker, and gyroscopes.

The project schedule is totally dependent on the schedules for the telescope and the liquid-helium valves. The telescope involves an eight-month delay, while the absence of qualified valves does not allow a reliable schedule prediction. All project efforts are geared towards obtaining suitable qualified valves in the Autumn and reviewing the project schedules in parallel.

Ground segment

Progress on the ground segment is satisfactory. Recent tests with the scientific instrument command stations and with a satellite radio-frequency transponder model have demonstrated their compatibility with the ground segment.

Huygens

Project activities in the USA have been concentrating on Cassini/Huygens mission and Cassini Orbiter spacecraft redesign to accommodate both the 1997 launch date introduced for budgetary reasons, and the spacecraft mass reduction of approximately 2000 kg due to a revision of the launcher configuration. On both fronts, the redesign efforts and results have been well received and confidence in completion of the mission in its present form is good.

European activities have been directed at completion of preliminary designs for all Probe subsystems as precursors to the preparation of offers for the Probe system development and manufacturing phase (Phase-C/D), and the System Design Review which will, inter alia, examine at Agency level, the actual design status of the Probe system. Certain advanced development tasks have also been running in parallel, devoted mainly to the evaluation and testing of those areas of technology that are by and large new to European space industry, such as parachute deployment at supersonic velocities and thermal protection for atmospheric entry and the associated huge heat fluxes. The results achieved at this early stage are encouraging.

EOPP

Aristoteles

The final presentation of the industrial ESA/NASA Cooperative Project Definition (Phase-A), led by Alenia Spazio, took place on 23 April. It was followed on 24 April by the final presentation by ONERA on the Accelerometer Pre-development Contract.

As a reflection of their very high scientific interest in this project, NASA has offered to increase their contributions to the programme. The Programme Proposal will be presented to potential participants on 19 June.

Meteosat Second Generation

Work on the satellite definition process continues through the Phase-A studies led by Aerospatiale (F) and Matra Marconi Space (UK). The Phase-A for the primary imaging instrument was completed in March. The plan is now to address critical development issues.

Meanwhile, progress has been made in defining the methodology for a cooperative development programme with Eumetsat, and a Programme Proposal is under preparation.

Low-Earth-Orbit (LEO) missions

Technical, technological and scientific

au télescope et aux vannes d'hélium liquide. Le retard imputé au télescope est de 18 mois, tandis que l'absence de vannes qualifiées ne permet pas de faire des prévisions fiables. Tous les efforts de l'équipe projet visent à obtenir à l'automne des vannes appropriées qualifiées et à revoir en parallèle le calendrier du projet.

Secteur sol

Les travaux sur le secteur sol progressent de façon satisfaisante. Des essais récents menés sur les stations de télécommande des instruments scientifiques et sur un répéteur RF de satellite ont montré leur compatibilité avec le secteur sol.

Huygens

Aux Etats-Unis, les activités relatives à ce projet ont été axées sur le remaniement du concept de la mission Cassini/Huygens et de l'orbiteur de Cassini afin de prendre en compte d'une part le report du lancement à 1997 pour des raisons budgétaires et d'autre part la réduction de masse du véhicule spatial, d'environ 2000 kg, imposée par la révision de la configuration du lanceur. Qu'il s'agisse de l'une ou l'autre contrainte, les travaux de remaniement et leurs résultats ont été accueillis dans un esprit constructif et l'on s'attend à pouvoir mener à bien la mission sous sa forme actuelle.

De leur côté, les Européens ont travaillé à terminer les concepts préliminaires de tous les sous-systèmes de la sonde qui serviront de base de départ pour la préparation des offres de la phase de développement et de fabrication du système de la sonde (phase-C/D) ainsi que pour la revue de conception système qui permettra notamment d'examiner au niveau de l'Agence l'état de la conception du système de la sonde. Certains travaux de développement se sont déroulés en parallèle; ils ont surtout été axés sur l'évaluation et l'essai des domaines technologiques qui sont généralement nouveaux pour l'industrie spatiale européenne, comme le déploiement de parachutes à des vitesses supersoniques et la protection thermique nécessaire en cas de rentrée atmosphérique en raison des formidables flux thermiques correspondants. Les résultats obtenus à ce stade précoce sont encourageants.

EOPP

Aristoteles

La présentation finale de la définition industrielle du projet de coopération ESA/NASA (phase-A), dirigée par Alenia Spazio, s'est tenue le 23 avril. Elle a été suivie le 24 d'une présentation finale du contrat de pré-développement de l'accéléromètre par l'ONERA.

En témoignage du très vif intérêt scientifique qu'elle porte à ce projet, la NASA a proposé d'augmenter sa contribution au programme. La proposition de programme sera présentée aux Participants potentiels le 19 juin.

Météosat deuxième génération

Le processus de définition du satellite se poursuit pendant toute la durée des études de phase-A réalisées par l'Aérospatiale (F) et Matra Marconi Space (R-U).

La phase-A du principal instrument imageur s'est terminée en mars. Il est maintenant prévu d'aborder les problèmes de développement critiques.

Pendant ce temps, on a fait avancer la définition de la méthodologie applicable à un programme de développement en coopération avec Eumetsat et une proposition de programme est en préparation.

Missions sur orbite terrestre basse

Les études techniques, technologiques et scientifiques d'un certain nombre de futurs instruments candidats se poursuivent. On commence d'ores et déjà à préparer les études de phase-A d'éventuelles missions faisant suite à POEM-1.

Campagnes

La campagne SAREX-92 au-dessus des forêts tropicales sud-américaines s'est terminée en avril de façon satisfaisante. Les résultats préliminaires montrent que la qualité des données est très bonne. Leur transcription est en cours.

Programme préparatoire POEM-1

Etudes de phase-B du système et des instruments

Les activités de phase-B du maître d'oeuvre sont presque terminées. La revue du concept de référence se tiendra début juin afin d'examiner les résultats de la phase-B.

Les activités de conception de phase-B portant sur les instruments (EFI) sont elles aussi presque achevées.

Les revues des concepts de référence ont commencé à la mi-avril pour l'ASAR et l'ASCAT et se sont poursuivies en mai avec celles de RA-2 et de MIPAS. Les revues de l'AMI, de MERIS et de GOMOS sont fixées au début juin. Le cycle complet des revues des concepts de référence devrait être achevé d'ici la mi-juillet.

Eumetsat a été invité à examiner officiellement la conformité de sa réponse technique et programmatique aux impératifs de l'Agence.

Les documents de contrôle des interfaces des instruments de l'avis d'offre de participation ont été préparés et soumis aux fournisseurs des instruments pour commentaires.

Instrument MIMR

La phase-B du MIMR est en cours; elle prend pour base de référence l'installation de cet instrument à bord du véhicule spatial EOS de la NASA. Un avenant au contrat sera conclu sous peu afin d'étudier la possibilité d'une installation du MIMR à bord de la plate-forme polaire européenne.

Secteur sol

L'évaluation de la proposition a pris fin et le Comité de la politique industrielle (IPC) de l'Agence a approuvé fin mai l'attribution du contrat à Logica.

Programme POEM-1

La Déclaration relative à POEM-1 est en cours de souscription et l'on studies continue for a number of possible future instruments. Work is now being initiated to prepare Phase-A studies for possible follow-ons to the POEM-1 mission.

Campaigns

The SAREX-92 campaign over the South American rain forests was successfully completed in April. Initial results indicate very high data quality. Data transcription is now in progress.

POEM-1 Preparatory Programme

System and instrument Phase-B studies

The mission Prime Phase-B activities are almost complete. The Baseline Design Review of the Phase-B results will be held in early June.

The Phase-B design activities for the instruments (EFI) are also nearly complete. The Baseline Design Reviews (BDRs) were initiated in mid-April for ASAR and ASCAT, followed in May by those for RA-2 and MIPAS. The AMI, MERIS and GOMOS reviews are scheduled for early June. The full BDR review cycle is expected to be completed by mid-July.

Eumetsat has been requested to support a formal review of their technical and programmatic response to the Agency's requirements.

Interface control documents for Announcement of Opportunity instruments have been prepared and submitted to the instrument providers for comment.

MIMR instrument

The MIMR Phase-B, baselined on accommodation onboard the NASA-EOS spacecraft, is in progress. A contract rider will be released shortly for study of the accommodation of MIMR onboard the European Polar Platform.

Ground segment

Proposal evaluation has been completed and at the end of May the Agency's Industrial Policy Committee (IPC) approved the award of the contract to Logica.

POEM-1 Programme

Subscriptions to the POEM-1 Declaration are being received and it is hoped that the necessary level of contributions will be reached in time to allow the planned kick-off of the industrial contract to take place in early July.

A Request for Quotation (RFQ) for the main development phase (Phase-C/D) of the POEM-1 Programme was released to industry in early April. Proposals for the first phase (C1), which is intended to last until the beginning of 1993, were received at the end of May.

Meteosat

Spacecraft

A de-commissioning review of Meteosat-2 was held in ESTEC in April to assess the adequacy of the final manoeuvres and configuration of the spacecraft, which is now drifting in an orbit more than 300 km above the geostationary arc. The Board recommended that, aside from minor points, the procedure used can be applied to the future de-orbiting of other Meteosats.

Launch of the new Meteosat, MOP-3, the last flight unit in the Meteosat Operational Programme, is scheduled for the second half of 1993.

The industrial work for the follow-on programme, the Meteosat Transition Programme, is progressing according to schedule, with the aim of launching the first unit, MTP-1, in late 1995.

LASSO

The accurate transfer of time between two ground stations with an accuracy of better than 1 ns via a geostationary satellite was first proposed for Sirio-2. When that spacecraft was lost due to a launch failure, the experiment was re-proposed for Meteosat-P2 (now renamed Meteosat-3).

The experiment was proposed to have two phases: first to demonstrate the time transfer between European stations; and secondly to demonstrate it between Europe and the United States.

The first phase was completed successfully in 1991 between stations in Grasse (F) and Graz (A). The second phase is now underway with the spacecraft stationed at 50°W for the meteorological Atlantic Data Coverage mission. In April, during a 10 min session between the station in Grasse and one in Texas, sufficient information was passed to demonstrate the time transfer, and the experiment is continuing.

Microgravity

After the very successful operation of the Biorack – its first reflight after the Spacelab-D1 mission – and the Critical-Point Facility onboard the Space Shuttle 'Discovery'/Spacelab during the first International Microgravity Laboratory (IML-1) mission at the end of January, ESA has been supporting the final-testing, crew-training and mission-preparation activities for its Glove Box for the 13 day US Microgravity Laboratory (USML-1) mission scheduled for launch on 25 June 1992 onboard Space Shuttle 'Columbia'. The Glove Box has been made available to NASA for the execution of 16 US experiments; in return, ESA will be given two free flight opportunities for its Advanced Protein Crystallisation Facility in the Shuttle's Mid-deck Lockers.

All experiment samples for the Eureca microgravity core payload, except protein samples, were prepared in Europe. Their installation in their respective instruments on Eureca was supported at Kennedy Space Center (KSC). Protein samples, because of their sensitivity to degradation, will only be prepared after final confirmation of the Eureca launch date. They will then be installed on the launch pad about 65 h before the Shuttle's launch.

espère que le niveau de contributions nécessaire sera atteint en temps voulu pour permettre le démarrage du contrat industriel début juillet comme prévu.

Une demande de prix portant sur la phase de développement proprement dite (C/D) du programme POEM-1 a été adressée à l'industrie début avril. Les propositions relatives à la première phase (C1), qui doit durer jusqu'au début de 1993, ont été reçues fin mai.

Météosat

Les véhicules spatiaux

Lors d'une revue de mise hors circuit de Météosat-2 tenue à l'ESTEC en avril, on a évalué les dernières manoeuvres et la configuration du satellite qui dérive aujourd'hui sur une orbite située à plus de 300 km au-dessus de la zone géostationnaire. Le Conseil directeur a recommandé qu'à l'avenir cette procédure, à l'exception de quelques points mineurs, soit appliquée à la mise sur orbite de dégagement des autres satellites Météosat.

Le lancement de MOP-3, dernière unité de vol du Programme Météosat Opérationnel, est prévu pour le second semestre 1993.

Les travaux menés par l'industrie dans le cadre du programme de suivi, Programme de transition Météosat, progressent conformément au calendrier; la première unité de cette série, MTP-1, devrait être lancée fin 1995.

LASSO

Le transfert entre deux stations sol, via un satellite géostationnaire, de signaux horaires avec une précision meilleure que 1 ns avait été proposé pour la première fois pour Sirio-2. Ce satellite ayant été perdu à la suite d'un échec du lancement, il a été proposé de conduire cette expérience sur Météosat-P2 (aujourd'hui rebaptisé Météosat-3).

Cette expérience devait se dérouler en deux parties: démontrer, tout d'abord, le transfert de signaux horaires entre stations européennes puis entre l'Europe et les Etats-Unis.

La première phase a été menée à bien en 1991 entre Grasse (F) et Graz (A). La seconde phase est en cours d'exécution, le satellite étant à poste à 50° ouest pour sa mission de couverture météorologique de l'Atlantique. En avril, lors d'une session de dix minutes entre la station de Grasse et une station située au Texas, le volume d'informations transmis a été suffisant pour démontrer la validité de l'expérience de transfert qui se poursuit.

Microgravité

Après la mise en oeuvre parfaite du Biorack – c'était la première fois qu'il repartait dans l'espace après la mission Spacelab D1 – et de l'installation Point critique embarqué sur le Spacelab, à bord de la Navette spatiale 'Discovery', lors de la première mission du Laboratoire international de microgravité (IML-1) exécutée fin janvier, l'ESA a apporté son concours aux derniers essais et aux activités d'entraînement de l'équipage et de préparation de la mission portant sur sa Boîte à gants en vue de la mission de 13 jours du Laboratoire américain de microgravité (USML-1) dont le lancement devait avoir lieu le 25 juin 1992, sur la Navette spatiale 'Columbia'. En contrepartie de la mise à disposition de sa Boîte à gants qui permettra à la NASA de conduire 16 expériences américaines, l'ESA se verra accorder deux occasions de vol à titre gratuit pour son Installation de point de cristallisation de protéines dans les casiers de la cabine de l'équipage de la Navette.

Tous les échantillons des expériences destinées au noyau de la charge utile de microgravité d'Eureca, mis à part les échantillons de protéines, ont été préparés en Europe. Un soutien a été apporté pour leur installation dans les instruments correspondants d'Eureca, au Centre spatial Kennedy (KSC). Très sensibles à la dégradation, les échantillons de protéines ne seront préparés qu'après confirmation définitive de la date du lancement d'Eureca. On procèdera alors à leur mise en place, sur la plate-forme de lancement, environ 65 heures avant le lancement de la Navette.

Eureca

Entre la mi-février et la mi-mai, tous les instruments scientifiques réétalonnés ont été réintégrés sur la plate-forme. Le fonctionnement du modèle de vol entièrement intégré a ensuite fait l'objet d'une nouvelle vérification, puis Eureca a été chargée en ergols et mise sous pression. Le système Eureca en parfaite configuration de vol a ensuite été transféré de l'installation d'intégration d'Astrotech au centre d'assemblage vertical du Centre spatial Kennedy (KSC) pour vérification supplémentaire des interfaces Navette/Eureca.

En ce qui concerne les opérations, les ingénieurs ESA et NASA de l'ESOC et du Centre d'opérations spatiales Johnson s'occupent de la mise au point définitive et de l'essai des opérations en vol du composite Navette/Eureca. Les simulations de vol communes NASA/ESA, qui représentent la majeure partie de ces activités, témoignent jusqu'à présent d'une excellente coopération entre le Centre de Houston et l'ESOC.

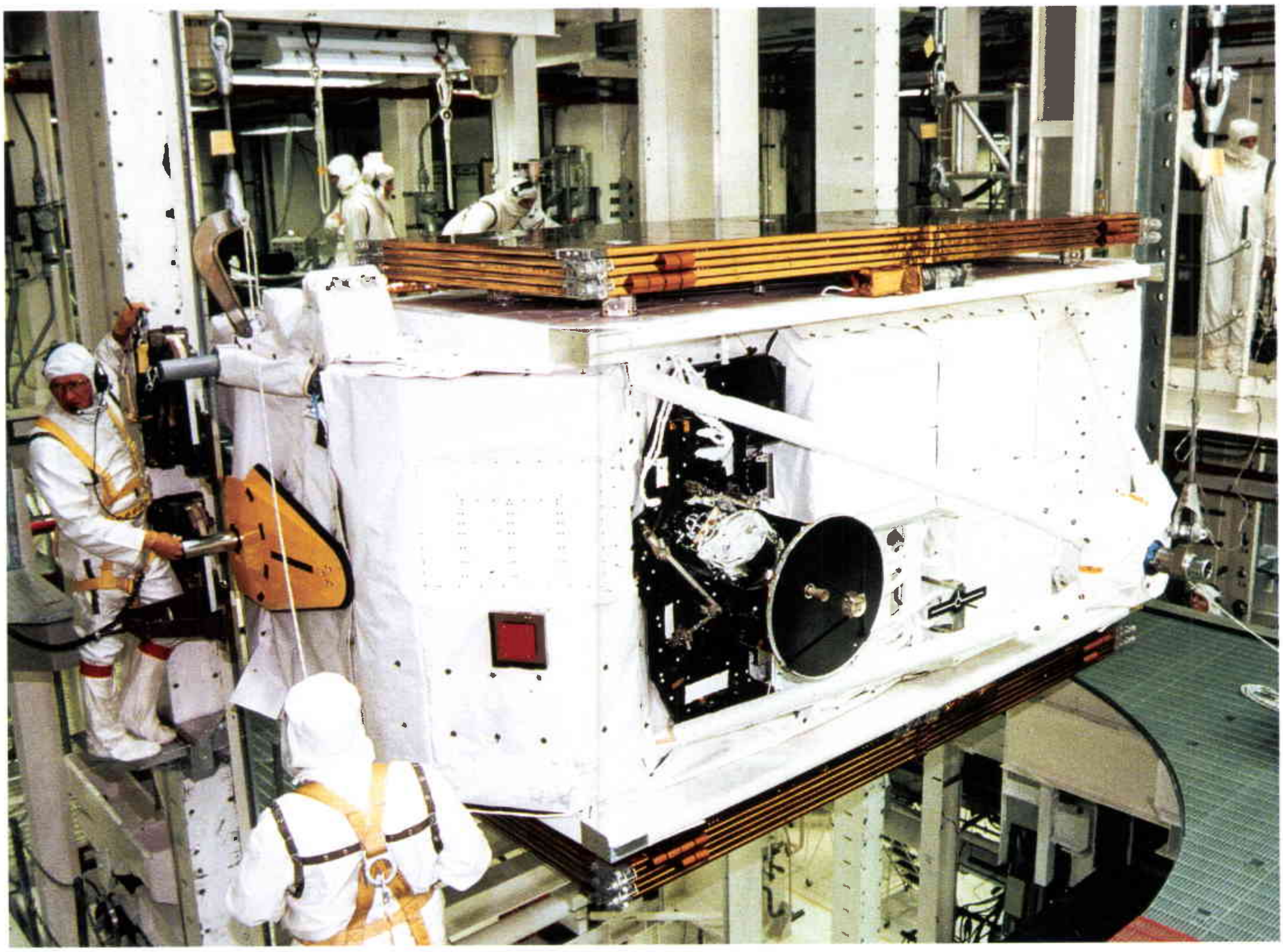
Toutes ces activités préparatoires visent un lancement le 16 juillet à bord de la Navette spatiale 'Atlantis' (vol STS-46). Il est actuellement prévu de récupérer Eureca le 22 avril 1993.

Dans le cadre du Programme de vols précurseurs Columbus, et dans l'attente d'une décision du Conseil de l'ESA, deux autres vols sont prévus à ce jour en 1995 et 1997.

Plate-forme polaire

Les activités industrielles se sont poursuivies de manière à ce que le développement de la plate-forme polaire progresse conformément au calendrier de référence et notamment que la Revue de conception préliminaire du système puisse se tenir en octobre.

Les activités de conception détaillée ont avancé de façon satisfaisante à tous les niveaux et nombre de revues se sont tenues au niveau des équipements et sous-systèmes.



Eureca being prepared for launch at Kennedy Space Center

Préparation d'Eureca au lancement du Centre spatial Kennedy

Eureca

Between mid-February and mid-May, all recalibrated scientific instruments were re-integrated onto the spacecraft. Subsequently, the performance of the fully integrated flight configuration of Eureca was re-verified. Thereafter Eureca was fuelled and pressurised. The fully flight configured Eureca system was then transferred from the Astrotech integration facilities to the Vertical Processing Facility at Kennedy Space Center (KSC), for further Shuttle/Eureca interface verification.

On the operations side, activities to finalise and test the joint Shuttle and Eureca flight operations are now occupying the ESA and NASA engineers at the Johnson and ESOC Space Operations Centres. The joint NASA/ESA flight simulations, which are a major part of these activities, have so far reflected excellent cooperation between the Houston and ESOC Centres .

All of these preparatory activities are now targetted towards a launch on 16 July aboard Space Shuttle 'Atlantis' (flight STS-46). Retrieval is currently planned for 22 April 1993.

As part of the Columbus Precursor Flight Programme, pending a decision by the ESA Council, two further flights of Eureca are currently planned in 1995 and 1997.

Polar Platform

Industrial activities have continued to progress the Polar Platform's development in line with the baseline schedule and, in particular, with the objective of holding the System Preliminary Design Review in October.

The detailed design activities at all levels have progressed well and a number of equipment- and subsystem-level reviews have been held.

Following the decision to embark the Dual-Mode Transponder (which allows command and control via DRS), an accommodation study has been carried out.

The full-scale configuration mock-up of the Polar Platform and its equipment have been completed. It will be used to define harness routings as well as to investigate and validate integration/interface procedures.

Manufacture of mechanical ground-support-equipment items has continued.

Parts lists for payload-module long-lead-time items items have been consolidated in preparation for the placing of orders in the near future.

Suite à la décision d'emporter le répéteur double mode (qui permet commande et contrôle via le satellite de relais de données, DRS), il a été conduit une étude de 'logeabilité'.

La maquette en vraie grandeur de la plate-forme polaire et de ses équipements est terminée. Elle servira à déterminer le tracé des câblages ainsi qu'à étudier et à valider les procédures d'intégration et d'interface.

La fabrication d'éléments des équipements de soutien sol mécaniques s'est poursuivie.

Pour le module de charge utile, les listes de pièces des éléments à longs délais de livraison ont été consolidées en préparation des commandes qui doivent être passées prochainement.

Des réunions d'interface se sont tenues avec Arianespace afin de consolider les documents d'interface. En outre, un petit contrat a été attribué à Arianespace pour couvrir des activités préliminaires à exécuter en soutien de la plate-forme polaire.

La coordination entre les activités de l'industrie relatives à POEM-1 et à la plate-forme polaire et celles de l'Agence a été améliorée. Plusieurs dotations en charge utile ont été étudiées et leur faisabilité évaluée en soutien des activités POEM-1 en cours.

Station spatiale 'Freedom'/Columbus

Laboratoires habités

Lors de sa 125ème réunion, le Comité de la politique industrielle de l'Agence a approuvé la proposition de contrat relative aux éléments habités de la station Columbus. La signature du contrat est toutefois subordonnée au résultat de la session du Conseil de l'ESA au niveau ministériel qui se

Full-scale configuration mock-up of the Polar Platform

Maquette en vraie grandeur de la Plate-forme polaire

Interface meetings have taken place with Arianespace to consolidate the interface documents. In addition, a small contract has been placed with Arianespace to cover preliminary activities in support of the Polar Platform.

Coordination between POEM-1 and Polar-Platform activities, both in industry and within the Agency, has been increased. Several payload complements have been studied and their feasibility assessed in support of on-going POEM-1 activities.

Space Station 'Freedom'/Columbus

Manned laboratories

The Agency's Industrial Policy Committee (IPC), at its 125th Meeting, approved the contract proposal for the Columbus manned elements. The signature of the contract is, however, in abeyance pending the outcome of the ESA Council Meeting at Ministerial Level scheduled to be held in Spain later this year.

The industrial development activities on the Attached Laboratory have been progressing, with the System Requirements Review, scheduled for June/July, with NASA participation. The Review plan has been formally released to MBB/ERNO.

The discussions between Columbus main contractors regarding the formation of the EuroColumbus Consortium have made substantial progress, with the legal establishment of the company foreseen for the second half of June.

In response to the Munich Ministerial Conference Resolution requirements to investigate potential increased international cooperation, an ESA Columbus Delegation met in March for the first time with representatives of the CIS's NPO Energia organisation, in Moscow. Since then, several meetings have been held, a communication link established, and a study contract covering assessment of the Free-Flyer baseline and its possible enhancement, placed with them.

As far as the interfaces with NASA are concerned, the successful outcome of the Level-1 Programme Coordination Committee meeting on 6 May in Washington DC marked an important milestone in the last months. Another noteworthy event was the NASA Administrator's directive to review all major NASA programmes. This review, started in late May, has involved participation by ESA Columbus representatives in the evaluation teams reviewing the Space-Station Programme.

On the operations-preparation side, the in-house CALIPSO Workshop was conducted at the end of March in ESRIN (I), allowing for the resolution/discussion of a range of issues, including function control documents, planning tools and databases, simulators and costs. Another workshop, dedicated specifically to the Attached Laboratory, was held in Brugge (B) on 25 May to brief the Columbus Programme Board Delegations on the current status of operations/utilisation costs.

As part of the utilisation activities, two additional meetings of the Potential Participants in the Columbus Precursor Flights Programme, took place in April and May. The Programme Proposal and the additional Declaration are in final preparation for the June meeting of the ESA Council.

The final selection, by ESA's Director General, of six astronaut candidates took place in May. These six candidates, from six different ESA Member States, will form part of the European Astronaut Corps, and will start a two-month introductory training session at the European Astronaut Centre in Cologne on 1 June.

In the context of Long-Term Programme activities, ten candidates for the EXEMSI experiment were selected in April. They will undergo a two-month crew training session in July and August, prior to the two-month isolation campaign due to start in September.

tiendra en Espagne à la fin de cette année.

Les activités industrielles de développement du laboratoire raccordé suivent leur cours. La revue des impératifs système est prévue en juin/juillet avec la participation de la NASA. Le plan de la revue a été remis officiellement à MBB/ERNO.

Les négociations menées par les contractants principaux de Columbus au sujet d'EuroColumbus ont bien avancé, puisqu'il est prévu de signer l'acte de création de ce consortium fin juin.

Dans l'esprit de la Résolution adoptée à la Conférence ministérielle de Munich, qui demandait d'étudier les possibilités d'élargissement de la coopération internationale, une délégation Columbus de l'ESA s'est rendue en mars à Moscou où elle a rencontré pour la première fois des représentants du consortium NPO Energia de la CEI. Depuis, plusieurs réunions ont eu lieu, une liaison de télécommunications a été établie, et l'Agence a passé avec cet organisme un contrat d'étude relatif à l'évaluation de la base de référence du laboratoire autonome et à son éventuelle amélioration.

En ce qui concerne les interfaces avec la NASA, le succès de la réunion du Comité de coordination du programme au niveau 1, tenue le 6 mai à Washington, a marqué une étape importante. On notera également que l'Administrateur de la NASA a donné l'ordre de réexaminer tous les grands programmes de l'Agence américaine. Dans le cadre de ce réexamen, qui a débuté fin mai, des représentants du programme Columbus de l'ESA ont été associés aux équipes d'évaluation chargées de réétudier le programme de Station spatiale.

Quant à la préparation des opérations, l'atelier CALIPSO de l'ESA s'est réuni fin mars à l'ESRIN (I) pour examiner et régler toute une série de questions ayant trait, notamment, aux documents de contrôle fonctionnel, aux outils et bases de données de planification, aux simulateurs et aux coûts. Un autre atelier traitant spécifiquement du laboratoire raccordé s'est tenu à Bruges (B) le 25 mai pour informer les Délégations au Conseil directeur du programme Columbus de la situation en matière de coûts d'exploitation et d'utilisation.

Dans le cadre des activités d'utilisation, deux autres réunions des participants potentiels au programme de vols précurseurs Columbus se sont tenues en avril et en mai. L'élaboration de la proposition de programme et de la Déclaration additionnelle est en voie d'achèvement pour la session de juin du Conseil de l'ESA.

Le Directeur général de l'ESA a procédé en mai à la sélection de six candidats astronautes. Ces candidats, représentant six Etats membres de l'Agence, feront partie du Corps des astronautes européens et participeront, à partir du 1er juin, à un stage d'initiation de deux mois au Centre des astronautes européens de Cologne.

Dans le cadre des activités du Programme à long terme, dix candidats ont été retenus en avril pour l'expérience EXEMSI. Ils subiront en juillet et en août un entraînement 'équipage' de deux mois, puis vivront, à partir de septembre, en conditions d'isolement pendant 60 jours.

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Authors Notified:
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Camera-Ready Paper Due:
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92-21419

In Brief

Eureca Safely in Orbit

The first European Retrievable Carrier, Eureca-1, the largest and at 4500 kg by far the heaviest free-flying spacecraft developed to date by the European Space Agency (see ESA Bulletin No. 70, pages 16–39), was launched successfully aboard Space Shuttle 'Atlantis' (mission STS-46) from Kennedy Space Center at 13 h 57 min UT on 31 July 1992.

The Carrier was subsequently deployed from the Cargo Bay, using the Shuttle's robotic arm, at 7 h 7 min UT on 2 August. The orbital transfer manoeuvre required to propel Eureca to its final operating altitude began as planned at 14.30 h UT on 2 August, but had to be terminated 6 min later because of indications of a deviation from the planned flight direction. An orbital altitude of 445 km had been attained at this point.

A thorough flight-data evaluation and in-orbit testing of the Carrier's sensors showed that there were no failures of hardware or executional functions onboard, but there were indications of an anomaly in parametric tables used by the onboard software for limit-checking and control. Appropriate adjustments were therefore introduced into the ground segment and onboard the Carrier itself.

It was subsequently decided to conduct a further orbit-raising manoeuvre between 10 h 27 min and 10 h 56 min UT on 6 August. The real-time telemetry received on this occasion showed that all of the Carrier's subsystems were working well. After this successful orbital transfer manoeuvre, Eureca-1 was in an elliptical orbit with an apogee altitude of 507 km and a perigee altitude of 472 km.

On 7 August at 11 h 26 min local time, while Eureca was over ESA's Maspalomas ground station, the Carrier's thrusters were fired for a further 11 min to circularise its thus far elliptical orbit. Data received half an hour later from the Carrier as it passed over the ESA ground station near Perth, in Australia, confirmed that it was in a healthy state and in a circular 508 km orbit around the Earth.

On 10 August, six of the fifteen scientific instruments onboard were activated successfully. The remaining experiments are planned to be switched on before 17 August.

Eureca being released from the Space Shuttle

Recent Olympus Activities

Olympus used to relay reports from Rio Summit to Europe

Television news reports from the World environmental summit in Rio de Janeiro, Brazil, in June 1992, were relayed to Europe via the Agency's Olympus satellite, via an ultra-portable satellite news-gathering terminal.

The 'fly-away' terminal used was developed for ESA by Continental Microwave Technology Ltd. (UK). It operates in the 20/30 GHz frequency band, as opposed to the 11/14 GHz frequencies generally used for news-gathering. Use of these higher frequencies, coupled with the steerable spot beams provided by Olympus, allows television news to be beamed directly by satellite to the broadcaster's headquarters, avoiding the multiple satellite links and large Earth stations normally used. The picture delivered is also deemed to be of considerably better quality than those received via existing operational satellite links.

The terminal can be packed into six small boxes, which can be transported via the normal airline baggage system. The antenna has a diameter of 1.2 m when deployed, and needs a power amplifier of only 50 W.

The receiving terminal for the Rio de Janeiro links was a receive-only station, also with a diameter of 1.2 m, on the roof of Starbird Communications' London headquarters.

The Olympus spacecraft

During the Rio Summit, feeds were provided to Starbird and to Worldwide Television News (WTN) for syndication. Dedicated feeds were also provided for Greek television and for the Fuji Japanese commercial network.

ESA Terminal Used in Remote Cattle Auction

One of ESA's satellite news-gathering terminals was also used during the Devon County Show in the United Kingdom to demonstrate the possibilities for conducting remote auctions. The terminal was used in conjunction with the steerable spot beams of ESA's Olympus satellite, and the video link was to Ontario, Canada.

Using such a direct television link to and from the small portable terminal, farmers in Devon were able to bid on cattle in Canada. Such applications have stimulated considerable interest in the farming community because remote viewing and bidding can save both time and money, and can also overcome difficulties with international livestock transit regulations by avoiding the unnecessary transport of animals.

Beginning in October 1992, six of Britain's largest farmers' cooperatives and six leading auction houses will join with Central Livestock Auction Satellite Sales (CLASS) Ltd. in trial national auction sales using ESA facilities located at the University of Plymouth (UK).

Canadian News Distributed in Europe via Olympus

Canadian television programmes are regularly transmitted to sites across Europe via ESA's Olympus satellite. Olympus's spot beams enable Canadian programmes to be sent across the Atlantic in a single hop to ESA's Redu Station, in Belgium.

The steerable spot beams being used operate in the 30/20 GHz frequency bands, which are of great importance for future communication systems because of the wide bandwidth available.

Upon arrival in Redu, the signals from Canada are redistributed using Olympus's Specialised Services payload to several sites, including Canadian Embassies in Europe.

VSAT System Links Universities

The Cooperative Olympus Data Experiment (CODE) using the Very Small Aperture Terminal (VSAT) system now has 12 active sites at various European universities. The system permits European academic institutes to experiment with new applications for data, voice and graphical communications by interconnection of their Local Area Networks (LANs).

Satellite news-gathering terminal installed at the Devon County Show (UK)

The system operates in the 30/20 GHz (Ka) frequency band and uses small ground stations (typically 80 cm dish diameters) at the various locations. Each station employs a transmit power amplifier delivering only 100 mW, but can support a data rate of 64 kbit/s. The hub station can also transmit at 2 Mbit/s to the VSATs.

The experiment has been used to deliver tele-education data to two African countries, Namibia and Ghana, as part of a UNESCO initiative to demonstrate to an audience of University Vice-Chancellors how satellite technology can be used to bypass some of the fundamental problems of an inadequate communications infrastructure, such as limited telephone and television services.

Videoconferencing System Used for Mir Space Station Link-up

A videoconferencing system developed by ESA, the Direct Inter Communication Experiment (DICE) system, was used successfully during the Austro-Mir space flight and the more recent German Mir-92 mission. The system, developed in the context of the Olympus Utilisation Programme, allows multiple locations to be linked together using small Earth stations.

During these flights, the Mir Control Centre near Moscow was linked with several sites in Western Europe for daily press conferences, experimenters' meetings, and briefings, thereby providing real-time interactive coverage of events.

Seventeenth ESA/Japan Coordination Meeting

The latest in this series of meetings between ESA representatives and their Japanese counterparts took place at ESTEC in Noordwijk (NL) on 17–19 June 1992.

Both sides reviewed space activities in Japan and Europe since the last meeting held in June 1991 in Japan, and reiterated their intentions to pursue more active and closer cooperation. The main areas of common interest within the framework of reinforced collaboration, defined on the occasion of the visit by ESA's Director General, Mr Jean-Marie Luton, to Tokyo in March 1992, were confirmed, particularly in the domains of Earth-observation, telecommunications, space science, space transportation, space station and precursor flights.

More specifically, in the areas of:

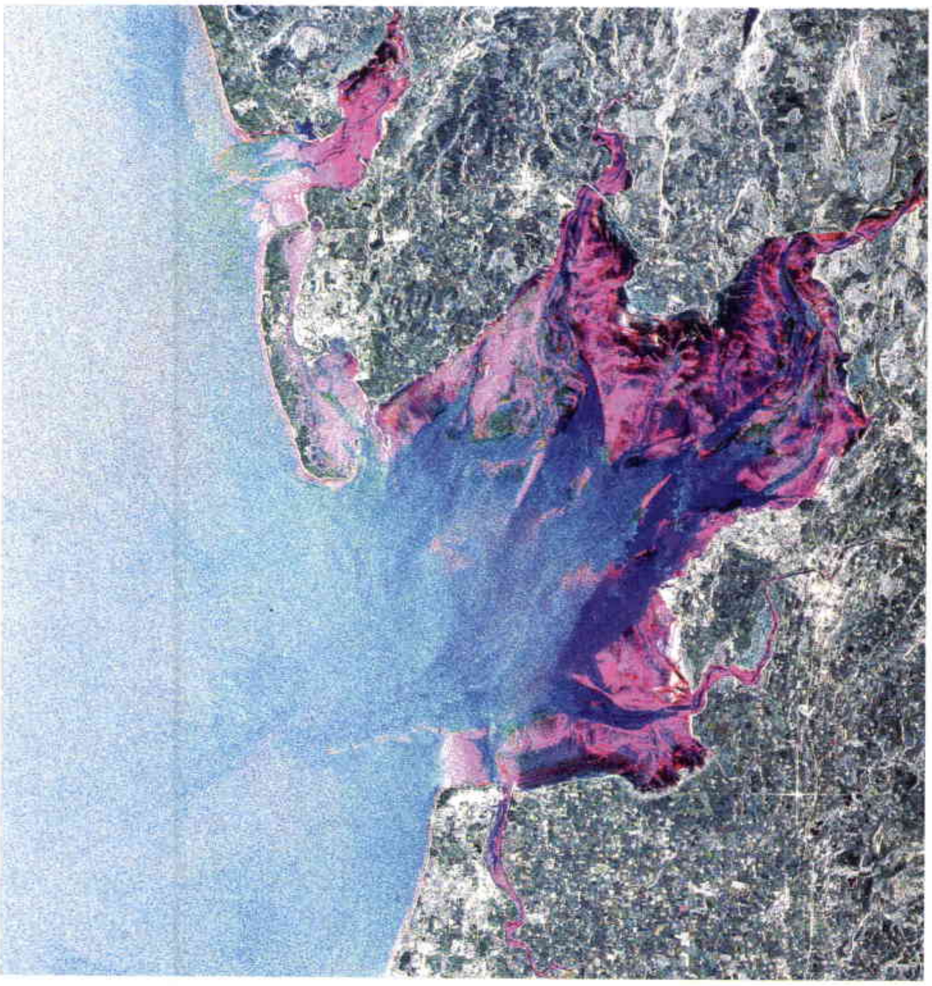
- *Earth Observation:* The Memorandum of Understanding between ESA and NASDA for the exchange of European ERS-1 data and Japanese JERS-1 data is now well implemented, and calibration experiments for the two missions have been set up. Exchange of data for future missions and the possible joint development of instruments for polar platforms and future missions were also discussed. Demonstrations of Earth-observation data transmission to ground via data-relay satellites are also envisaged.
- *Space Station:* Cooperation was discussed for precursor missions and for the utilisation of the Japanese Space Experiment Module (JEM) and Columbus, the European contribution to International Space Station 'Freedom'.
- *Space Transportation:* A new working group, HOPE/Hermes, was formally established, to cooperate on computational and experimental data exchanges, common facility utilisation and flight demonstrations.
- *Telecommunications:* Continuation of collaboration on the Japanese and European Data-Relay Systems (DRS) has been agreed and the possibility of performing joint inter-satellite experiments has been investigated. Discussions will also continue on other potential areas of cooperation.
- *Space Science:* Following the approval by ISAS of the cooperation with ESA on the ISO (Infrared Space Observatory) project, discussions are under way for its implementation.
- *Product Assurance:* Continuation of collaboration between ESA and NASDA, including a support contract for high-reliability space technologies.

In addition, the regular ESA/NASDA staff-exchange programme will continue during 1993.

The next ESA/NASDA Meeting is scheduled to take place in Japan in 1993.

The ESA/Japan Meeting in progress at ESTEC (NL)

A Successful First Year for ESA's ERS-1 Satellite



ERS-1 Synthetic Aperture Radar image of Morecambe Bay (UK)

At 03 h 46 min on the morning of 17 July 1992, it was exactly one year since ESA's first Earth-observation satellite, ERS-1, was put into orbit. The spacecraft's advanced instruments have since scanned the globe during 5243 orbits at an altitude of 800 km. Its imaging radar has generated over 160 000 high-resolution images of land, coastal, ocean and ice areas. In its first twelve months, ERS-1 has already made significant contributions to environmental research.

The performance of ERS-1 has been outstanding right from the launch. Thorough testing revealed that both the ESA-developed instrument package and the Along-Track Scanning Radiometer provided by the UK Science and Engineering Research Council met, and in most cases exceeded, the design specifications. Shortly after the launch, spectacular radar images and exciting data from the other instruments were already being presented to the public and the media.

ERS-1's operations are supported by the most complex ground segment ever set up in Europe. There are five ESA ground stations in Europe and Canada, four Processing and Archiving Facilities – in France, Germany, Italy and the United Kingdom – and an expanding network consisting at present of a further twelve ground stations around the globe for the reception of radar imagery.

Global ERS-1 wind and wave data are now routinely processed and dispatched within three hours of observation to operational users, such as meteorological offices. The same is true for selected radar images, which are made available to, for example, sea-ice forecasting services. The Processing and Archiving Facilities generate various off-line products relevant to many scientists and operational users. The methods of processing the ERS-1 data continue to be improved to meet the evolving scientific user requirements.

Some 275 scientists and their research groups are being given free access to ERS-1 data for their scientific projects, while 30 pilot projects enjoy the same privilege in order to explore future applications. Also, the ERSC Consortium is marketing ERS-1 data and products to commercial users worldwide.

The first scientific results have now started to come in, and they too are reflecting the high quality of ERS-1 data. Significantly, most of this research would not have been possible without ERS-1, as the majority of this type of data cannot be supplied by other satellites. Many of the natural phenomena that ERS-1 is designed to observe have time scales of months or even years, and scientists need to accumulate ERS data over long periods before they can begin their detailed analysis. Nevertheless, interesting results have already been produced. These include, for example, near real-time observation of the El Nino climatic anomaly at the end of 1991 and beginning of 1992.

El Nino is a regional climate phenomenon in the Pacific involving changes of sea level and sea-surface temperature. It lasts for about six months, occurring at irregular intervals of between three and seven years. It has widespread climatic effects that are not yet fully understood; these include droughts in Australia and rain storms in Chile. This research on El Nino with ERS-1 data is being performed by scientists from the US National Oceanographic and Atmospheric Administration (NOAA) and the Rutherford and Appleton Laboratory in the United Kingdom.

ERS-1 Radar Altimeter data have also allowed a group of scientists at the Mullard Space Science Laboratory of University College London (UK) to set up the best topographical map of Antarctica that has ever been achieved.

Last but not least, the Tropical Ecosystem and Environment Monitoring System (TREES) project, a joint endeavour by ESA and the European Community to set up an inventory of the tropical rainforests, is now being supplied with ERS-1 radar imagery. Only radar instruments can operate irrespective of cloud cover, day and night, making this technology an ideal tool for monitoring changes at tropical and polar latitudes.

A first review of early ERS-1 results will be given at an ESA Symposium to be held on 4–6 November 1992 in Cannes (France), which is expected to be attended by several hundred scientists.

On the occasion of ERS-1's first anniversary, ESA can therefore look back proudly on a year filled with achievement and look forward with confidence to making significant contributions in the future years to the observation of the Earth and its environment.

ESA and Technology Transfer

ESA's Technology Transfer Programme is starting to gather pace, a prime objective being to exploit existing space technology for new applications within non-space companies in Europe. A group of technology transfer companies has been contracted to identify space technology that could be used to advantage, and to introduce it to the non-space firms. Initial responses have been positive, with many candidate technologies emerging both from the ESA Centres and from Industry.

The goal in 1992 is to generate a few initial examples of technology suitable for transfer and to establish a process for that transfer. Support may be made available to adapt the technology to a non-space company's needs, where appropriate.

Further information can be obtained from the following local technology-transfer representatives:

Ms A.-M. Hieronimus
ESA Headquarters, Paris
Tel: (33) 1 4273 7329

Mr P. Brisson
ESTEC, Noordwijk
The Netherlands
Tel: (31) 1719-84929

Mr H. Dworak
ESOC, Darmstadt, Germany
Tel: (49) 6151 90 2737

Mr R. Stevens
ESRIN, Frascati, Italy
Tel: (39) 6 941 80 280

The above team would like to hear from companies who believe they might be able to benefit from space technology transfer, perhaps to solve a particular problem or develop a new product.

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 using the Order Form inside the back cover of this issue.

ESA Journal

The following papers have been published in ESA Journal Vol. 16, No. 2:

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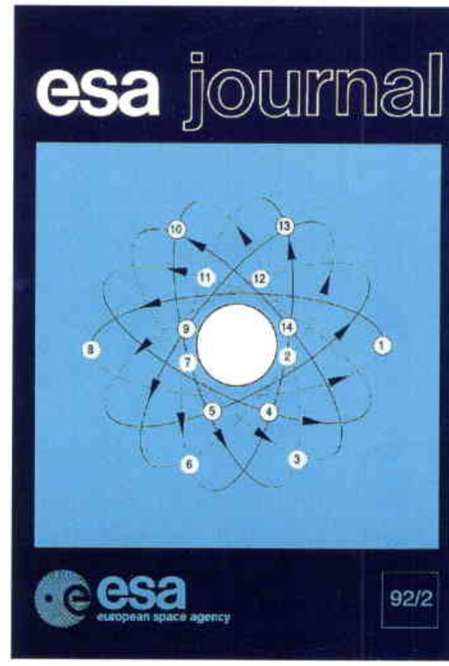

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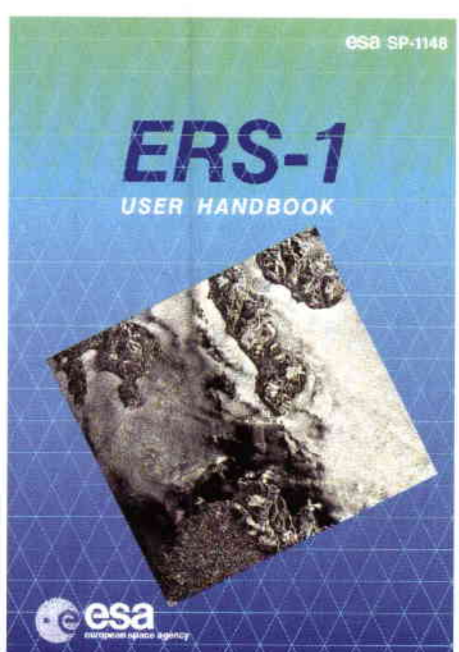

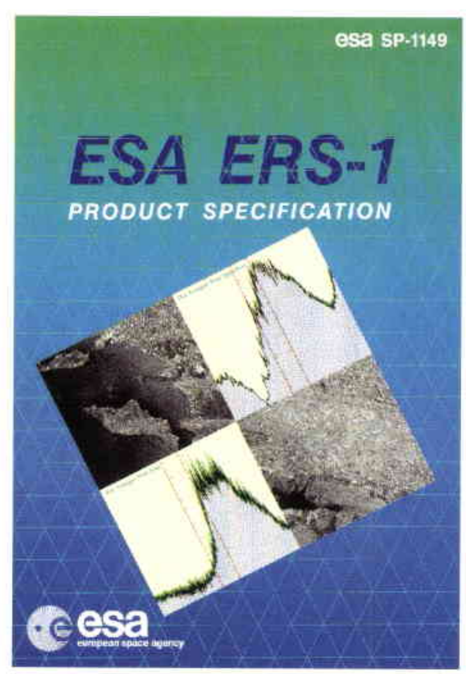

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ED. C. MATTOK

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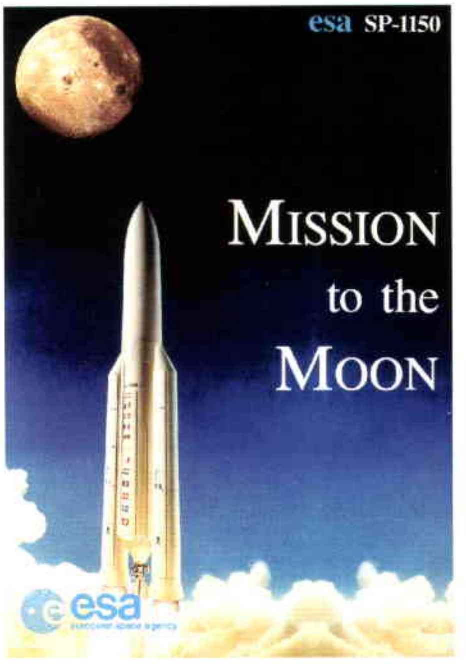

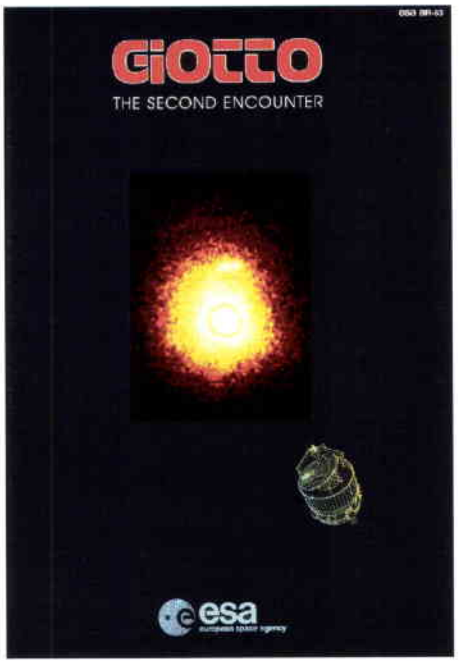

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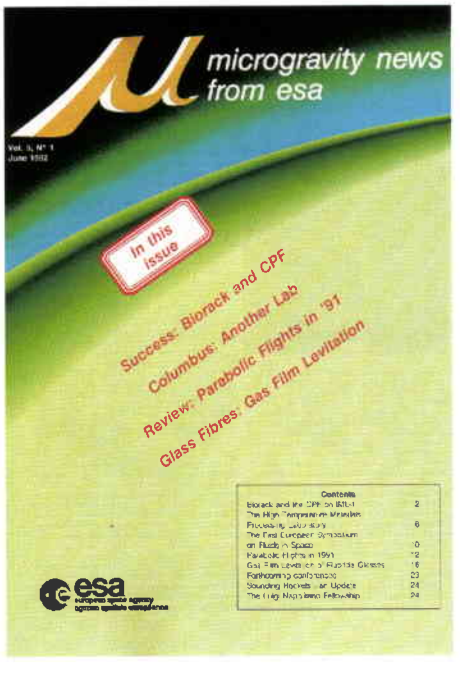


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