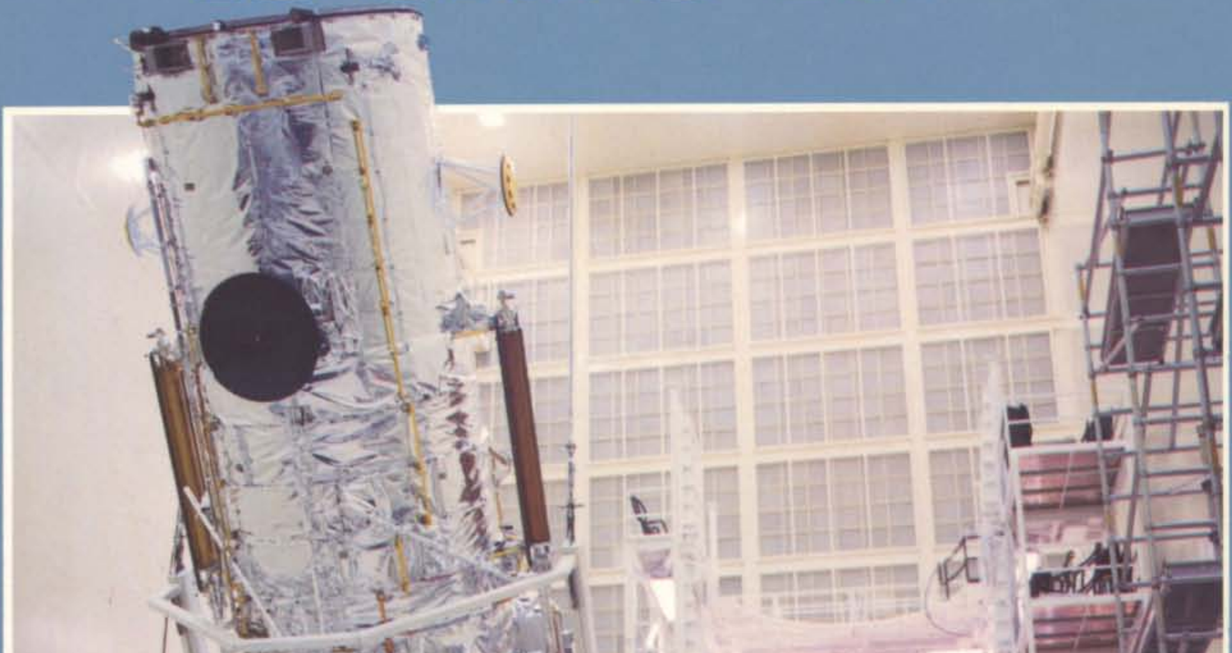
european space agency

esa bulletin

agence spatiale européenne



number 61

february 1990

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr H. Grage.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie

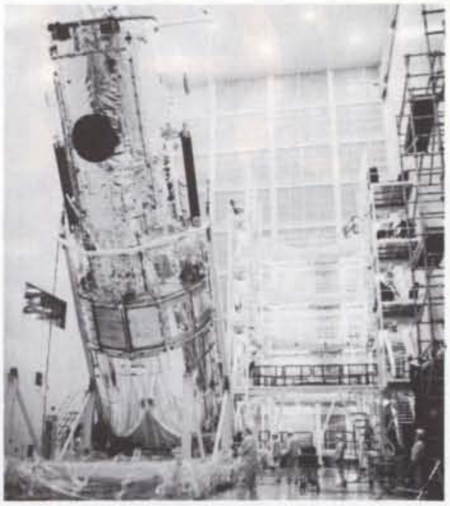
Président du Conseil: M H. Grage.

Directeur général: Prof. R. Lüst.

esa bulletin

no. 61 february 1990

contents/sommaire



Cover: The Hubble Space Telescope (see articles on pages 9 and 13)

The History of the Hubble Space Telescope and ESA's Involvement
R.J. Laurance 9

ESA's First In-Orbit-Replaceable Solar Array
B.W. Henson 13

The Scientific Instruments for ISO — Technical Highlights
H. Eggel, H. Schaap & G. Bagnasco 21

Wissenschaftliche Zusammenarbeit im Weltraum
C. Habfast & B. Pfeiffer 29

The Data-Relay Preparatory Programme
A. Dickinson 39

Le Moteur Vulcain — Travaux technologiques sur la chambre propulsive et le générateur de gaz
H. de Boisheraud 46

New Structural Materials for Space Applications
D.C.G. Eaton, A. Pradier & M. Lambert 50

The ESOC Spacecraft Performance Evaluation System (SPES)
J.C. Guillaumé, J.F. Kaufeler & F. Sell 56

World-Wide Interactive Access to Scientific Databases via Satellite and Terrestrial Data Network
T.R. Sanderson et al. 63

The ESA Astronaut Sleep Restraint — Its Development and Use Onboard Spacelab and MIR
W. Ockels & H. Stoewer 71

In Brief 78

Tribute to Dr Ernst Trendelenburg 85

Programmes under Development and Operations
Programmes en cours de réalisation et d'exploitation 87

Publications 101

Editorial/Circulation Office
ESA Publications Division
c/o ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Assistant Editor
Erica Rolfe

Layout
Carel Haakman

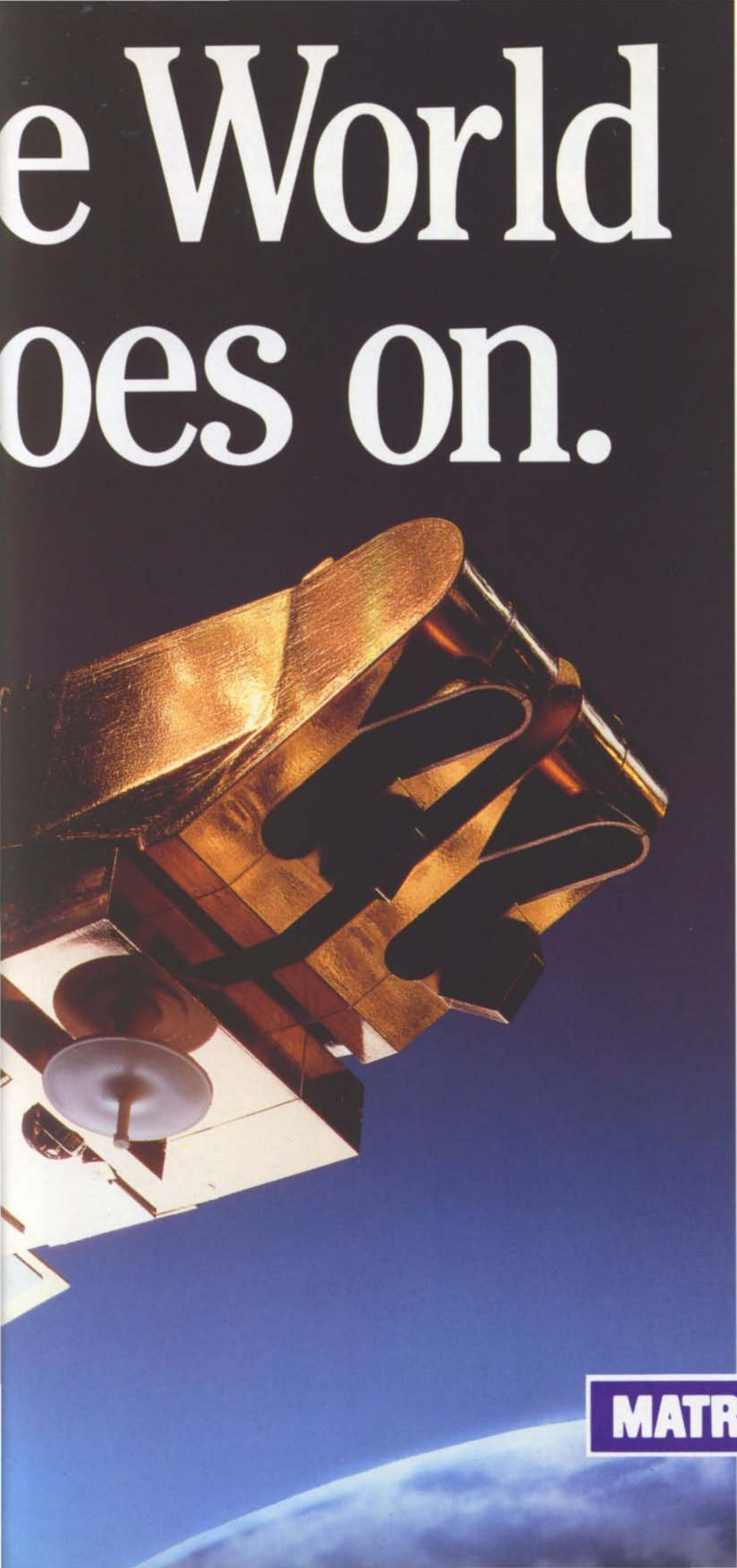
Montage
Keith Briddon, Paul Berkhout

Advertising
Brigitte Kaldeich

Printed in The Netherlands
ISSN 0376-4265

european space agency
agence spatiale européenne

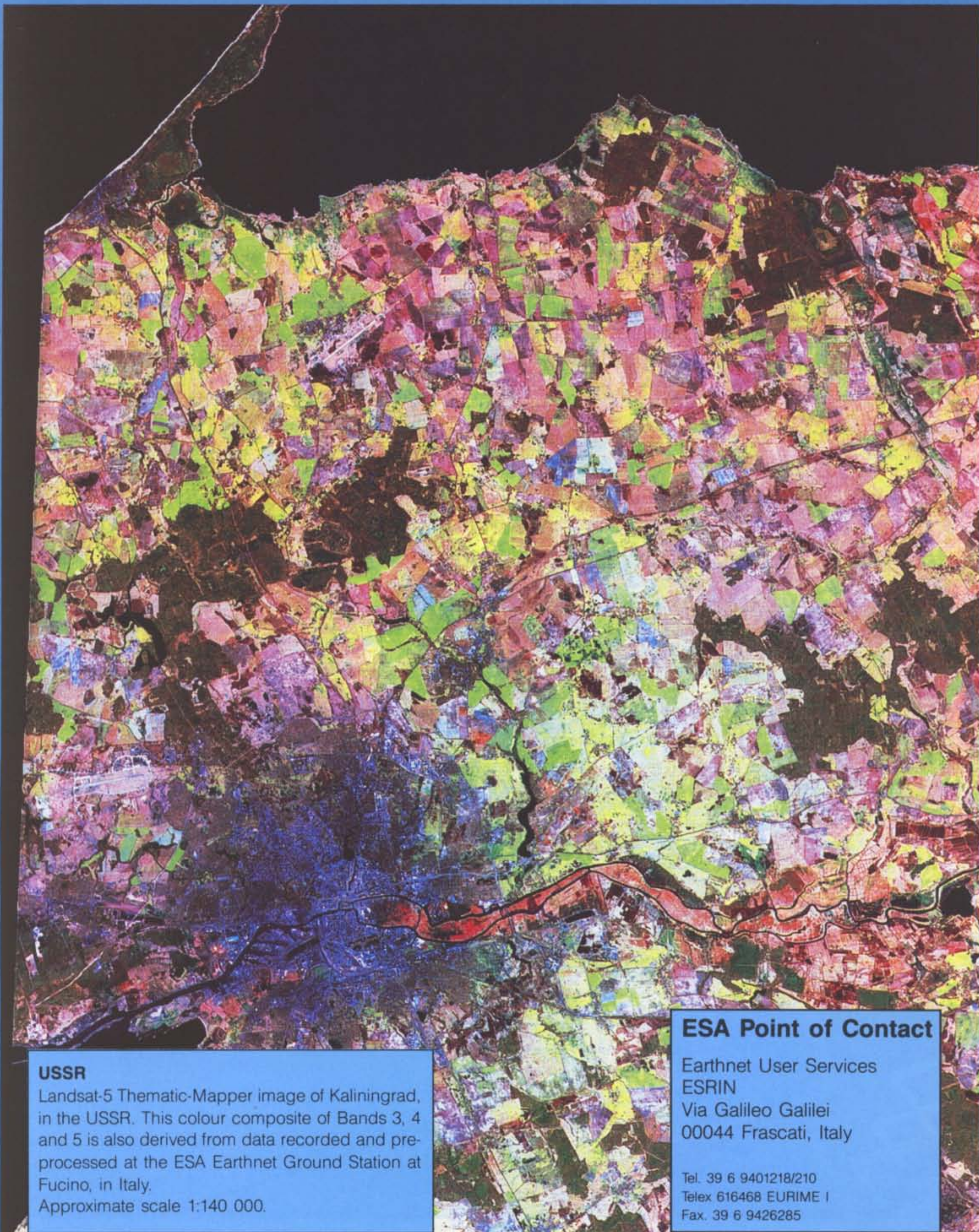
Around th
the Race g


e World
oes on.

Focus

Greece
Gulf of Pátrai, in Western Greece, as seen by the Landsat-5 satellite's Thematic Mapper. This colour composite of Bands 1, 2 and 4 is derived from data recorded and pre-processed at the ESA Earthnet Ground Station at Fucino, in Italy.
Approximate scale 1:180 000.

Earth



USSR

Landsat-5 Thematic-Mapper image of Kaliningrad, in the USSR. This colour composite of Bands 3, 4 and 5 is also derived from data recorded and pre-processed at the ESA Earthnet Ground Station at Fucino, in Italy.
Approximate scale 1:140 000.

ESA Point of Contact

Earthnet User Services
ESRIN
Via Galileo Galilei
00044 Frascati, Italy

Tel. 39 6 9401218/210
Telex 616468 EURIME I
Fax. 39 6 9426285

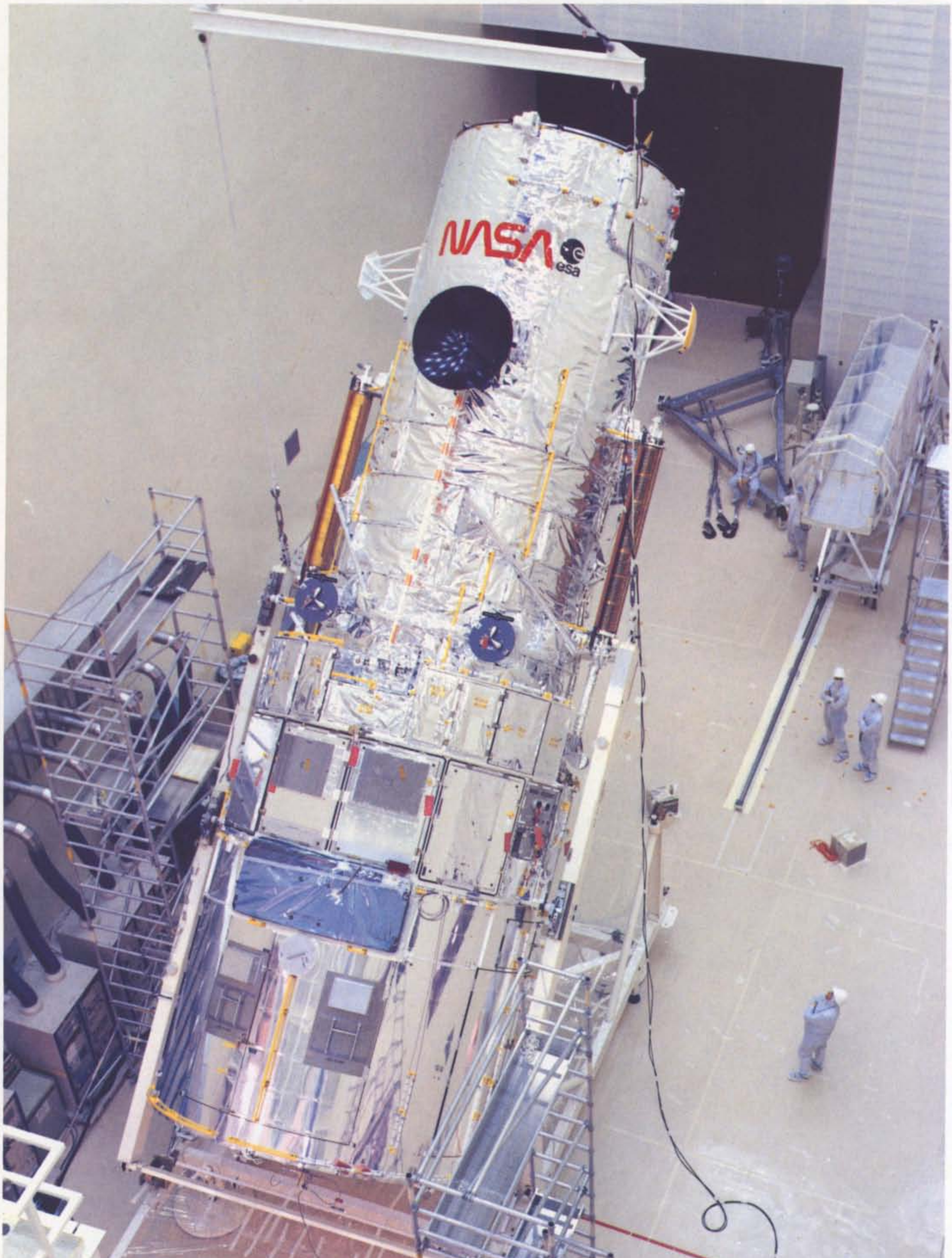


Figure 1. The Hubble Space Telescope (photo courtesy of Lockheed)

The History of the Hubble Space Telescope and ESA's Involvement*

R. J. Laurance
Space Telescope Project, ESA Scientific Programmes Department, ESTEC, Noordwijk, The Netherlands

When the Hubble Space Telescope (HST) is launched in the coming weeks, a major step forward will be achieved in optical astronomy. It will provide such an improvement in performance compared with existing optical telescopes that it will surely lead to significant changes in our basic understanding in astronomy.

The HST's angular resolution is expected to be 0.1 arcsec in the visible wavelengths, which is some ten times better than is typically achievable today with the best ground-based telescopes. This higher resolution, when combined with the darkness of the orbital sky, will allow the observation of fainter objects at much greater distances.

One of the HST's most rewarding features may well prove to be its high-performance imaging capability in the ultraviolet, which is totally unattainable from the ground.

The first serious study of the benefits of an optical observatory in space dates back to 1946 with the issue of a report in the United States by Lyman Spitzer**. More than a decade later, NASA, soon after it formation in 1958, established a set of scientific objectives that included an optical observatory*** Cooperation with ESA was first formally raised in 1973 when the Astrophysics Working Group recommended that Europe should consider and explore the possibility with NASA of participation in what was then known as the 'Large Space Telescope' (LST).

Initial studies concentrated on the potential provision of a scientific instrument to be placed in the Telescope's focal plane. A first study looked at a number of instruments for possible cooperation. This initial selection was subsequently narrowed down, through a series of discussions within the Astrophysics Working Group and with NASA, to the 'Faint Object Camera' (FOC).

This decision was prompted in part by the fact that this instrument required a detector imaging system that could work in a so-called 'photon counting mode' in order to exploit the LST's potential to the full. At that time, Europe had something of a lead in this area, in that University College London had developed the only photon-counting imaging system then in routine use for optical astronomy.

In June 1975, a NASA/ESA working group was set up with the task of establishing a common position regarding the basis of an eventual cooperation on LST. This working group proposed that, as well as the Faint Object Camera, a continuing contribution by Europe to the Telescope's operation, and the provision of a major subsystem, would be appropriate to allow ESA to secure a significant share of the observing time for European astronomers during the planned ten years of operations.

The proposed operations support was that ESA should help to staff the Science Operations Facility, later renamed the Space Telescope Science Institute (now located at the John Hopkins University in Baltimore, USA).

Later, ESA was to set up its own European Coordinating Facility (ECF) at the European Southern Observatory (ESO) site in Garching, W. Germany, to support astronomers in Europe in preparing proposals for HST observations to be submitted to the Space Telescope Science Institute, and for researching data obtained from the HST to be held in an archive.

The major observatory subsystem selected for provision by Europe was the solar arrays, because their interfacing would be relatively simple and could build on the previous good co-operation on the IUE satellite.

Further studies were conducted by both parties throughout 1975 and 1976. On the NASA side, it was decided to reduce the size of the Telescope's primary mirror from 3 m to

* The scientific rationale and technical features of the Hubble Space Telescope were described in detail in ESA Bulletin No. 58, in May 1989.

** Spitzer L 1946, Astronomical Advantages of an Extraterrestrial Observatory, Project RAND Report, Douglas Aircraft Co., September 1946.

*** National Academy of Sciences 1962, A Review of Space Research, Publication No. 1079 (Chapter 2), Washington DC.

2.4 m for cost reasons. As a result, the term 'large' was dropped from the mission's title, which NASA later changed to the 'Hubble Space Telescope' in honour of the American Astronomer Edwin P. Hubble (who discovered that faint nebula observed on photographic plates were in fact distant galaxies, and that these galaxies are moving away from us at velocities proportional to their distance away).

On the ESA side, the project's feasibility study (so-called 'Phase-A') was completed and the Agency's Science Programme Committee (SPC) gave the go-ahead, subject to satisfactory negotiation of the Memorandum of Understanding (MOU) with the United States.

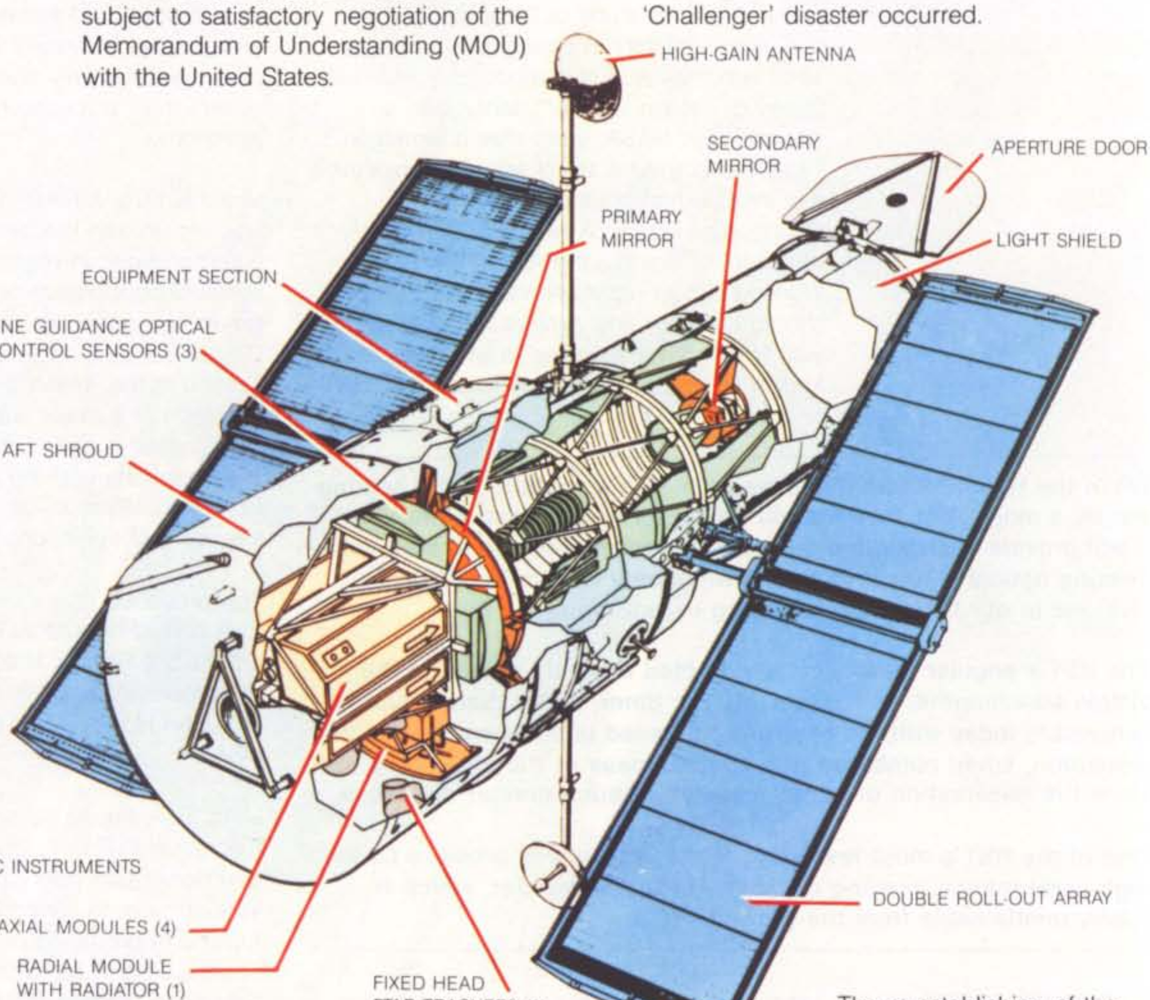


Figure 2. Cutaway view, showing the main elements of the Hubble Space Telescope

Because the other four instruments destined for the Telescope were to be selected in competition, NASA requested that a team of scientists and engineers be allowed to visit Europe to review its ability to provide the Faint Object Camera. This review team, under the chairmanship of Mr John Thole, visited eight establishments in Europe (ESA and ESA Contractors) over a ten-day period in June 1976 and subsequently submitted a positive report.

The Memorandum of Understanding between NASA and ESA was finally signed in October 1977. It gave European astronomers from the ESA Member States a minimum of 15% of the available observing time in exchange for our providing the Faint Object Camera, the solar arrays, and the operations support.

The HST Programme at this time had an expected launch in October 1983 but, due to a series of financial and technical difficulties on the American side, this date was to be put back on no less than five occasions, resulting in a three-year delay overall. The HST was finally being prepared for a launch in October 1986 when the Shuttle 'Challenger' disaster occurred.

The re-establishing of the Shuttle programme has led to a further delay of about three and a half years, but everything now looks good for launch on 18 April 1990.

These delays have had several repercussions on the ESA elements of the HST. The solar arrays had been delivered and installed in final flight configuration in early 1986. There was some concern at this stage that the further delayed launch date would coincide with a period of maximum solar activity (solar flares, etc.), thereby exposing the HST, at its planned orbital altitude of 600 km, to the resulting expansion of the Earth's outer atmosphere and the corrosive effects of atomic oxygen. The silver interconnects between the cells of the solar arrays would be particularly vulnerable. In addition, NASA's planned power utilisation had increased, making the Telescope's power budget marginal.

The decision was therefore taken to remove the solar arrays from the HST and bring them back to Europe for upgrading. The two array wings were reworked in the course of 1988, with new blankets being fitted with high-performance and atomic-oxygen-resistant cells and interconnects. The arrays were returned to the United States and re-fitted to the Telescope in early 1989.

The launch delays have had less impact on the Faint Object Camera, which was delivered to the USA in December 1983. Except for some minor reworking in 1984 and 1985, it has been operated without problem since then, over 3000 images having being taken during testing and calibration. Although the FOC was originally designed for five years of operation, it is still hoped to obtain several years of good astronomical observations once this novel instrument is in orbit.

The Space Telescope Science Institute has recently completed the observing time allocation process based on the first cycle of so-called 'General Observer Proposals'. The scientific community's response was highly encouraging, with the available spacecraft time being nine-times oversubscribed. ESA Member State Principal Investigators have been allocated 18% of the primary time available. Assuming that the launch and in-orbit checkout phases can now be completed on schedule, we will see a new era in optical astronomy open this year with ESA Member State astronomers very much in the forefront.

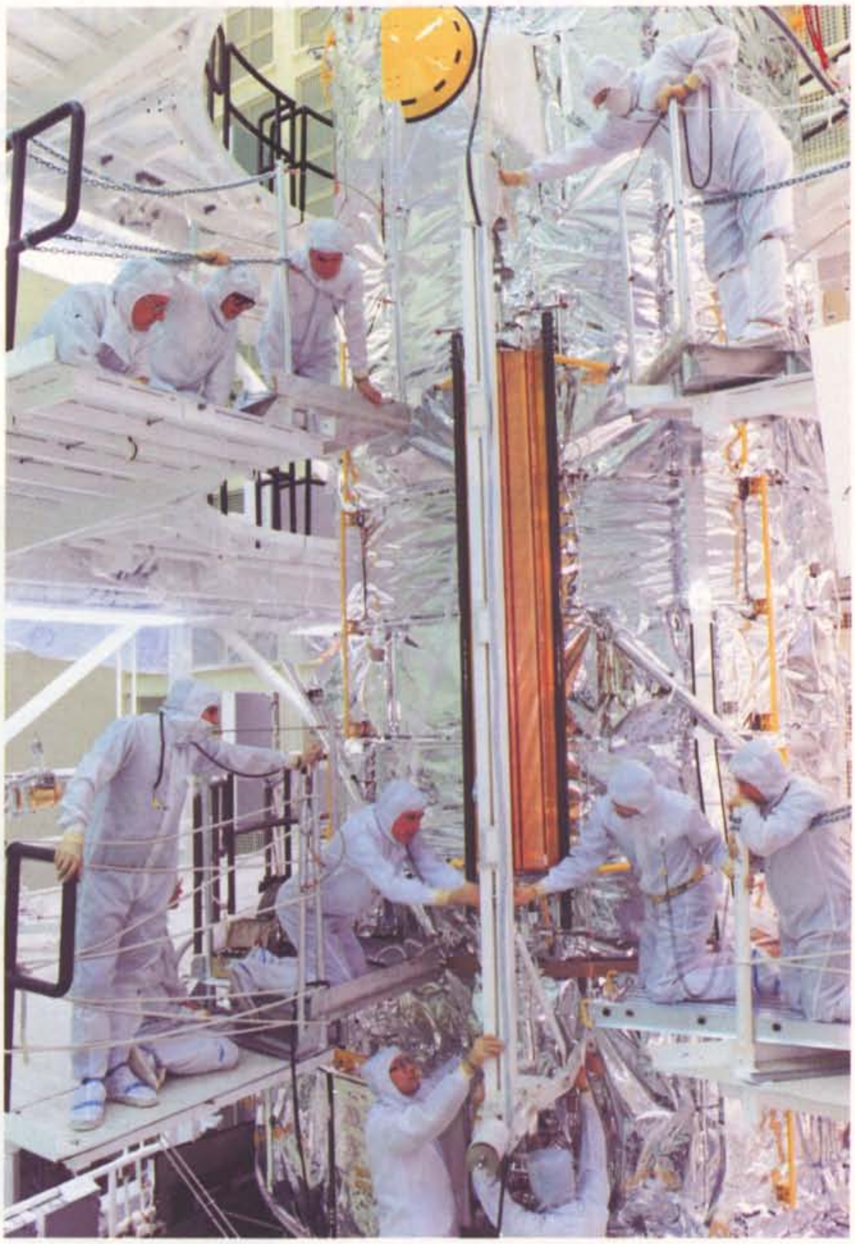


Figure 3. Fitting of one of the flight Solar Array wings to the Hubble Space Telescope (photo courtesy of Lockheed)

ESA's First In-Orbit-Replaceable Solar Array

B. W. Henson
Space Telescope Project, ESA Scientific Programmes Department, ESTEC, Noordwijk, The Netherlands

ESA is providing two major elements of the soon to be launched Hubble Space Telescope, namely the Solar Arrays and the Faint Object Camera. The Telescope was designed from the outset with a view to facilitating both in-orbit maintenance, and the exchanging of the scientific instruments and certain key subsystems, including the two large roll-out Solar Arrays. Exploitation of the capabilities of the visiting astronauts has also been a baseline feature in all major mechanisms design.

Figure 1. Space Shuttle rendezvous with the Hubble Space Telescope (artist's impression)

The Hubble Space Telescope was originally planned to have a 15 year lifetime, based on its being returned to Earth every five years for major refurbishment. Well into the programme, the flight policy was changed by a decision to undertake all refurbishment in orbit. As a result, the Solar Arrays, along with many subsystems and electronic boxes, were re-designated as 'Orbital Replacement Units' (ORUs).

The Solar-Array System

The Hubble Space Telescope's power is provided by two interchangeable Solar-Array wings (Fig. 1), each employing a double-roll-out, flexible solar-cell blanket. The power generated will exceed 4.4 kW (at 34 V) after two years in-orbit, taking into account all degradation factors.

Each wing has five subsystems:
- a Solar-Array Drive Adaptor (SADA)
- a Solar-Array Drive Mechanism (SADM)
- a Primary Deployment Mechanism (PDM)
- a Secondary Deployment Mechanism (SDM), and
- a Solar-Cell Blanket.

plus the associated electronics, which are housed in separate boxes:
- Solar-Array Drive Electronics (SADE)
- Deployment Control Electronics (DCE)
- Diode Box Assembly (DBA).

Each Solar Array, which is almost 5 m long in its stowed-for-launch configuration (Fig. 2), is attached to the Hubble Space Telescope at three interface points, called the 'forward latch', the 'aft latch' and the 'SADA'. Two of the original requirements on the Solar-Array mechanisms were that:
- all functions should have both main and redundant drive motors, including the capability of manual override during astronaut EVA (Extra-Vehicular Activity)
- it must be possible, in an emergency, to jettison the Solar Arrays by EVA

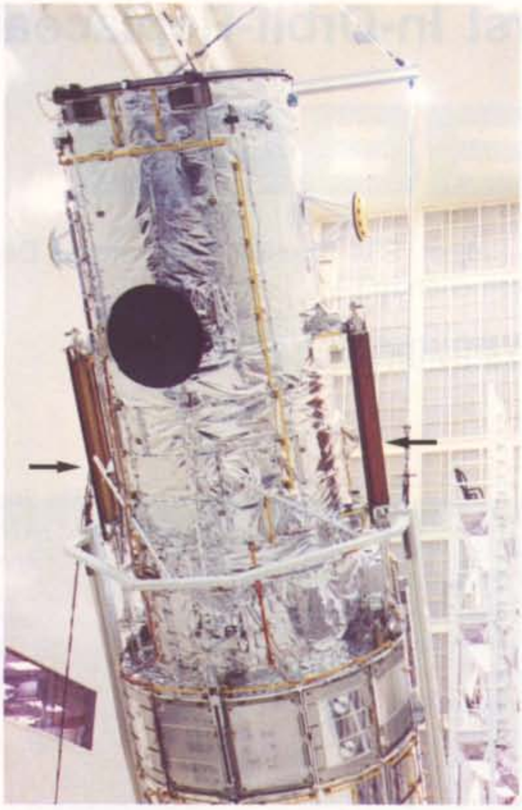


Figure 2. The Hubble Space Telescope's two European Solar Arrays (arrowed) in stowed configuration (each is 5 m long)

intervention, to allow the Space Telescope to be stowed in the Shuttle Orbiter for return to Earth.

Solar-Array Subsystems
The three major subsystem mechanisms each have unique tasks to perform, and consequently completely different concepts are employed in their design.

The Primary Deployment Mechanism has to deploy the Solar-Array Wing from its launch configuration, in which it is stowed and latched parallel to the body of the Telescope, to the 90° position. This mechanism employs a stepper-motor drive via a low-ratio planetary gearbox and mechanical linkage. The EVA manual override has an additional reduction gear (3:1), but operates through the same mechanism drive chain.

The Secondary Deployment Mechanism has the task of deploying the blankets. This is achieved by four bi-stem booms which pull the blanket, via spreader bars, off the storage drum. Blanket tension is maintained by springs acting on the drum. The mechanism uses a tandem DC motor, which drives a planetary gearhead. The EVA manual override is achieved via a gearbox (1:1) which meshes directly with the torque tube. The mechanism also incorporates a grapple-fixture receptacle which allows an attachment to be fitted to facilitate jettisoning of the Solar Array, either by using the Shuttle's Remote Manipulator System (RMS) or manually using a handle (Fig. 3).

The Solar-Array Drive Mechanism provides rotational control for the Array over a 340° arc, with extremely low interactive torque feedback to the Telescope itself, which is also a primary performance requirement (less than 0.1 Nm during slew manoeuvres). This is achieved using a brushless DC motor and special control electronics. For launch, the bearings are protected by an off-load device, which allows the launch-induced loads to be taken through a separate load path (i.e. not through the bearings). Crew interfaces are provided to manually release the off-load device, rotate the Array wing to a particular position, and lock it in that position with a manual brake.

In addition to these mechanisms, there is the Solar-Array Drive Adaptor (Fig. 4), which is a double-cone structure joined by a special clamp. It allows the interface to be separated and re-mated by the visiting astronauts, thereby facilitating the jettisoning or re-installation of the Solar Array.

Crew interfaces
Crew interfaces established at the beginning of the project were standardised as far as possible on the use of a 7/16-inch double-height hexagon. This allowed a standard socket to be used for captive fixation bolts as well as for mechanism drive interfaces.

The subsequent broadening of the ORU philosophy required the addition of several extra tools, including different-sized sockets and special screwdrivers. As it was not

Figure 3. The Secondary Deployment Mechanism's (SDM) manual override (centre), and the grapple-fixture receptacle (left)

Figure 4. The Solar-Array Drive Adaptor (SADA) and Clamp-Release Mechanism

feasible to replace all electrical connectors with 'EVA-types' at this stage, special tools were made for the removal and installation of the relevant connectors. The necessary torques can be applied with a manual tool or, for cases in which a large number of turns are required, a power tool is available (Fig. 5a,b). Both tools employ torque limiters, a range of which have been established for the Space Telescope.

There are numerous crew-interface aspects that need to be taken into account in the mechanism design. For example:

- Interface dimensions must be precisely defined and controlled. A master gauge is necessary to ensure that all manufactured items comply, including future builds. Fit checks need to be rigorously applied.

- Access to the drive points must be ensured at all times, i.e. with the Solar Arrays in both their stowed and deployed positions. The access envelope has to take into account the 'total tool envelope', including the torque limiter and any extensions to be used. So-called 'wobble' or flexible drives (Fig. 6) can alleviate the need for direct line of attachment by some 15°.

- The torque required to operate the device should be more than the ratcheting torque of the wrench, to facilitate one-handed operation by the crew. This minimum-torque approach also has benefits for the mechanism in terms of resistance to rotation under random vibration, for example due to the launch environment.

- The thermal implications of access holes (3 cm diameter) in thermal blankets (Fig. 7) have to be evaluated.

Neutral-buoyancy testing

The first Solar-Array neutral-buoyancy tests were conducted in 1979 at Marshall Space-Flight Center (MSFC) in Houston. The purpose of these tests was to demonstrate reach and access to all the mechanism manual overrides and to practise jettisoning the complete Array. In order to jettison the Array, it is also necessary to demate the EVA

a

b

Figure 5. (a) An EVA manual tool, incorporating ratchet and mushroom head. (b) An EVA power tool, incorporating a torque limiter

Figure 6. Fitting of Diode Box Connectors with a manual tool and torque limiter, illustrating the benefit of the 'wobble drive'

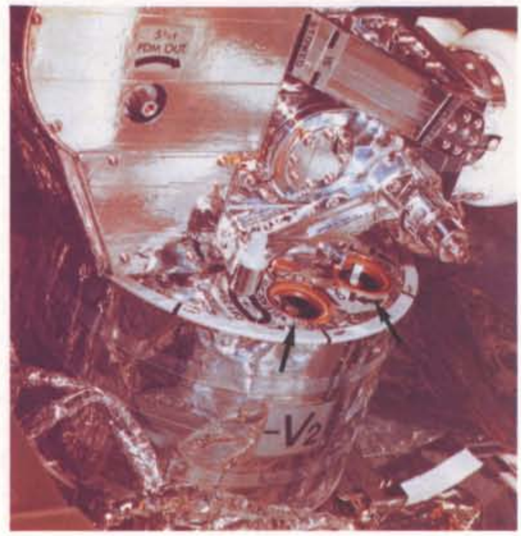


Figure 7. Access holes (arrowed) in the thermal shielding for the bearing off-load device and manual override. The Primary Deployment Mechanism (PDM) manual override (top left), visual position labels (top right), and PDM locking device (centre right) can be seen in this view

connectors on the Diode Box Assembly (DBA). The removal/installation of this ORU was therefore also checked at the same time (Fig. 8).

This series of tests was repeated successfully in 1981 with improved flight-hardware fidelity, thereby confirming the feasibility of the Solar Arrays being designated as ORUs.

To ensure familiarity with the flight hardware, the Space-Telescope Mission-Specialist astronauts themselves participated in the Array integration and removal activities at the Hubble Space Telescope integration site at Lockheed Missiles and Space Company (LMSC) in Sunnyvale (Calif., USA). These trials were repeated several times during the verification programme, and on two occasions simulated jettison tests (with gravity compensation) were conducted (Figs. 9a,b).

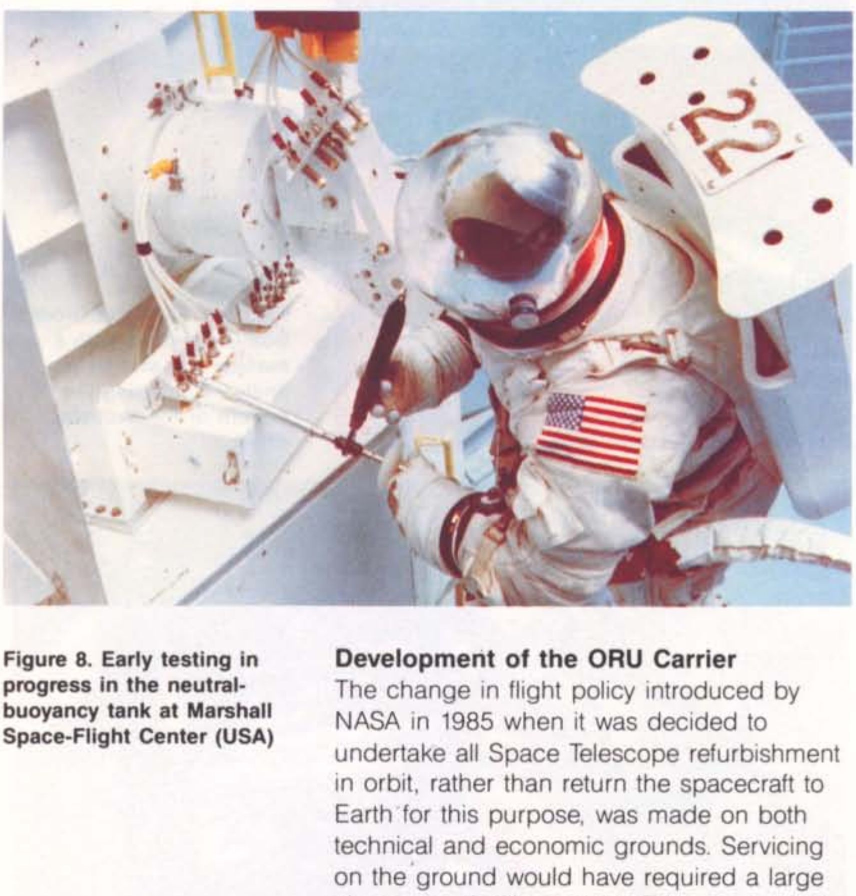


Figure 8. Early testing in progress in the neutral-buoyancy tank at Marshall Space-Flight Center (USA)

Development of the ORU Carrier

The change in flight policy introduced by NASA in 1985 when it was decided to undertake all Space Telescope refurbishment in orbit, rather than return the spacecraft to Earth for this purpose, was made on both technical and economic grounds. Servicing on the ground would have required a large clean-room facility and the Telescope would have been out of commission for a long period. There was also the risk of damaging or contaminating its highly sensitive components during its return to Earth, due largely to the re-pressurisation involved.

It meant, however, that almost overnight the Solar Arrays and the electronics boxes became ORUs, giving a new sense of urgency to the so-called 'Maintenance Mission Concept'. An ORU Carrier (ORUC) design was established by MSFC with specific provisions for two Solar Arrays plus several small ORU boxes.

The initial ORUC concept based on a Pallet design incorporated a 'mass-tuned system' to support the Arrays, which were to be mounted on an inverted T-bar at the base of the concave structure. Fresh neutral-buoyancy tests were therefore arranged in 1987 to evaluate this ORUC concept and the handling of the Solar Arrays. The concept was declared acceptable with some revisions, but there were still some problems with access to EVA points and handling difficulties.

A subsequent revision of the ORUC design replaced the inverted T-bar with a raised flat bed in the Shuttle Pallet. This concept reduced the overall mass and gave better access and improved handling possibilities. The flat-bed concept (Fig. 10) also allows the Arrays to be mounted in 'reversed positions', with the advantage that the EVA manual overrides on the latches can be located on the outside, both providing good access and eliminating any need to make them left- or right-handed.

In September 1988, responsibility for the 'Maintenance Mission' was transferred from MSFC to Goddard Space-Flight Center (GSFC). A new Solar-Array Carrier (SAC) has since been designed which consists of a stiff platform mounted on dampers. Retention of the flat-bed concept means that access to all EVA points, and the handling possibilities, remain good.

Solar-array modifications

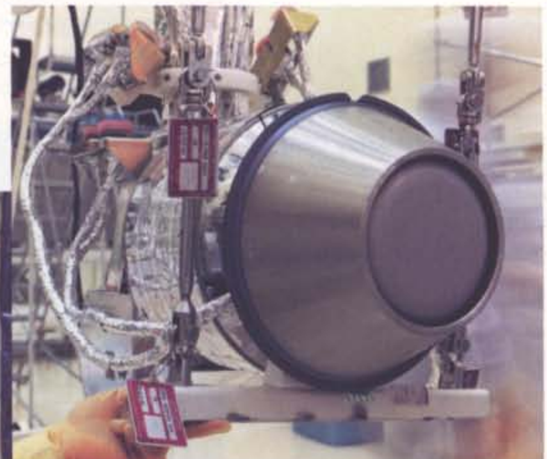
During this same period, four design

changes were proposed to make the Solar Arrays more 'user friendly' for the astronauts during the change-out scenario. The first two modifications were considered essential for the first flight Solar Arrays, while all four are being applied to the Arrays destined for the first Maintenance Mission.

Firstly, the SADA clamp has been redesigned as an ORU itself, to eliminate a single-point failure for Array change-out in the case of a malfunction or accidental damage. The new design incorporates a secondary means of opening the clamp by use of an emergency release bolt, and changes to the fixing which allow the clamp to be removed and replaced in-orbit.

Unfortunately, the locking device violated the single-point-failure ruling (in theory at least), and NASA requested that it be replaced by a wire lock. The inclusion of this wire locking has introduced a non-standard EVA task to the Solar-Array activities in that the crew have to cut and retrieve the wire prior to opening the clamp.

The interfacing halves of the SADA structure have been revised to permit integration with a temperature differential of 50°C. Assembly and environmental tests have been conducted to demonstrate that the integrity of the structure has been maintained.



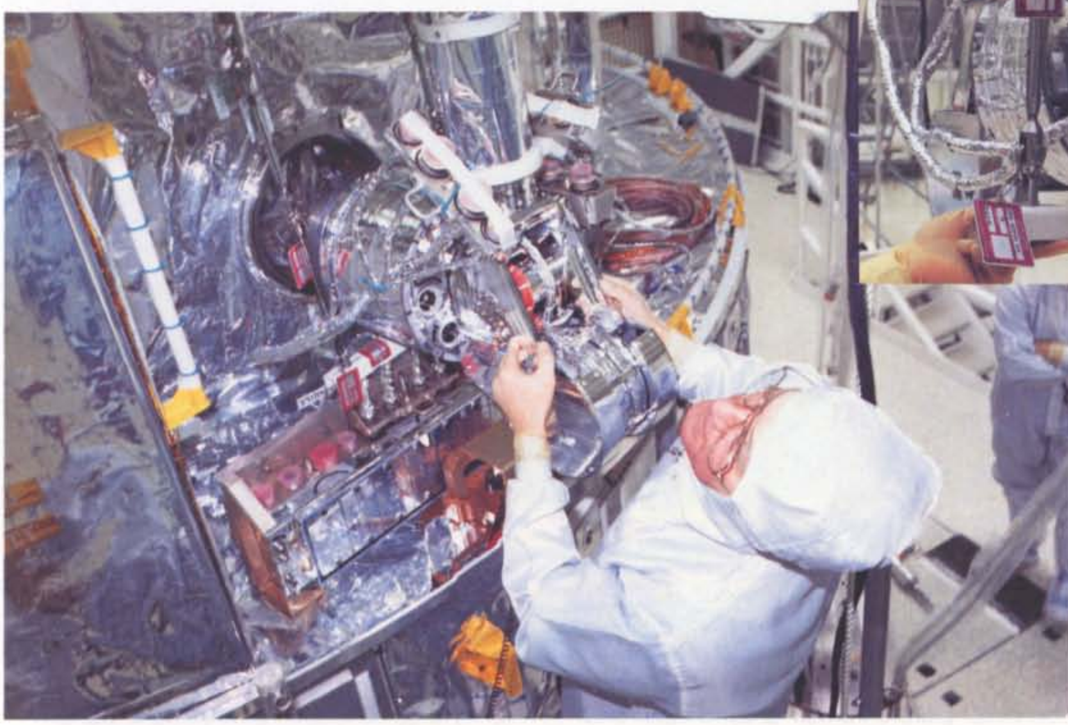


Figure 9. Solar-Array jettison tests in progress at Lockheed Missiles and Space Company (USA). The inset above shows the SADA interface

The clamp itself is an interesting example of obeying a fundamental ORU rule, namely there must be no loose parts when the device is opened and/or removed, as these would tend to float away. The two semi-circular halves of the clamp and its pivoting fixation attachments must all remain captive as one assembly when the clamp is opened.

The basis of the redesign was 'minimum change' in an effort to preserve as much test history as possible. However, it became evident in requalification that some subtleties of the redesign were affecting the clamp's integrity. It was observed that under random vibration the self-locking feature of the spindle had become marginal and it was deemed necessary to add a special locking device.

Secondly, a locking device has been incorporated into the Primary Deployment Mechanism to clamp the 'free' rotating hinge during EVA handling activities. This device is an on/off locking system, which provides a detent of up to 100 Nm. This is considered sufficient to give stability to the assembly during change-out, and has to be limited due to the loads that could be induced on the hinge by the large leverage (Fig. 7).

One difficulty with this type of design is to establish a realistic specification. The question of how much load/torque the crew can or will apply is very subjective, depending on a combination of the astronaut involved, the conditions applying at the time, and the leverage assistance employed.

Thirdly, to reduce the EVA tasks, it was proposed that the Solar Array's connector brackets should be mounted on the Array itself. Some special receptacle brackets, which simulate the Diode Box, have been designed to fit on the PDM arm. The EVA interface has been designed to represent that on the DBA and the brackets have been set at angles to provide optimum EVA access.

Lastly, integral EVA handles have been specially designed to facilitate handling by the crew and provide hardware protection during the change-out scenario. They form complete 'picture frames' around each end of the SDM, which besides offering all-round access for the crew also protect the equipment's vulnerable extremities against accidental damage. A plug-in 'steering-wheel' handle at the back of the PDM completes the EVA handling configuration.

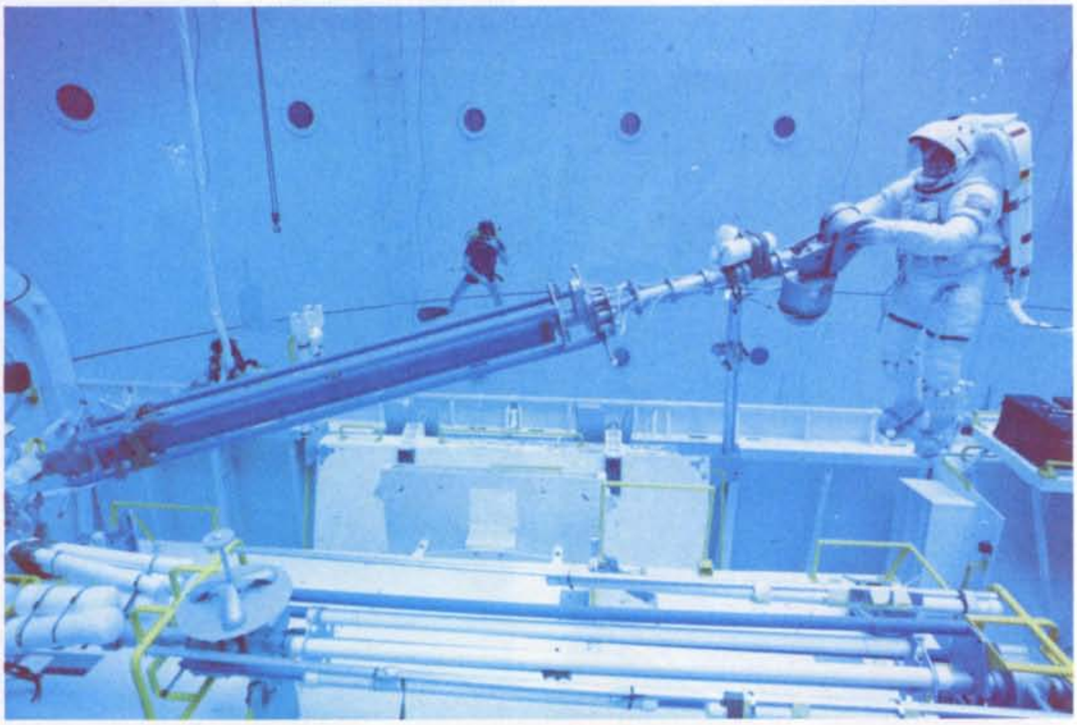


Figure 10. Solar-Array ORU Carrier flat-bed configuration trials during neutral-buoyancy testing

In case the Orbiter's Remote Manipulator System should not be available for some reason for Solar-Array change-out, two 'spine-bars' have been designed to fit between the SDM handles to give the crew longitudinal handover control.

In addition to these tasks on the Solar Arrays themselves, it was necessary to modify the electronics boxes, the SADE and DCE such that they could be installed, connected, disconnected and removed in-orbit.

Modelling analysis

A fundamental principle established at the start of the Maintenance-Mission activities for the Solar Arrays was that the environment encountered should be no more severe than that designed for in the Space-Telescope Programme itself. This was intended to ensure that all previous qualification history would remain valid, the areas of particular interest being the 'loads' and 'thermal' environments, which are inextricably bound together.

The predictions for the conditions to be encountered have to consider:

(i) the same launch environment, but a different mounting structure, namely the Solar-Array Carrier in place of the Space Telescope
(ii) the change-out scenario with periods when no heater power will be available and eclipse conditions will prevail
(iii) integration and clamping of structures at temperatures far from the ambient conditions experienced on the ground, and with differential temperatures in both directions
(iv) the landing case with a combination of delta stresses due to (iii).

The approach taken has been one of establishing detailed mathematical models for the stowed-Solar-Array launch and landing scenarios. The separate landing-case modelling is necessary because an Array that has been deployed and retracted will not have the same clamped configuration that it had initially during launch.

Analysis has also been performed to determine the minimum temperature that can be withstood in orbit with and without external loads, i.e. clamped and unclamped. The temperatures at change-out have also been evaluated to determine the maximum differential that can exist and still be within the latching range. This type of analysis is essential to determine whether the EVA astronauts can work under all conceivable conditions without inducing unacceptably high loads.

Array change-out scenario
The Solar-Array change-out scenario starts with the Telescope mounted on the Flight Support System (FSS) with the old Solar Arrays stowed, and the new Solar Arrays on their Carrier (SAC). It is assumed that the Shuttle Orbiter's Remote Manipulator System (RMS) will be used for Solar-Array (SA) handling.

The sequence of operations is as follows:
- RMS to first old SA, grapple and release from Space Telescope.
- Transfer to 'parking' position.
- RMS to first new SA, grapple and release from SAC.
- Transfer to SA position on Telescope and integrate in stowed position; release RMS.
- Rotate Telescope to access second old SA; grapple with RMS and release from Telescope.
- Transfer to vacant position on SAC; integrate, and release RMS.
- RMS to second new SA; grapple and release from SAC.
- Transfer to SA position on Telescope and integrate in stowed position; release RMS.
- RMS to old SA in parked position; grapple and transfer to vacant position on SAC; integrate, and release RMS.

The whole sequence has to be completed as quickly as possible, due to two main limitations:
(i) a total permissible EVA time of 6 hours (during one session)
(ii) the need to safeguard battery power, by ensuring a minimum overall discharge time.

For the complete cycle, one has to consider the time from retraction of the old Array until new-Array redeployment. Whilst the Solar Arrays were originally designed for deployment on a free-flying Space Telescope, active consideration is now being given to rendezvous with and capture of the Space Telescope with its Solar Arrays deployed. This has imposed the need for a comprehensive coupled dynamic analysis with the Shuttle Orbiter, in order to establish the viability and limitations of such a scenario.

Maintenance logistics
The supporting of an orbital servicing programme requires a dedicated team of personnel to provide and maintain all the necessary hardware and software needed to ensure continuity over a fifteen-year period.

The tasks involved include the supply, storage, periodic inspection, functional testing, and transportation of the ORUs and their supporting equipment. They also include the establishment and maintenance of a complete design databank as a reference source to ensure compatibility and interchangeability of items to be exchanged five or ten years after the Telescope's original launch.

The first Solar-Array change-out is foreseen to occur six years after the Telescope's launch, but contingency plans are in place to make this switch within two years after launch if necessary.

Conclusion
The Hubble Space Telescope is one of the most sophisticated scientific observatories ever conceived for studying the Universe. To enable it to carry out its mission successfully, it will be drawing its electrical power from a pair of in-orbit-replaceable Solar Arrays that are the product of pioneering European space technology.

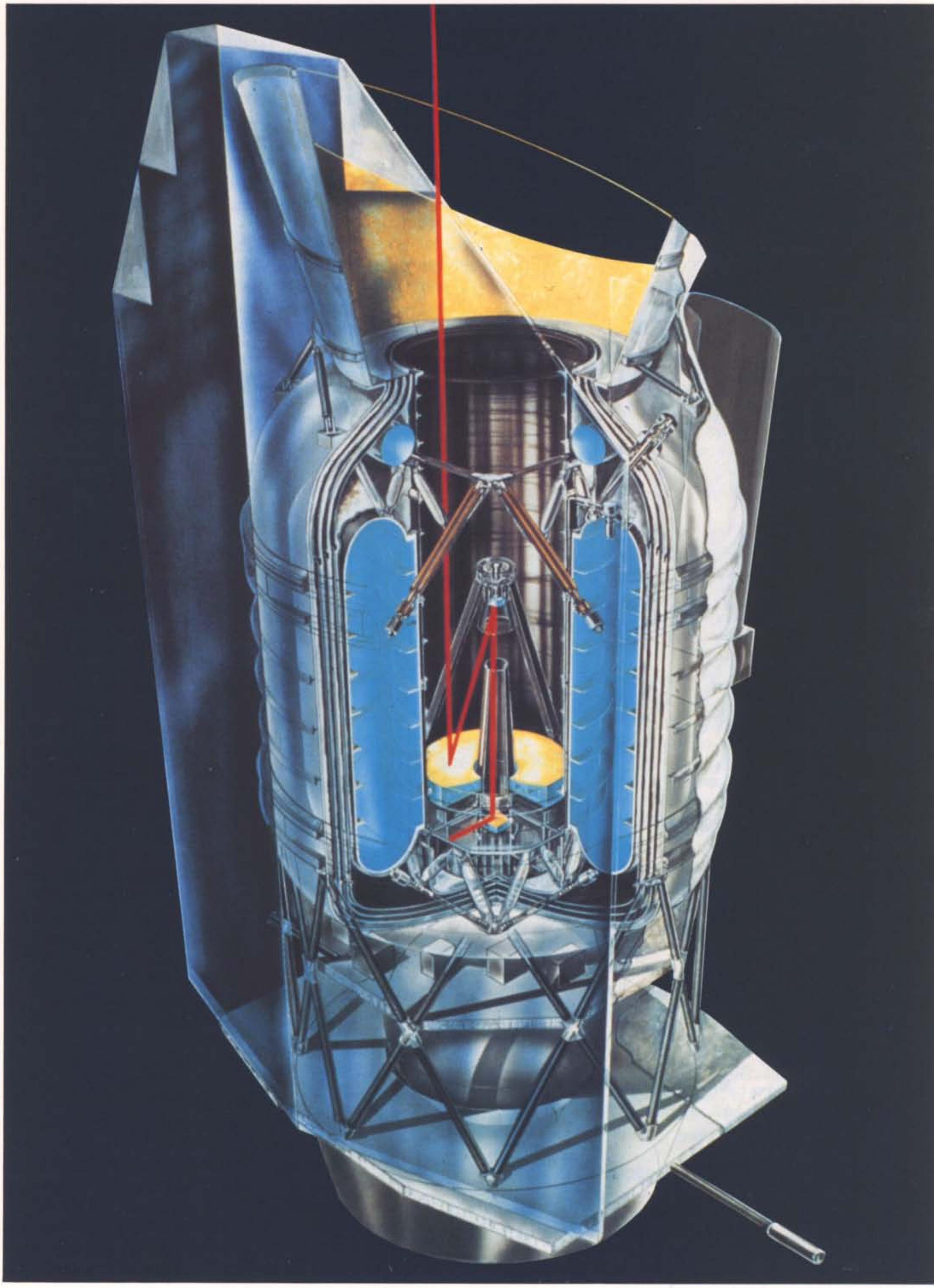


photo: MBB

The Scientific Instruments for ISO — Technical Highlights

H. Eggel, H. Schaap & G. Bagnasco
ISO Project Division, ESA Scientific Programmes Department,
ESTEC, Noordwijk, The Netherlands

The payload of the Agency's Infrared Space Observatory (ISO), to be launched in 1993, consists of four scientific instruments: a camera (ISOCAM), an imaging photo-polarimeter (ISOPHOT), a long-wavelength spectrometer (LWS), and a short-wavelength spectrometer (SWS). Each of these instruments, the main features of which are described here, is being built by an international consortium of scientific institutes using national funding. ESA will be responsible for their subsequent integration into the ISO spacecraft and the in-orbit operations.

Introduction

The Agency's Infrared Space Observatory (ISO) is an astronomical satellite that will provide astronomers with an unique facility of unprecedented sensitivity for detailed exploration of the Universe. Operating at wavelengths from 2.5 to 200 micron, it will have the ability to study objects in the solar system right out to the most distant extragalactic sources.

In keeping with ISO's role as an observatory, about two-thirds of its observing time will be made available to the general astronomical community via proposal submission and peer review.

The ISO satellite consists essentially of a large cryostat, the payload module, containing about 2300 litres of superfluid helium to maintain the Ritchey-Chrétien telescope, the scientific instruments, and the optical baffles at temperatures between 2 K and 8 K*.

The telescope has a 60-cm diameter primary mirror, and is diffraction-limited at a wavelength of 5 micron. A pointing accuracy of a few arcseconds is provided by a three-axis stabilisation system consisting of reaction wheels, gyros and optical sensors.

ISO will be launched in early 1993 by an Ariane-4 vehicle, into an elliptical orbit with an apogee of 70 000 km and a perigee of 1000 km. It will be operational for at least 18 months.

*See ESA Bulletin No. 57, pp. 53—60.

The cold focal-plane units (FPUs) of the scientific instruments are mounted behind the telescope's primary mirror. They are connected to 'warm' instrument electronics boxes on the spacecraft platform. The main characteristics of the four instruments are summarised in Table 1.

Infrared technology

Detectors

The ISO instruments use photo-conductors made from indium-antimonide (InSb), silicon (Si) and germanium (Ge). The last two are doped with various materials to achieve particular sensitivities in different wavelength ranges of interest. To extend the long-wavelength coverage of the gallium-doped germanium detector, the detector crystal is 'stressed' by applying mechanical pressure using a clamp. Infrared radiation falling on the detector produces a proportional photoelectric current (ranging from 0.1 to 100 V for different detector materials), which is integrated as the output signal.

For correct operation, the detectors have to be kept at well-defined stable temperatures (range 2—10 K for different materials). The detectors for the longer wavelengths (Ge) require the lowest operating temperatures.

Detectors are configured either as single elements (up to 1x1x1 mm in size), linear arrays (max. 64 pixels), or two-dimensional arrays (max. 32x32 pixels), and are directly connected to the pre-amplifiers and multiplexers within the focal-plane units.

Optical elements

Mirrors are needed in the focal-plane units (FPUs) to fold the optical paths (flat mirrors) and for focussing purposes (curved mirrors). Aluminium substrates are diamond-machined and the surfaces coated with gold. Lenses made from silicon, germanium and zinc-selenide (ZnSe) are used for focussing and

Table 1 — Main characteristics of ISO's scientific instruments

Instrument/ Principal Investigator	Main function	Wavelength (μm)	Spectral resolution	Spatial resolution	Outline description
ISOCAM (C. Cesarsky, CEN-Saclay, F)	Camera and polarimetry	2.5—17	Broad-band narrow-band, and circular variable filters	Pixel FOVs of 1.5, 3, 6 and 12 arcsec	Two channels each with a 32 × 32 element detector array
ISOPHOT (D. Lemke, MPI für Astronomie, Heidelberg, D)	Imaging photo-polarimeter	2.5—200	Broad-band and narrow-band filters Near-IR grating spectrometer with R ~ 90	Variable from diffraction-limited to wide beam	Four subsystems: (i) Multi-band, multi-aperture photo-polarimeter (3—110 μm) (ii) Far-infrared camera (30—200 μm) (iii) Spectro-photometer (2.5—12 μm) (iv) Mapping array (18—28 μm)
SWS (Th. de Graauw, Lab. for Space Research, Groningen, NL)	Short-wavelength spectrometer	2.5—45	1000 across wavelength range and 2×10^4 from 15 to 35 μm	10 × 20 and 20 × 30 arcsec	Two gratings and two Fabry-Pérot interferometers
LWS (P. Clegg, Queen Mary & West Field College, London)	Long-wavelength spectrometer	45—180	200 and 10^4 across wavelength range	1.65 arcmin	Grating and two Fabry-Pérot interferometers

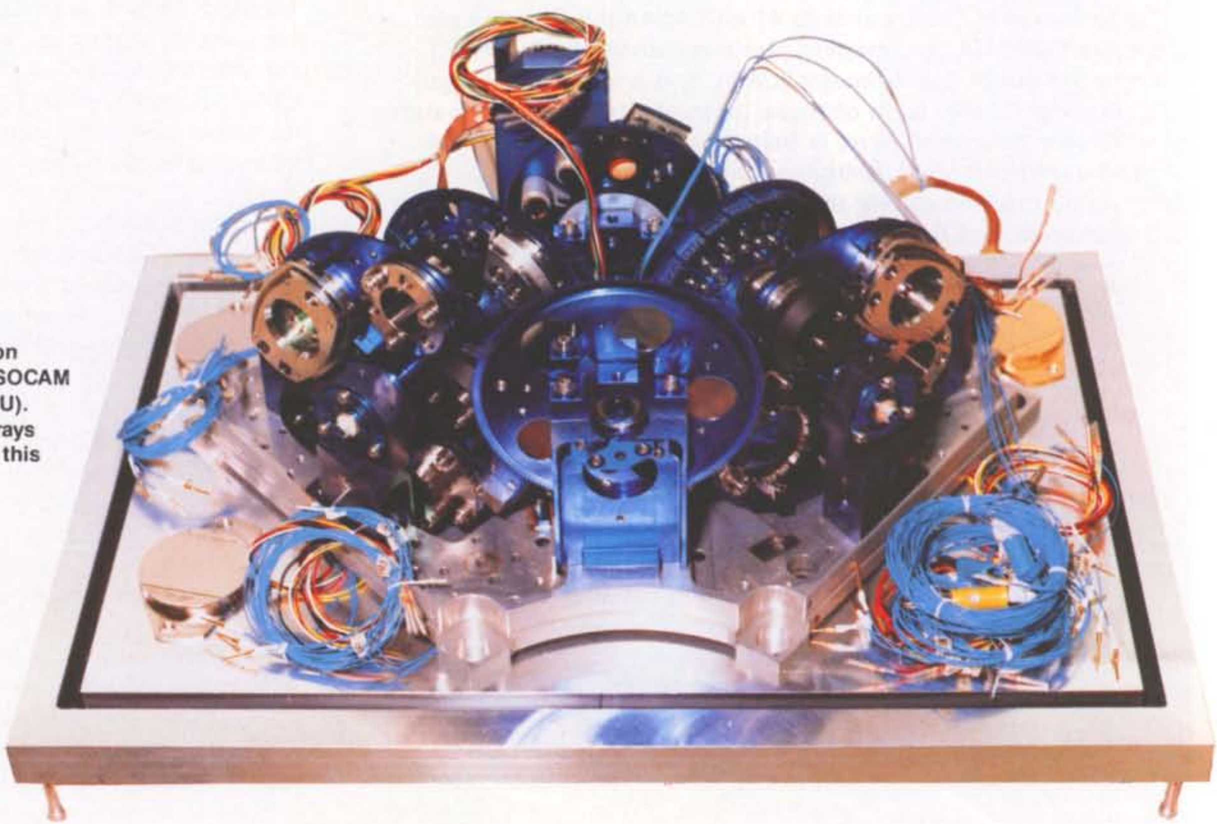


Figure 1. Qualification model (QM) of the ISOCAM Focal-Plane Unit (FPU). The two detector arrays are not mounted on this model

changing the field of view (FOV) at shorter wavelengths (up to 15 micron).

Filters are used to select specific wavelength bands for each detector. Materials like germanium, silicon, calcium-fluoride, sapphire, and quartz are used as carrier substrates for multilayer interference filters.

The dichroic beam splitters, which combine the functions of beam separation and filtering, are made from crystals such as sapphire, strontium-fluoride or lithium-fluoride. For longer wavelengths, multilayer metal-mesh assemblies are used.

Polarisers allow different orientations of the electromagnetic field vectors of the infrared radiation to be distinguished.

Diffraction gratings (ruled on aluminium blanks, 8 to 100 lines/mm) disperse the wavelengths for spectroscopy, for which Fabry-Pérot etalons provide a very high resolution. Within the etalon, a resonant cavity between two partly reflecting, partly transmitting mirrors (metal meshes) is created. Only the 'resonant' wavelengths are transmitted. Tuning is performed by changing the distance between the metal meshes.

The Infrared Camera (ISOCAM)
The ISOCAM consists of two similar optical channels which operate in two spectral regions with two different arrays of infrared detectors, each with 32x32 elements (Fig. 1).

In the short-wave (SW) optical channel, one InSb array operates in the 2.5—5.5 micron wavelength range. In the long-wave (LW) channel, a Si:Ga array covers the 4—17 micron band.

Opto-mechanical design
A schematic of the camera layout is shown in Figure 2. On entering the camera, the optical beam, deflected by a pyramidal mirror, first encounters the 'entrance wheel'. In addition to clear apertures, this wheel also carries a set of three polarising grids spaced at angles of 120°. These grids allow polarisation measurements to be made in either channel.

Next, the beam encounters the 'selection wheel', which allows of one of the two optical channels to be chosen, by means of two Fabry mirrors. This wheel is also used for the in-orbit calibration of the detectors.

On the following two 'filter wheels', one for the long-wave and the other for the short-wave section, a total of 26 filters are mounted. These filters, including three Circular Variable Filters (CVFs), define the infrared spectral range of the observations.

Finally, in each channel, a so-called 'lens wheel', positioned in front of the array, carries four lenses with different magnification factors for matching the fixed pixel size of the detectors to the desired pixel field of view (PFOV) on the sky, or in other words the size of the window through which the detector will

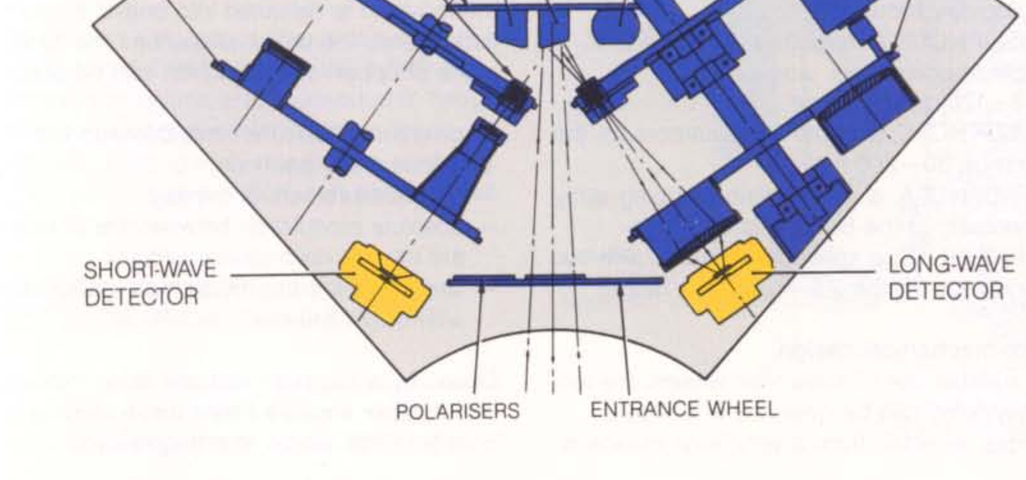


Figure 2. Schematic of the ISOCAM instrument's opto-mechanical design

observe the sky. Choices of 1.5, 3, 6 and 12 arcsec per pixel are possible.

Each wheel, made from titanium, is driven by a superconductive stepper motor (which eradicates Joule losses) in order to limit heat dissipation inside the unit and thereby minimise temperature fluctuations. Vespel, a composite polymeric material, has been chosen for the motor pinion, both for its good elastic properties and satisfactory mechanical behaviour at low temperatures, and for its low coefficient of friction.

The Infrared Photo-polarimeter (ISOPHOT)

The ISOPHOT instrument (Fig. 3) is a photo-polarimeter designed to work in the infrared spectral band, between 2.5 and 200 micron.

wavelength/aperture combinations. When ISOPHOT-P is selected, through wheels 2 and 3, 14 bandpass filters, with apertures ranging from 5 to 180 arcsec, can be used in combination with the three single detectors (Si:Ga, Si:P and Ge:Ga) mounted on it.

In ISOPHOT-C, three two-dimensional arrays (3x5 Ge:Be, 3x3 Ge:Ga and stressed 2x2 Ge:Ga) are each used in combination with nine bandpass filters and three polarisers.

By appropriate setting of wheel 1, a two-dimensional array (8x8 Si:P) can be used with the choice of one of four broadband filters in ISOPHOT-A.

Finally, with ISOPHOT-S selected, by means of wheel 1, the 128 detector elements,

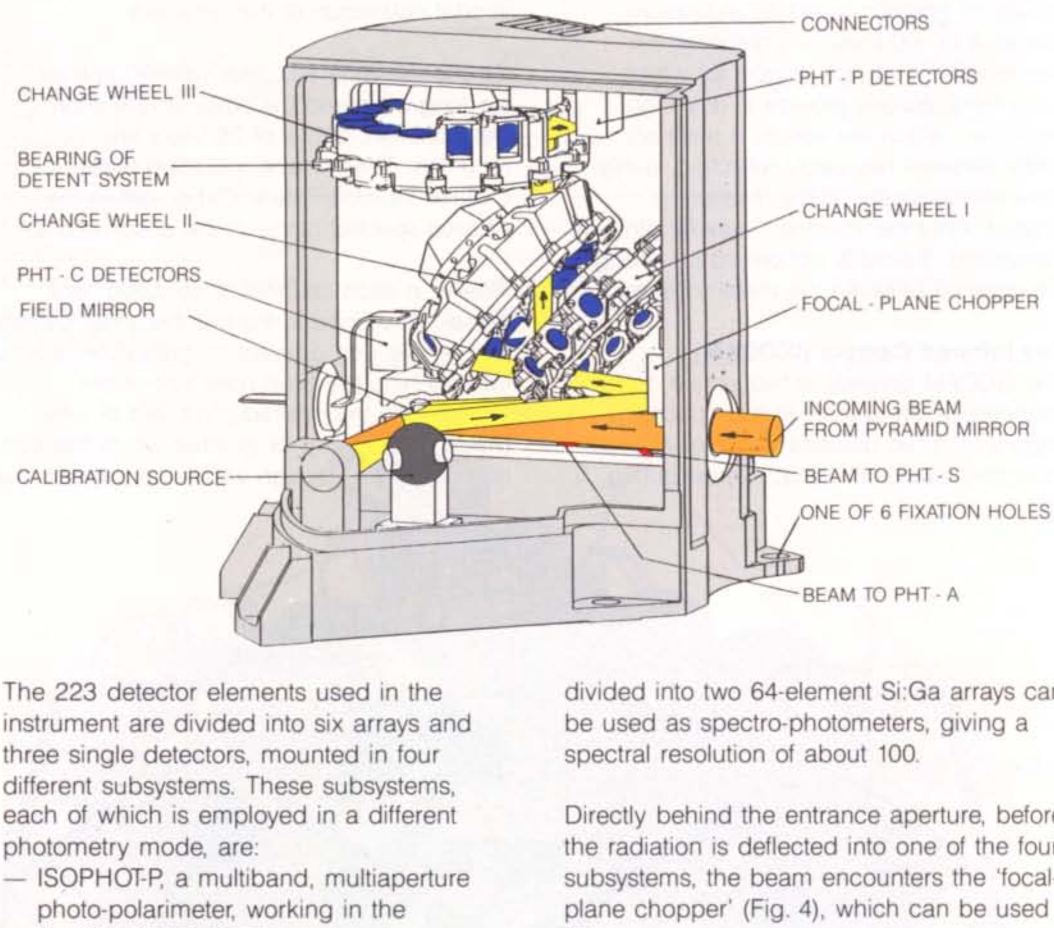


Figure 3. Schematic of the ISOPHOT instrument's opto-mechanical design

The 223 detector elements used in the instrument are divided into six arrays and three single detectors, mounted in four different subsystems. These subsystems, each of which is employed in a different photometry mode, are:
- ISOPHOT-P, a multiband, multiaperture photo-polarimeter, working in the 3—120 micron range
- ISOPHOT-C, a photometric camera for the range 30—200 micron
- ISOPHOT-A, a photometric mapping array working in the 8—28 micron range
- ISOPHOT-S, a spectrophotometer with two gratings for the 2.5—12 micron range.

Opto-mechanical design

By suitable use of three filter wheels, the four subsystems can be operated in different modes, selected from a very large choice of

divided into two 64-element Si:Ga arrays can be used as spectro-photometers, giving a spectral resolution of about 100.

Directly behind the entrance aperture, before the radiation is deflected into one of the four subsystems, the beam encounters the 'focal-plane chopper' (Fig. 4), which can be used for:
- differential measurements between two adjacent sky positions
- DC measurement of the sky
- absolute modulation between the sky and the internal calibration sources
- step scanning to provide high resolution with bright sources.

Driven by a magnetic coil, the tilting mirror of the chopper allows a beam throw ranging from 5 to 360 arcsec at a frequency of

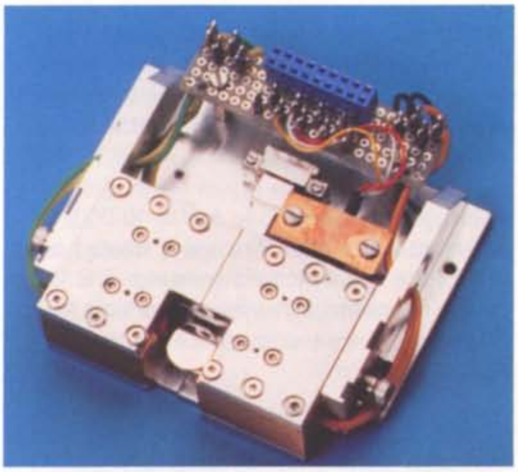


Figure 4. Development model of the focal-plane chopper. The mirror is visible in the cavity at the bottom

between 1/256 Hz and 16 Hz. A position sensor of the field-plate type enables the drive to generate any travel/time cycle within the limits specified above.

The Short-Wave Spectrometer (SWS)
The SWS is a grating spectrometer designed to cover the 2.5 to 45 micron band, with a spectral resolution** of 1000; this can be raised to 20 000 in the 15—35 micron range.

A variety of detectors have been chosen to cover the short-wave band, ranging from InSb (2.5—4.5 micron) to Si:Ga (4.5—12 micron), from Si:P (12—28 micron) to Ge:Be (27—45micron), for a total of 52 detectors, mounted on four different arrays, and two Fabry-Pérot sections.

Opto-mechanical design
The instrument consists of two parallel sections, which work in two infrared sub-bands at 2.5—13 and 12—45 micron (Fig. 5).

An optical input unit, positioned directly behind the entrance aperture, allows both spatial and spectral separation of the light into the two sub-bands and the selection of the possible fields of view, by means of dichroic beam splitters and different input slits.

Using collimating optics (two independent sets of toroidal and paraboloidal cylindrical mirrors), the beams are focussed onto two diffraction gratings, which disperse the radiation. Each grating has its own scanning mirror, allowing use of both sub-bands at the same time.

After reflection from the grating, each sub-band almost retraces its path before it is finally refocussed on the detector blocks by means of re-imaging optics.

Tunable Fabry-Pérot etalons allow a resolving power of up to 20 000 to be achieved in the range from 15 to 35 micron, by suitably deflecting the beam coming from one of the two gratings.

The grating drive (Fig. 6) employs a linear motor and has two flexural pivot hinges. The yoke, which carries the flat scanning mirror, is pushed by a coil in the field of a permanent samarium-cobalt magnet, against the counterforce of the flexural pivots. The full range of rotation is 12°, with a position reproducibility of 3 arcsec. The power consumption of this unit is less than 1 mW.

The Long-Wave Spectrometer (LWS)
The LWS is a grating spectrometer working in the infrared band between 45 and 180 micron, with a spectral resolution of either 200 or 10 000 across this entire wavelength range. Three types of photoconductive detectors will be used:
— one Ge:Be detector, to cover the 45—55 micron region
— five Ge:Ga detectors, to cover the 55—110 micron region
— four stressed Ge:Ga detectors for the 110—180 micron region.

These three types of detectors are mounted in a single array.

Opto-mechanical design
The LWS has three main subsystems (Fig. 7):
— input/collimating optics, which contains seven mirrors

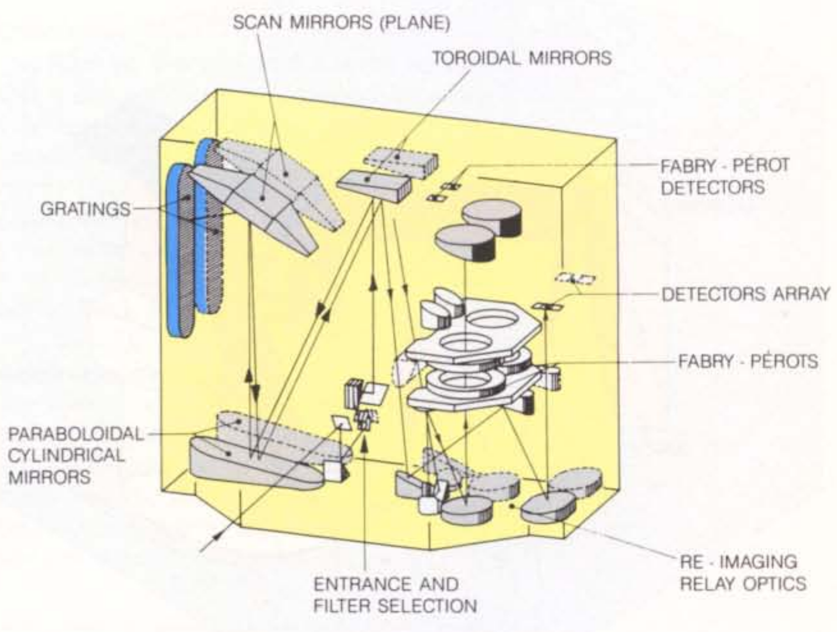


Figure 5. Schematic of the SWS instrument's opto-mechanical design

**The 'spectral resolution' is the capability to distinguish different monochromatic components.

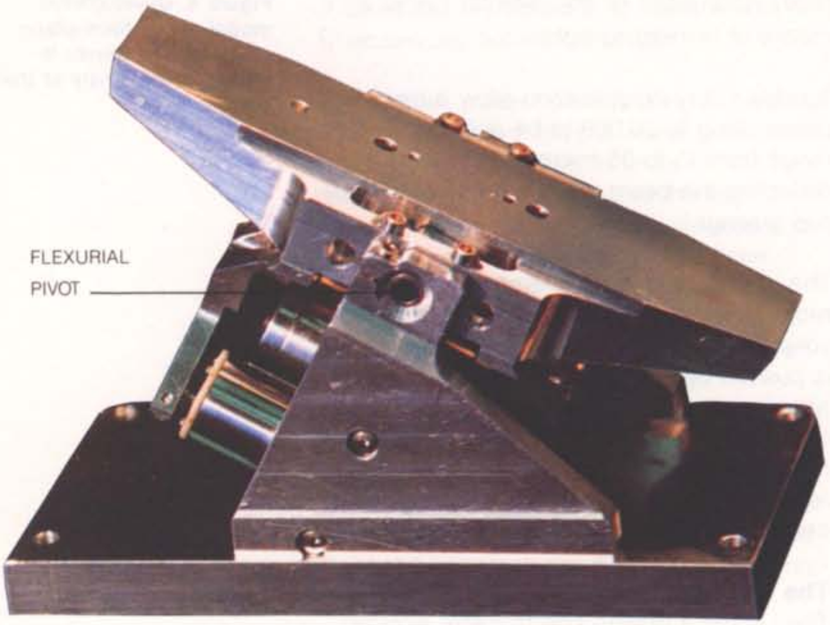


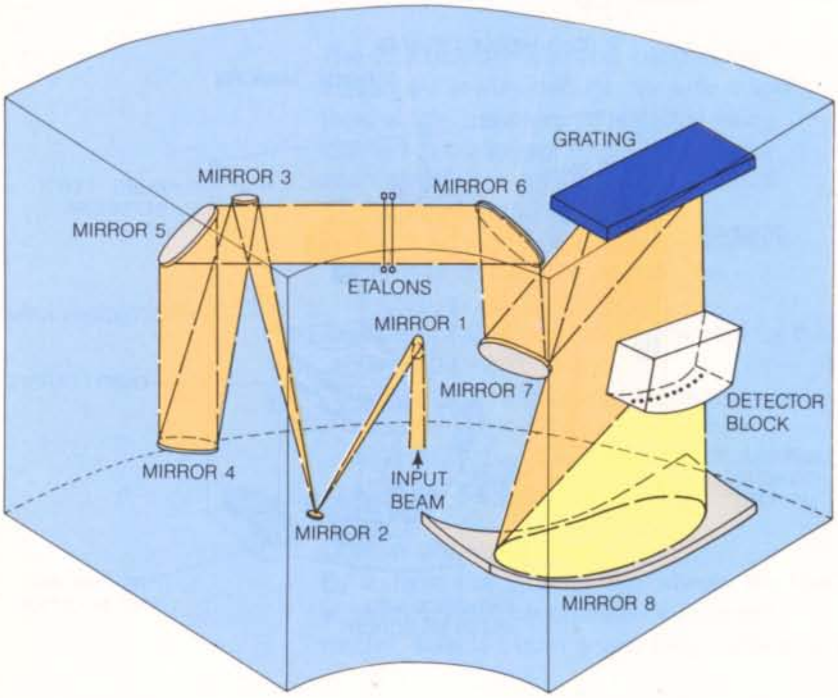
Figure 6. Development model of the SWS grating drive

— a Fabry-Pérot etalon assembly (FP), mounted on an FP exchange wheel controlled by a cryo stepper motor
— a diffraction grating, mounted with its own scanning structure, as in the SWS, and completed by refocussing optics and the detector array.

After having been deflected by the first five mirrors, which define the field of view and produce a parallel beam, the radiation passes through the FP exchange wheel. In addition to the two FP etalons, the latter also carries a clear aperture.

Figure 7. Schematic of the optical components of the LWS

In the low-resolution mode (neither of the two Fabry-Pérot etalons selected), the beam illuminates the diffraction grating directly, via mirrors M5 and M6. The grating disperses the radiation, which the refocussing mirror M8 then brings to a focus at the ten-detector assembly. A resolving power of about 200 is achieved by this approach.



The high-resolving mode (up to 10 000) is activated when the FP wheel is rotated and one of the two etalons is selected. The first one is optimised for wavelengths from 45 to 90 micron; the second covers the range 90—180 micron.

The FP system (Fig. 8) contains three triangular-shaped plates carrying three electromagnet assemblies, which move the meshes of the etalons against the force of three leaf springs.

Instrument electronics

The instrument electronics can be divided into:
— detector read-out and amplification
— analogue signal conditioning
— digital processing
— power supply
— spacecraft interfaces.

With the exception of the detector read-out, which is part of the focal-plane unit (FPU) and is mounted inside the cryostat, the remainder of the electronics are mounted either on the spacecraft's equipment platform or on the cryostat itself (ISOCAM preamplifier)

Detector readout and amplification

Single-element detectors (LWS, SWS and ISOPHOT) are read-out by means of integrating amplifiers, located close to the detector itself, on the support structure. The detector signals, which are generally in the microvolt range, are amplified and bandwidth-limited before being converted to digital form (12-bit analogue-to-digital converter).

Analogue signal conditioning

This involves various tasks, such as:
— generation of detector bias voltages
— temperature sensor conditioning
— heater control
— calibration source control
— mechanism control.

Bias voltages are variable within a certain range and can be commanded to achieve optimum detector performance. Voltages are as high as 100 V and need extremely good filtering as any noise would directly feed into the detector amplifier and thereby cause serious degradation.

As detector performance is temperature-dependant, this temperature must either be known exactly or controlled within narrow limits. For this purpose, the FPUs contain a variety of temperature sensors capable of measuring in the range up to 10 K.

Various motor types are used to rotate/move the FPU mechanisms such as the filter wheels and the grating. All of these motors have been carefully selected for minimum power dissipation.

Mechanisms are monitored using position encoders. The CAM instrument, for example, uses magneto-resistors for wheel origin and step counting. Hall sensors are used to determine the positions of the three PHT ratchet wheels. Servo loops are used for the gratings and etalons in the spectrometers.

Digital processing

All instruments will completely controlled by one of two redundant 16-bit microprocessor assemblies.

Each assembly consists of a processor, memories and spacecraft interfaces. Address, data and control busses are generally separated, but each assembly can interface to any part of the analogue electronics.

In summary, the assemblies will:

- accept, interpret and execute commands
- output formatted scientific and housekeeping data (approx. 25 kbit/s)
- control mechanisms
- control calibration sources
- control and read-out the analogue electronics
- control detector temperature.

Operational software is stored in read-only memory and can be called automatically or by ground command.

Power supply

All instruments use redundant converters to generate secondary voltages from the 28 V spacecraft bus.

Spacecraft interfaces

Instrument sensitivities dictate the use of opto-couplers and pulse transformers as digital interface circuits in order to separate the various grounding points. For analogue signals, differential stages are used.

A total mass of 90.5 kg is allocated to the instruments (36.1 kg to the FPUs). The total instrument power is 80 W, but only 10 mW are allowed to be dissipated per FPU for thermal reasons.

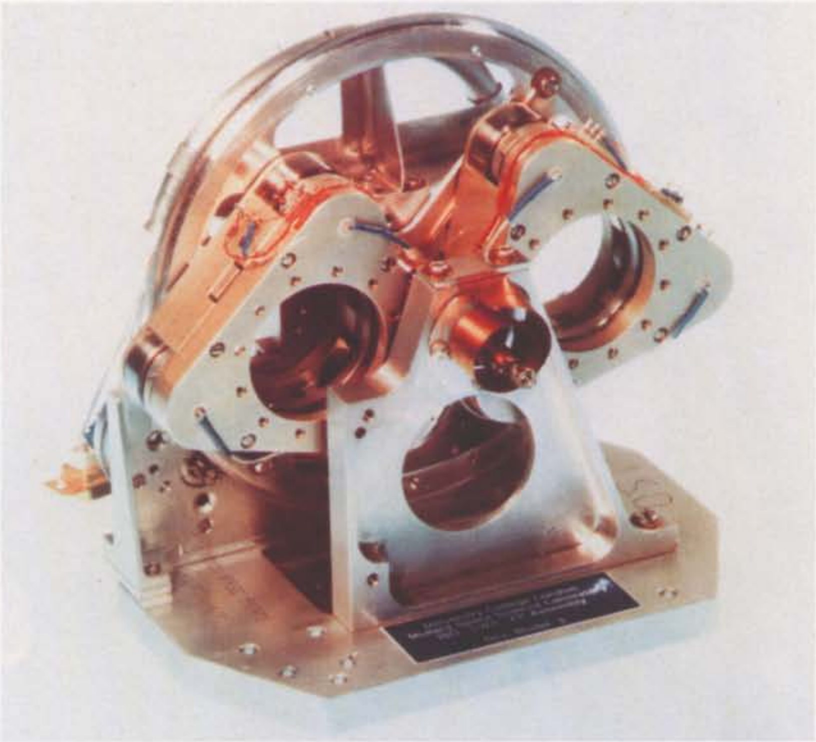


Figure 8. The two Fabry-Pérot etalons of the LWS mounted on the exchange wheel

A more unusual 'resource' on ISO is the limited cross-section of the cryo-harness which connects the FPUs with the warm electronics. Stainless-steel and brass in two wire gauges have been selected, to minimise the heat loss along the harness.

With an average cryo-harness length of 5 m, this leads to typical operational resistance values of 500 ohm for stainless steel. Brass wires are only used where the higher wire resistance would lead to impractical voltages and/or high dissipative losses in the harness.

Conclusion

The scientific instruments that make up the ISO spacecraft's scientific payload constitute a complete, complementary and versatile package for infrared astronomy. Having completed the design and development phase, the qualification models of the four instruments are now being built for delivery to the Agency in mid-1990. The flight models will be ready in early 1991.

Acknowledgement

The authors wish to acknowledge the efforts of the ISO Principal Investigators (noted in Table 1) responsible for the four instruments making up the ISO spacecraft's scientific payload, and their groups, on whose work this article has been based.


ISO

Wissenschaftliche Zusammenarbeit im Weltraum

C. Habfast
Kabinett des Generaldirektors, ESA, Paris

B. Pfeiffer
ESA Büro für das 'International Space Year',
ESTEC, Noordwijk, Niederlande

Etwa zwanzig Raumfahrtagenturen rund um den Globus bereiten sich derzeit auf das 1992 stattfindende 'International Space Year' vor. Diese gemeinsame Anstrengung soll ein Jahr lang die Aufmerksamkeit der Weltöffentlichkeit darauf lenken, daß die Nutzung des Weltraums einen wichtigen Beitrag zur Zukunftssicherung der Menschheit leisten kann. Hauptthema sind die Aktivitäten unter dem Oberbegriff 'Mission to Planet Earth'. Zwanzig Raumfahrtagenturen haben sich im 'Space Agencies Forum of International Space Year' (SAFISY) zusammengeschlossen mit dem Ziel, der Umweltforschung das große, noch viel zu wenig genutzte Potential der satellitengestützten Erdbeobachtung zu erschließen. Kürzlich hat auch die Vollversammlung der Vereinten Nationen diese Aktivitäten ausdrücklich gutgeheißen. Treibhauseffekt, Rückgang des tropischen Regenwalds, Ozonloch — diese und verwandte Schlagworte sind zwar seit einigen Jahren in aller Munde, und dank eines wachsenden Bewußtseins über die Gefahren anthropogener Umweltveränderungen hat die Forschung über ihre Ursachen und Wirkungen in den letzten Jahren einen großen Aufschwung erlebt. Dennoch ist die Menschheit von einem umfassenden Verständnis des 'Systems Erde' noch weit entfernt. Jeder Versuch, diesen Gefahren wirksam mit politischen Maßnahmen zu begegnen, muß jedoch auf einem echten wissenschaftlichen Verständnis beruhen und nicht auf Trendmeldungen, Schätzungen oder Hysterie.

Das 'International Space Year' könnte in zwei Bereichen einen wertvollen Beitrag zum Bemühen um ein besseres Verständnis unserer Umwelt leisten: Zunächst durch Überlassung von Daten der zahlreichen Erderkundungssatelliten, sowie anschließend durch Unterstützung bei ihrer Auswertung, Verknüpfung und Interpretation; sowie zweitens durch Anregen internationaler und interdisziplinärer Zusammenarbeit, was auch durch die Weitergabe der in der Weltraumforschung über drei Jahrzehnte gewonnenen Erfahrungen erfolgen könnte.

In diesem Beitrag wird daher zunächst die internationale Zusammenarbeit in der Weltraumforschung analysiert. Ein zweiter Teil befaßt sich damit, welche der dabei gewonnenen Erfahrungen und Organisationsformen auf 'Mission to Planet Earth' anwendbar sind.

Internationale Zusammenarbeit in den Weltraumwissenschaften — Rückblick und derzeitiger Stand

Seit den frühen 1960er Jahren haben sich Wissenschaftler über Grenzen und Fachgebiete hinweg zusammengeschlossen, um ihre Instrumente auf Satelliten und Raumsonden plazieren zu können. Da sowohl die Instrumente als auch die Satelliten ständig größer und komplexer wurden, kann sich diesem Trend schon seit geraumer Zeit kein Wissenschaftler mehr entziehen, der international konkurrenzfähige Forschung betreiben will. Heute haben deshalb faktisch alle wissenschaftlichen Weltraummissionen eine mehr oder weniger stark ausgeprägte internationale Komponente.

Historisch gesehen hat diese Zusammenarbeit zwei Wurzeln: Zunächst einmal waren Zusammenarbeit und Austausch von Resultaten und Erfahrungen schon immer ein wichtiger Bestandteil jeder wissenschaftlichen Arbeit. Die gemeinsame Planung und Durchführung von Experimenten über Ländergrenzen hinweg ist allerdings eine Errungenschaft der zweiten Hälfte unseres Jahrhunderts, begonnen mit CERN und auch dem Internationalen Geophysikalischen Jahr 1957/58, die beide erheblich zum Aufschwung der Weltraumforschung beitrugen. Denn seitdem die Rolle des Forschers nicht mehr auf die eines erdgebundenen Beobachters des

Weltraums beschränkt war, sondern dieser seine Instrumente im Weltraum plazieren konnte, bestand der Wunsch, sich diese Möglichkeit auch zunutze zu machen. Die sehr begrenzten Möglichkeiten, Instrumente zuerst auf Höhenraketen und dann auf Satelliten zu plazieren, zwangen die Wissenschaftler aber ganz automatisch zu enger Zusammenarbeit. Selbst die Gründung von ESRO ging auf eine gemeinsame Initiative europäischer Wissenschaftler zurück.

Bereits in dieser ersten Phase der modernen Weltraumforschung konnte sich COSPAR, das 'Committee on Space Research' des 'International Council of Scientific Unions' (ICSU), als wichtigstes internationales Forum für den Austausch und die Diskussion von Ergebnissen etablieren. Es verwundert deshalb kaum, daß COSPAR seit nunmehr drei Jahrzehnten auch im Vorfeld der Auswahl zukünftiger Missionen eine wichtige Rolle spielt.

Internationale Zusammenarbeit in der Weltraumforschung geht allerdings nicht ausschließlich auf die Initiative von Wissenschaftlern zurück. Bereits in den 1960er Jahren begannen die Weltraumagenturen ihre Kräfte in manchen Gebieten zu bündeln, allerdings aus unterschiedlichen Beweggründen, weil ESRO und die nationalen europäischen Raumfahrtorganisationen zu dieser Zeit bei gemeinsamen Missionen mit der NASA höchstens die Rolle eines Joniorpartners spielen konnten; dennoch brachte diese Zusammenarbeit beiden Seiten Vorteile, auch den USA, weil das Niveau der europäischen Wissenschaft sich durchaus auf einer Höhe mit dem der Wissenschaft in den USA befand. Es sei hier nur daran erinnert, daß das erste von Menschen auf dem Mond in Gang gesetzte Experiment, das sogenannte 'Sonnenpaddel', aus Europa stammte.

Komet Halley

So ist es seit den Anfangsjahren der Weltraumfahrt üblich, daß die Weltraumagenturen ihre eigenen wissenschaftlichen Satelliten für Instrumente auswärtiger Wissenschaftler öffnen. Seit kurzem haben sogar die USA und die UdSSR einen solchen gegenseitigen, regulären Austausch vereinbart. Allerdings unterwerfen sich die Partner in solchen Fällen eindeutig den Regeln, Spezifikationen und vor allem dem Missionsplan derjenigen Weltraumagentur, die das jeweilige 'Announcement of Opportunity' unterbreitet. Auch auf die Auswahl der Instrumente haben die auswärtigen Wissenschaftler, wenn überhaupt, nur begrenzten Einfluß. Dennoch war Zusammenarbeit auf dieser Ebene in der Vergangenheit wichtig, und sie hat viel zu den wissenschaftlichen Fortschritten der Weltraumforschung in den letzten dreißig Jahren beigetragen.

Im Laufe der letzten Jahre kam zum Austausch von Instrumenten schließlich ein neues Element hinzu. Heute ist Europa eine erfahrene 'Weltraumnation', ebenso wie Japan, Kanada sowie eine ständig wachsende Zahl weiterer Staaten. Zudem hat die Sowjetunion im Zuge von 'Glasnost' und 'Perestroika' den westlichen Nationen ihr ziviles Weltraumprogramm für gemeinsame Vorhaben geöffnet. Missionen in internationaler Zusammenarbeit werden deshalb heute nicht mehr von einer der beiden Großmächte dominiert, sondern sind im Idealfall von einem pluralistischen Zusammenspiel vieler, an der Weltraumforschung interessierter Nationen charakterisiert.

Immer häufiger planen deshalb heute mehrere Partner eine wissenschaftliche Mission von Beginn an gemeinsam, d.h. sie legen ihre wissenschaftlichen, technischen und finanziellen Randbedingungen gemeinsam fest und führen die Mission anschließend auch, bei verteilter Aufgabenstellung, gemeinsam durch.

Einen Meilenstein auf diesem Weg zu pluralistischer Zusammenarbeit setzten vier Raumfahrtagenturen in der ersten Hälfte der 1980er Jahre, als sie mehrere Missionen zum Kometen Halley gemeinsam planten und koordiniert durchführten. Das Gemeinschaftsprojekt bestand aus europäischen, japanischen und russischen Raumsonden sowie der Möglichkeit zur Mitbenutzung des 'Deep-Space Tracking Network' der NASA. Die Koordination wurde im wesentlichen von einer 'Inter-Agency Consultative Group for Space Science' geleistet, deren Tätigkeit mit dem Vorbeiflug der letzten Raumsonde, Giotto, an Halley übrigens keineswegs beendet war. Heute kümmert sich diese Arbeitsgruppe um das Gelingen eines noch ambitiöseren Projekts für die 1990er Jahre, des internationalen 'Solar-Terrestrial Programme'.

Der europäische Beitrag zum Solar Terrestrial Programme ist die Soho/Cluster Mission — die wie alle gegenwärtigen wissenschaftlichen Projekte der ESA aus dem Langzeitplan 'Horizon 2000' abgeleitet ist. Der Horizon 2000-Plan ist in diesem Zusammenhang auch deshalb bemerkenswert, weil er sowohl eine Unabhängigskeitserklärung der Europäer darstellt, mit dem Anspruch, in allen wichtigen Bereichen moderner Weltraumforschung konkurrenzfähige Missionen durchzuführen, als auch ein Angebot an alle außereuropäischen Weltraumnationen, sich an diesen Missionen zu beteiligen oder sie durch eigene Projekte zu ergänzen. Einige Missionen in Horizon 2000 wurden bei der Aufstellung des Plans ererbt, weil ihre Durchführung zu diesem Zeitpunkt bereits feststand, und sie wurden daher in den Plan eingebettet. Dazu gehören Ulysses, die europäische Beteiligung am Hubble Space Telescope und Hipparcos. Aus dieser Aufzählung wird deutlich, daß enge internationale Zusammenarbeit bereits vor Horizon 2000 existierte, wenn auch — wie bei Ulysses — nicht immer ohne Umwege und gelegentliche Schwierigkeiten. Soho/Cluster, ISO und Huygens/Cassini sind innerhalb des von Horizon 2000 gesetzten Rahmens definiert bzw. ausgewählt worden. Auch hier sind sowohl kooperative Missionen als auch fast lupenrein europäische Projekte vertreten. Was hat sich im Vergleich zu den Anfangsjahren der Weltraumforschung geändert?

ISO ist ein weitgehend europäisches Projekt, obwohl einer von fünf 'Mission Scientists' von einer amerikanischen Universität berufen wurde. ISO macht deutlich, daß die Weltraumforschung in Europa heute in der Lage ist, sich zwar nicht auf der ganzen Breite, aber doch in einzelnen, ausgewählten Bereichen weltweit an die Spitze zu stellen. Denoch hätte die ESA eine gewisse internationale Beteiligung an diesem Projekt begrüßt, schon alleine aus Kostengründen. Bei ISO standen dem ausgeprägten europäischen Interesse an einem Infrarotobservatorium auf seiten potentieller Partner jedoch entweder andere wissenschaftliche Schwerpunkte, fehlendes Interesse oder unzureichende Mittel gegenüber. Die ESA führt dieses Projekt deshalb in alleiniger Verantwortung durch. Auch die vier Instrumente der Nutzlast werden unter europäischer Federführung entwickelt.

Der europäische Teil des Solar Terrestrial Programme, dessen Kernbaustein Soho/Cluster darstellt, wird im Gegensatz hierzu vollkommen von internationaler Zusammenarbeit bestimmt sein. Die Soho-Raumsonde wird in Europa gebaut und anschließend bei der NASA zum Teil getestet, in den USA gestartet und auch von dort aus gesteuert werden. Die Sowjetunion wird mit

Cassini/Huygens

großer Wahrscheinlichkeit vier, zu den vier europäischen Cluster-Satelliten kompatible, Regatta-Satelliten beisteuern, was die Genauigkeit und Aussagekraft der Messungen erheblich verbessern wird.

Auf eine Initiative der NASA geht der zweite Teil des Solar Terrestrial Programme zurück, das sogenannte 'Global Geosphere Satellite Programme', das vier Satelliten und Raumsonden vorsieht: Geotail, Wind, Polar und Equator. Zwei dieser Satelliten werden von der NASA alleine entwickelt, zwei weitere gemeinsam mit Japan sowie wahrscheinlich der Sowjetunion.

Auch die Instrumente der Nutzlast von Soho/Cluster werden zum Teil unter Federführung auswärtiger Institute entwickelt. Schon bei Giotto beteiligten sich alle großen Forschungsinstitute in den USA an der Entwicklung der zehn Instrumente (allerdings ließ sich dieser Umstand zum Teil auch darauf zurückführen, daß die NASA keine eigene Raumsonde zu Halley schickte). Bei Soho und Cluster wurden nun sogar vier amerikanische Wissenschaftler zu 'Principal Investigators' bestimmt.

Soho/Cluster

Der erste Start innerhalb des Solar Terrestrial Programme soll 1992 — also während des 'International Space Year' — erfolgen. Nach 'Wind' und 'Geotail' folgen die anderen Satelliten zwischen 1993 und 1996.

Die Zusammenarbeit der vier beteiligten Raumfahrtagenturen beschränkt sich jedoch nicht nur darauf, mehr als zehn Missionen zeitlich und programmatisch aufeinander abzustimmen und für Instrumente der beteiligten Partner zu öffnen. Das Ergebnis des Solar-Terrestrial Programme soll nach dem Willen aller Beteiligten ein einziger, einheitlicher Datensatz auf der Grundlage von Meßwerten aller Missionen sein. Dazu müssen zunächst die Rohdaten ausgetauscht, gegenseitig abgeglichen und miteinander kombiniert werden. So praktische Fragen wie Datenstandards und -übertragungsprotokolle stehen deshalb seit geraumer Zeit ganz obenan auf der Liste der Aktivitäten der 'Inter-Agency Consultative Group for Space Science'. Die dabei gewonnene Erfahrung wird anschließend sicher auch in anderen Bereichen von Nutzen sein.

Ein Beispiel, wohin die Entwicklung, auch dank der Fortschritte in der Computertechnologie, gehen kann, ist die Exosat-Datenbank. Jeder Wissenschaftler auf der ganzen Welt kann seit Mitte 1987 von seinem Institut aus über ein Computernetzwerk die Kataloge der gesamten von Exosat gewonnenen Rohdaten, der vorausgewerteten Daten sowie der bislang gewonnenen Ergebnisse konsultieren. Anschließend besteht die Möglichkeit, Magnetbänder mit relevanten Daten zu ordern. Seit Einrichtung dieser Datenbank wird von dieser Möglichkeit zwischen 400 und 600 mal pro Jahr Gebrauch gemacht.

Die ESA versucht, die beschriebene neuere Form internationaler Zusammenarbeit nach Kräften zu fördern. So ist die jüngste Mission im Horizon 2000 Plan — Huygens/Cassini — zwar in erster Linie nach wissenschaftlichen Kriterien ausgewählt worden. Ihr Charakter als bilaterales Projekt hat aber sicher dazu beigetragen, daß sich dieses Projekt wissenschaftlich gegenüber starker Konkurrenz durchsetzen konnte. Übrigens zeigte sich hier ein weiteres Mal der strategische Vorteil eines Langzeitplans: Der ESA gelang es, ihre Wahl für Huygens mehr als ein Jahr vor der offiziellen Genehmigung des NASA Projekts CRAF/Cassini in den USA zu treffen. Die Konzeption von Huygens macht deutlich, daß auch in diesem Fall nicht hinter bereits Erreichtes zurückgetreten werden soll: Die Huygens-Probe wird von der Cassini Raumsonde zum Saturnmond Titan getragen werden, sich dort von ihr lösen und in die Titanatmosphäre eintauchen. Es ist offensichtlich, daß dieses Konzept ohne engste Zusammenarbeit und Abstimmung bald an praktischen Schwierigkeiten scheitern würde.

Bei bilateralen Projekten nationaler europäischer Raumfahrtagenturen zeigt es sich vielleicht noch deutlicher, daß internationale Zusammenarbeit in der Weltraumforschung heute unverzichtbar geworden ist. Weder von der finanziellen Leistungskraft noch vom wissenschaftlichen Potential her könnte eine einzelne europäische Nation ein Projekt wie IUE oder CRAF verkraften bzw. voll ausnutzen. Wenn sie es dennoch versuchte, ginge dies nur zu Lasten der gesunden Balance zwischen den einzelnen wissenschaftlichen Disziplinen der Weltraumforschung, die auch im nationalen Maßstab nicht aus dem Gleichgewicht geraten sollte.

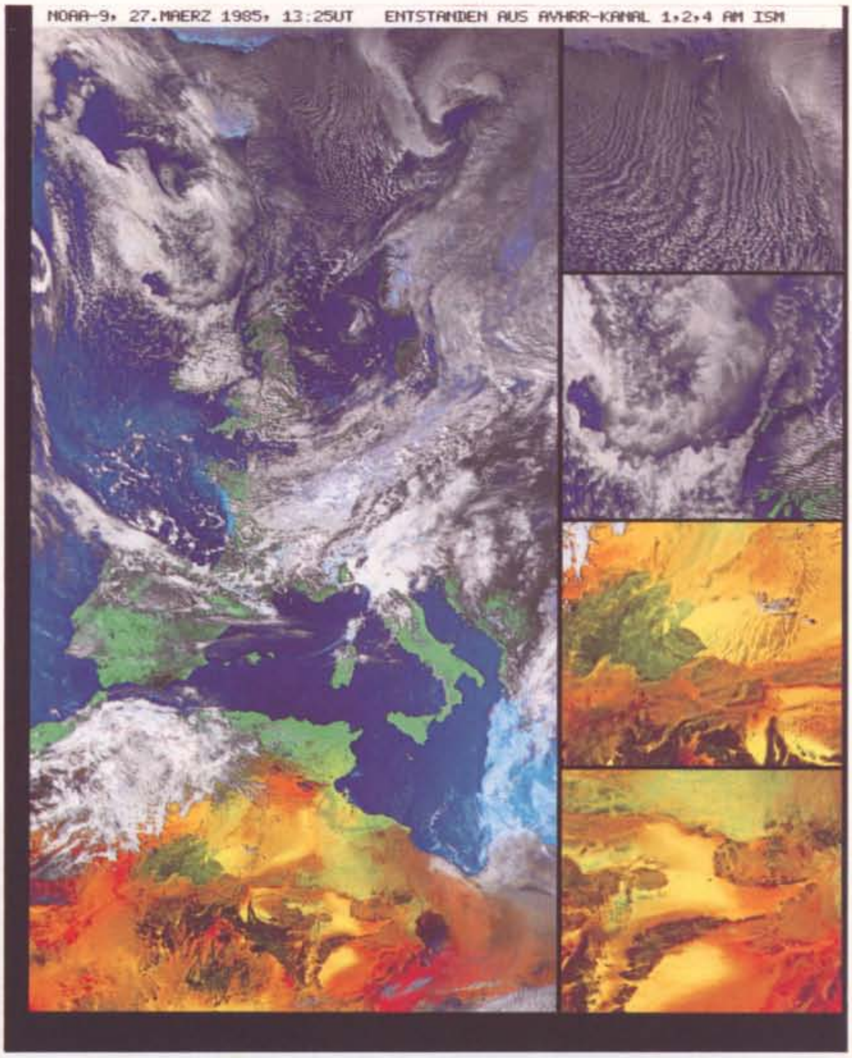
Erderkundung und internationale wissenschaftliche Zusammenarbeit — gegenwärtiger Stand und Ausblick

Die Tatsache, daß satellitengestützte Erdbeobachtung nicht nur von wissenschaftlichem Wert, sondern auch von kommerziellem Interesse und von militärstrategischer Bedeutung ist, macht deutlich, daß sich die geschilderten Erfahrungen und Beispiele aus der Weltraumforschung nicht ohne weiteres auf dieses Gebiet übertragen lassen. So wäre es hier im Gegensatz zur Situation in der Weltraumforschung durchaus vorstellbar, daß ein Wissenschaftler die Ergebnisse seiner Untersuchungen mit Gewinn vermarktet; außerdem hat nicht jedes Land ein Interesse daran, daß Aufnahmen seiner militärischen Anlagen an ausländische Forscher abgegeben werden.

Wenn im folgenden dennoch versucht wird, die beschriebenen Erfahrungen mit wissenschaftlicher Zusammenarbeit daraufhin zu prüfen, ob sie für die wissenschaftliche Erforschung des Systems Erde nutzbar gemacht werden können, so geschieht dies aus zwei Gründen: Die ESA dient erstens weder kommerziellen noch militärischen Zielen; die von ihr entwickelten und erprobten Modelle für internationale wissenschaftliche Zusammenarbeit könnten deshalb vielleicht überall dort Anwendung finden, wo die wissenschaftliche Komponente nicht zu vernachlässigen ist — wie zum Beispiel in der Erdbeobachtung. Und zweitens ist es an der Zeit, daß manche Hindernisse, die sich der wissenschaftlichen Nutzung von Erdbeobachtungsdaten immer noch in den Weg stellen, beiseite geschafft werden.

Die ersten Nutzer der Erderkundung von Satelliten aus waren zweifellos die Militärs. Auch heute noch wird der größte Teil der Erderkundungsdaten für militärische Zwecke gewonnen, und der militärischen Fernaufklärung stehen in den USA und der UdSSR substantielle Finanzmittel zur Verfügung. Aus offensichtlichen Gründen sind diese Daten der Öffentlichkeit bzw. der Wissenschaft aber entweder gar nicht oder nur in sehr begrenztem Umfang, d.h. absichtlich in ihrer Aussagekraft verschlechtert, zugänglich.

Da die Daten für militärische Anwendung zivilen Nutzern nur begrenzt zur Verfügung standen, diese Daten aber auch nicht in jeder Hinsicht den zivilen Anforderungen genügten, entstanden Programme mit zivilen Schwerpunkten z.B. 'Landsat' in den USA und SPOT in Frankreich. Daten beider Programme können sowohl kommerziell genutzt als auch zu Aufklärungszwecken herangezogen werden. Aber nicht nur diese Beispiele machen deutlich, daß die Grenzen zwischen den Nutzern von Erdbeobachtungsdaten ins Fließen geraten sind.

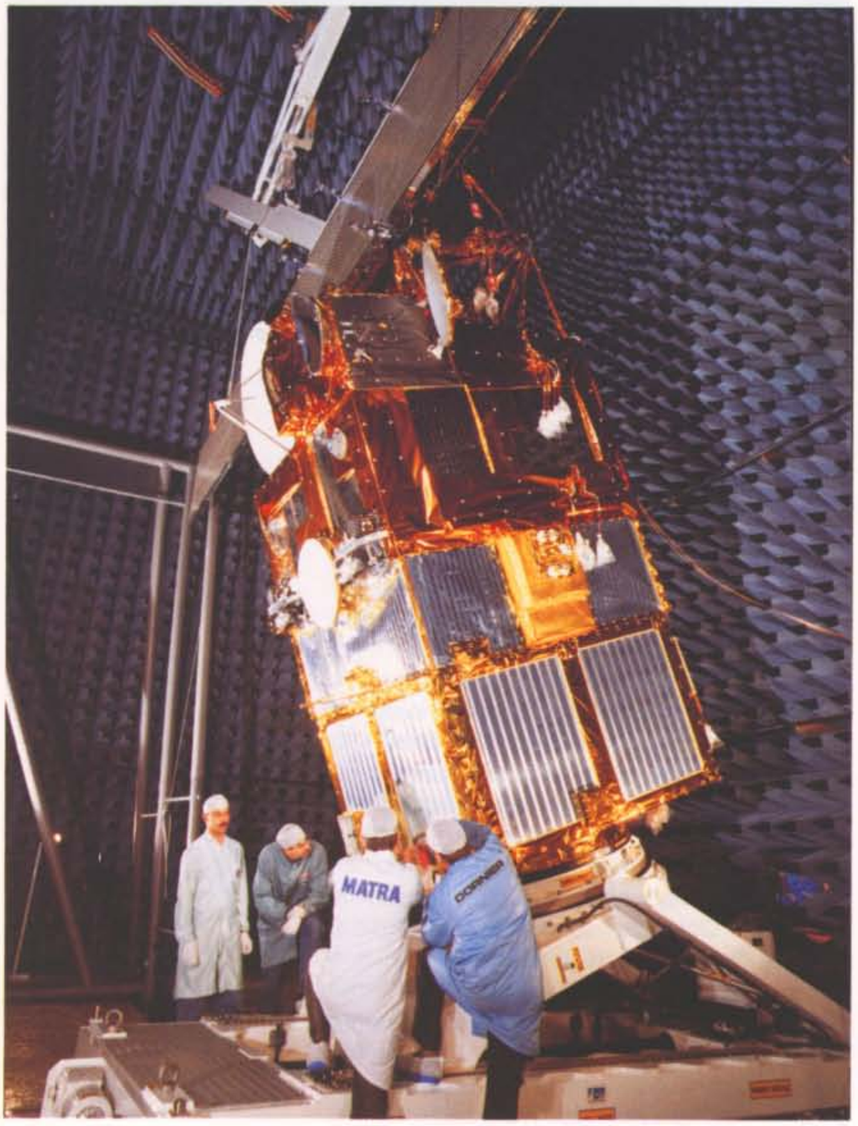


Wetterbeobachtung durch Satelliten

Die zweite, historisch bedeutsame Wurzel der Erdbeobachtung ist die Meteorologie. Was vor 20 oder 25 Jahren auf der ganzen Welt als mehr oder weniger experimentelles Programm begonnen wurde, hat sich mittlerweile zu einem 'World Weather Watch' mit polaren und geostationären Satelliten entwickelt, an der alle großen Weltraumnationen beteiligt sind. Die beträchtlichen Fortschritte der letzten Jahre in der Wettervorhersage über mehrere Tage sind nicht nur auf die erhöhte Rechengeschwindigkeit der Computer, sondern auch auf die bessere Qualität der in die Rechenprogramme eingespeisten Eingangsdaten zurückzuführen. Diese Aussage bezieht sich weniger auf die Genauigkeit der Daten, sondern vor allem auf die globale Datenerfassung: Dank der Wettersatelliten stehen heute auch Messungen von den Polen, den Ozeanen und aus dünn besiedelten Gebieten zur Verfügung.

Die bis vor wenigen Jahren vorherrschende Situation, daß Erdbeobachtungsmissionen von einer recht genau umreißbaren Nutzergruppe wie z.B. Meteorologen, Kartographen oder militärischer Aufklärung angestoßen wurden, hat sich jedoch mittlerweile grundlegend geändert. Dies liegt zum einen daran, daß die Daten moderner Instrumente, wie sie zum Beispiel die des 'Synthetic-Aperture Radars' und die von spektral zerlegenden, hochauflösenden optischen Sensoren darstellen, für mehrere Nutzergruppen von Interesse sind. Zweitens ist die Erdbeobachtung heute auch außerhalb der originär staatlichen Interessensphäre von Bedeutung; zu Wettervorhersage, Kartographie und Aufklärung gesellten sich in jüngerer Zeit Anwendungen in der Erntevorhersage, der Ölprospektion, dem Vegetationsmanagement, der Waldschadenbeobachtung, sogar in der polizeilichen Überwachung von großflächigen Waldbränden wie z.B. im Amazonasgebiet — alles von herausragender ökonomischer Bedeutung. In jüngster Zeit trat schließlich ein drittes Element immer weiter in den Vordergrund, nämlich der Stellenwert der Erdbeobachtung für die wissenschaftliche Erforschung des 'Systems Erde' — der für den Menschen so wichtigen Biosphäre.

ERS-1



Das wachsende öffentliche Bewußtsein der Bedrohung der Umwelt durch anthropogene Einflüsse verdanken wir in der Tat zu einem großen Teil der Grundlagenforschung. Allerdings sind selbst von der Forschung bislang mehr Fragen gestellt denn Antworten gegeben worden; von einer umfassenden Kenntnis der Ursachen und Wirkungen von Umweltveränderungen ist die Wissenschaft noch weit entfernt. Die zu deren Gewinnung notwendige interdisziplinäre Anstrengung können Erdbeobachtungsdaten substantiell unterstützen, weil die meisten Phänomene, um deren Untersuchung es geht, nur in der Wirklichkeit, nicht jedoch im Labor untersucht werden können. Derzeit ist ein rapider Anstieg der Nachfrage nach bestehenden Daten von Erdbeobachtungssatelliten zu beobachten. Der Überlassung zu Forschungszwecken stehen allerdings nur zu oft unangebrachte kommerzielle Gesichtspunkte im Weg.

Klimatische Trends und die dahinter stehenden Phänomene können nur dann wirklich verstanden werden, wenn globale Datensätze über lange Zeiträume — eher in Dekaden denn in Jahren gemessen — zur Verfügung stehen. Bei einer kommerziellen Vermarktung von Satellitendaten besteht jedoch die Gefahr, daß der für derart umfangreiche Datensätze zu entrichtende Preis die finanziellen Möglichkeiten der Forscher bei weitem übersteigt. Der Gegensatz zwischen kommerzieller und wissenschaftlicher Nutzung wird dadurch weiter verschärft, daß die wissenschaftlichen Nutzer der Daten sich auf viele verschiedene Disziplinen aufteilen und daher weit weniger schlagkräftig auftreten können als dies zum Beispiel bei der Gemeinde der Weltraumwissenschaftler der Fall ist.

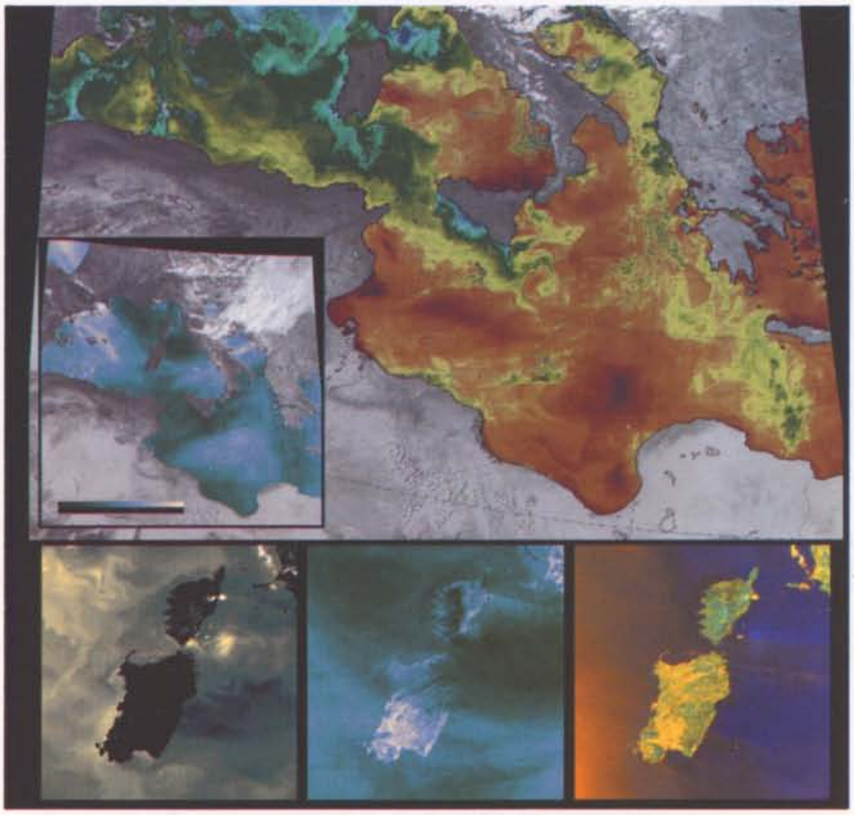
Die Bedeutung des Beitrags von Erdbeobachtungsdaten wird noch nicht gebührend berücksichtigt, und es bedarf noch erheblicher Forschungsarbeit, um die Daten richtig interpretieren zu können. Dies erfordert indessen ausgedehnte Vergleichsuntersuchungen mit aus der Erdbeobachtung gewonnenen Daten.

Deshalb müssen auf der ganzen Welt — die ESA hat in dieser Richtung bereits entscheidende Schritte unternommen — Wissenschaftler der verschiedenen Disziplinen an der Definition von Erdbeobachtungsmissionen besser beteiligt werden und ihnen zudem bei der Entwicklung und dem Bau der Nutzlast mehr Mitwirkung geboten werden als bisher. Es müssen Wege gefunden werden, Daten wissenschaftlich nutzen zu können, ohne daß dadurch eine mögliche kommerzielle Verwertung gestört wird.

Für die ESA stellt sich dieses Problem erstmals in voller Schärfe mit ERS-1. Bis zum Start dieses ersten europäischen FernerkundungssatellIten muß eine diesen Forderungen gerecht werdende Datenpolitik formuliert sein. Es ist offensichtlich, daß die Wetterdienste sowie die direkt mit der Umweltforschung befaßten staatlichen Stellen in Europa kostenlosen Zugang zu den ERS-1 Daten haben werden. Da Wissenschaftler an der Konzeption der Mission entscheidend beteiligt waren, werden darüber hinaus etwa 200 'Principal Investigators' bestimmte Daten kostenlos zur Verfügung gestellt bekommen, unter der Bedingung, daß sie ausschließlich zu wissenschaftlichen Zwecken verwandt werden. Solange es die Ressourcen des Programms erlauben, soll im Prinzip schließlich jeder ernsthaft interessierte Wissenschaftler ERS-1 Daten zu Vorzugsbedingungen erhalten können, allerdings in gewissem zeitlichen Abstand zu den Principal Investigators. In allen Fällen soll die Weitergabe der Daten selbst wie auch etwaiger daraus gewonnener 'Value-Added Products' an Dritte ausgeschlossen sein. Dadurch sollen Störungen der Vermarktung von ERS-1 Daten im privaten Sektor wie auch in Bereichen, die nicht der Umweltforschung zuzuordnen sind, verhindert werden.

Vielerorts wird noch die Meinung vertreten, daß die Erderkundung sich als ein Anwendungsprogramm überwiegend aus ihrer kommerziellen Perspektive heraus rechtfertigen müsse. Dabei werden jedoch zwei Dinge übersehen: Die Erforschung des Planeten Erde in seiner Gesamtheit oder der Atmosphäre und Ozeane sind zweifelsfrei wissenschaftliche Forschungsgebiete von höchstem Rang. Sie zu verfolgen läßt sich auch ohne jede Aussicht auf eine spätere kommerzielle Nutzung rechtfertigen. Zweitens stellt die Ausschöpfung des in den Daten von ERS-1 enthaltenen Potentials selbst ein wissenschaftliches Arbeitsfeld dar. Würde der Zugang der Wissenschaft zu den Rohdaten eingeschränkt, schadete dies nur einer eventuellen späteren Vermarktung daraus gewonnener 'Value-Added Products'. Deshalb wird ERS-1 als voroperationeller Experimentier-Satellit bezeichnet, dem ERS-2 als operationelles Programm folgen soll.

Ähnliches gilt auch für die Nutzlasten, die für die zukünftigen Polaren Plattformen der ESA entwickelt werden und nicht zuletzt im Interesse wissenschaftlicher Zusammenarbeit auch auf 'fremden' Plattformen zum Einsatz kommen sollen.



Aufzeichnung der Oberflächentemperatur der Ozeane aus dem Weltraum

Allerdings setzt die volle Ausschöpfung des Potentials der Daten von Erdbeobachtungssatelliten auch auf Seiten der Wissenschaft erhebliche Anstrengungen voraus. Die Arbeitsaufteilung mag in Programmen wie dem 'International Geosphere-Biosphere Programme' oder dem 'World Climate Programme' noch entlang traditioneller Trennlinien zwischen Disziplinen erfolgen; bei Erdbeobachtungsmissionen ist dies nicht mehr möglich. Die an einer Mission interessierten Wissenschaftler müssen deshalb zur Zusammenarbeit während aller Phasen der Mission ermutigt werden. Um dies zu unterstützen, sieht die Erdbeobachtungsstrategie der ESA eine Einteilung der verfügbar gemachten Daten in vier Gebiete (ERS-2, Polar Platform, Aristoteles und 2. Generation Meteosat) vor, die sich an spezifischen, interdisziplinären Forschungsschwerpunkten orientieren. Diese Kategorien sollen von den einzelnen Missionen nach Möglichkeit gleichmäßig abgedeckt werden. Dieser Ansatz ist übrigens durchaus mit demjenigen des Horizon 2000 Plans vergleichbar, dessen vier 'Cornerstone Missions' alle relevanten Bereiche der modernen Weltraumwissenchaft abdecken.

Wenn es gelingt, zum einen eine Verbindung zwischen diesen Forschungsschwerpunkten, oder besser Themen, und den einzelnen Missionen herzustellen, und zweitens die Gemeinde der Wissenschaftler umfassend an der inhaltlichen Füllung der einzelnen Themen beteiligt wird, könnte sich im Laufe der Jahre tatsächlich eine Situation ähnlich der in den Weltraumwissenschaften herausbilden. Dort leisten die Wissenschaftler selbst einen entscheidenden Beitrag zu allen Missionen. Allerdings darf aus europäischer Sicht nicht verhehlt werden, daß die beiden Großmächte in der Erdbeobachtung immer noch eine führende Rolle spielen. Durch die Konzentration auf die wissenschaftliche Nutzung und die überwiegende Ausrichtung auf wissenschaftliche Prinzipien hofft die ESA jedoch besonders schnell voranzukommen und den Rückstand zumindest in den wichtigsten Bereichen aufholen zu können. Hier sei nur daran erinnert, daß auch ESRO seinen Erfolg zu einem großen Teil der Strategie verdankte, die Missionen ausschließlich nach wissenschaftlichen Gesichtspunkten auszuwählen.

Trotz der europäischen Autonomiebestrebungen sollte auch in der Erdbeobachtung der internationalen Zusammenarbeit eine hervorragende Rolle zukommen. Wie in den Weltraumwissenschaften gilt, daß eine gemeinsame Anstrengung bessere Resultate erbringt als die Summe einzelner Projekte. Wie aber kann internationale Zusammenarbeit gefördert werden, wenn im Gegensatz zur Weltraumwissenschaft weitere, dem entgegenstehende Interessen vorhanden sind?

Hier setzt die Rolle des 'International Space Year' ein. Wie schon bei der Weltraumwissenschaft wird man für die Anfangsjahre einer Zusammenarbeit kaum gemeinsame Missionen erwarten können — von Gebieten mit Tradition wie der Meteorologie vielleicht einmal abgesehen. Aber zum verstärkten Austausch der Daten, zur Koordination der Forschung, zur Kompilation umfassender Datenkataloge, zum gemeinsamen Entwickeln von Auswerteverfahren und zum Entwurf neuer Instrumente sowie schließlich auch zum Aufbau internationaler Arbeitsstrukturen kann 'Mission to Planet Earth' sicher einen Beitrag leisten. Bereits die in den Archiven der Weltraumagenturen gespeicherten Datenmengen können als Informationsquelle gar nicht hoch genug eingeschätzt werden, zumal ihre Aussagekraft durch Kompilation noch gesteigert werden könnte. Unter der Voraussetzung der freien Verfügbarkeit für die Wissenscnaft, wie dies bei ERS-1 der Fall sein soll, stellen diese Daten ein ausgezeichnetes 'Übungsfeld' dar.

Im Hinblick auf die Erfahrungen mit der Weltraumforschung ist es von großer Bedeutung, daß beim 'International Space Year' Weltraumagenturen offiziell zusammenwirken. Nur wenn auf deren Seite der gemeinsame Wille vorhanden ist, zunächst einmal Erdbeobachtungsdaten für die Erforschung des Systems Erde zur Verfügung zu stellen, kann eine Zusammenarbeit ähnlich wie im Solar Terrestrial Programme überhaupt nur ins Auge gefaßt werden.

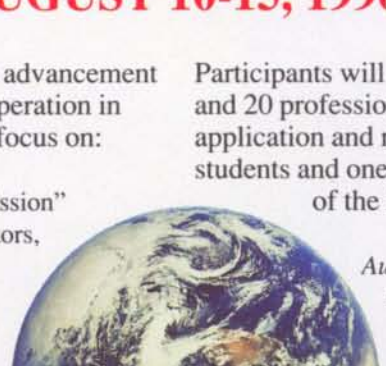
Deshalb ist es auch so wichtig, daß erste gemeinsame, konkrete Forschungsergebnisse der 'Mission to Planet Earth' schon vor 1992 vorliegen, und es war sicher richtig, sich in dieser anfänglichen Phase internationaler Zusammenarbeit auf den Rückgriff auf Bestehendes zu einigen und keine illusorischen und nicht finanzierbaren Zukunftspläne zu entwerfen. Wenn die Fortschritte dann sichtbar werden, darf nur nicht übersehen werden, daß den anfänglichen kleinen Schritten in Richtung Zusammenarbeit bald größere folgen können und müssen.

INTERNATIONAL SPACE CAMP®

AUGUST 10-15, 1990

PROGRAM GOALS: To promote the advancement of all mankind through international cooperation in space studies. Briefly, the program will focus on:

- Hands-on training for an "international mission" including shuttle and space station simulators, astronaut training devices, space experts from representative nations, and tour of NASA facilities.
- Cooperative international space ventures.
- U.S. Space Station Freedom.
- International space agencies and aerospace educational facilities.
- Projecting cooperative ventures based upon current international program goals. Also, brainstorming for international cooperation in aerospace education.



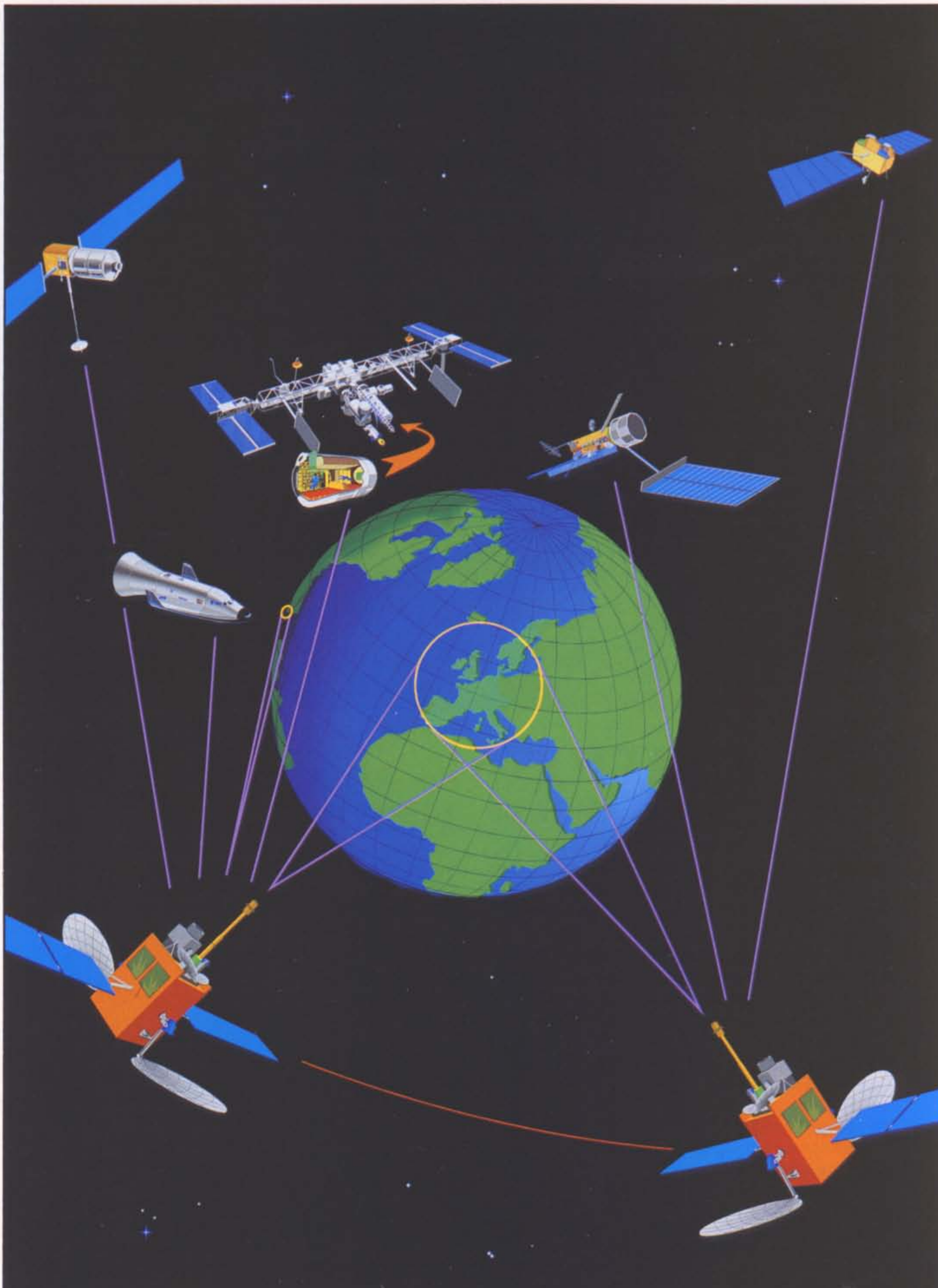
Participants will include 40 students (14-18 years) and 20 professional educators. They will apply by application and recommendation letters. Two students and one teacher will be selected from each of the following countries:

Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Norway, Soviet Union, Spain, Sweden, Switzerland, United Kingdom, and the United States.

TO APPLY, CONTACT:

Renee Jackson
U.S. SPACE CAMP®
One Tranquility Base
Huntsville, Alabama 35807 U.S.A.

Phone: 205-721-7142 Fax: 205-837-6137



The Data-Relay Preparatory Programme

A. Dickinson
ESA Communications Satellites Department, ESTEC, Noordwijk, The Netherlands

The Data-Relay Preparatory Programme (DRPP) is now reaching the conclusion of many of its major activities, and preparations are actively underway for the next phases of the Data-Relay System (DRS) Programme. It is therefore an appropriate moment to summarise both the results and conclusions of the DRPP and the plans for the future of the DRS Programme.

Introduction

The Data-Relay Preparatory Programme (DRPP) was approved in late 1986, with the primary objectives of:

— establishing and defining in detail the preferred configuration for the Data-Relay System (DRS) space and ground segments needed to provide cost-effective data-relay, information-transmission, telemetry, telecommand and ranging services for foreseen European space programmes, including particularly Columbus, Ariane-5, Hermes and advanced Earth-observation satellites;

— investigating the feasibility and determining the costs/benefits of incorporating European DRS elements into a possible global data-relay satellite system, in cooperation with other organisations;

— studying technology elements that require development activities and initiating these to ensure their timely availability in support of the overall programme; and

— obtaining, by the end of the programme, a technical baseline for the space and ground segments that will need to be developed, implemented and operated in subsequent phases, along with cost and schedule assessments for these.

The DRPP has been carried out in two main areas: system studies and technological developments. The former have been divided into three main phases of activities (delineated as Phases-A1, A2 and B1).

Phase-A1, which ran from mid-1987 to early-1988, concentrated upon the system design, defining the configuration of the ground and spaceborne elements of the DRS. This phase verified that a DRS able to provide a reliable operational service, using largely available technology, could be developed and deployed by 1996, a date commensurate with the needs of the system's primary users.

Following on from this, while expanding upon the definition of the system design, Phase-A2 had as one of its major objectives the definition of the DRS satellite configuration, and of the capacity best able to meet the communications requirements of its users.

The Phase-B1 studies, which have been in progress since mid-1989 and will come to an end in spring 1990, will design the selected satellite and the DRS ground-segment facilities to subsystem and initial-equipment levels, in order to provide a firm basis for the subsequent DRS Development Programme.

Data-relay system design

The principles and objectives of the European Data-Relay System were described in ESA Bulletin No. 51, in August 1987. These principles and objectives have been confirmed by the subsequent studies.

The Data-Relay System configuration will provide two operational satellites in geostationary orbit, visible almost continuously to satellites in low Earth orbits (LEOs) of up to 1000 km altitude, and able to relay data between those LEO satellites and a wide area of Europe.

The orbital positions of the two DRS satellites have been optimised to maximise the percentage of an orbit during which a user spacecraft can relay data, with the constraint that the link from the DRS satellite to ground should be received over a wide area of Europe. The optimisation process also took into account the atmospheric attenuation, the DRS satellite's attitude variation, and the feasibility of designing a single antenna for the satellite able to cover Europe from both the orbital positions of interest.

Since adequate bandwidth is not available at low frequencies, the 20/30 GHz bands have

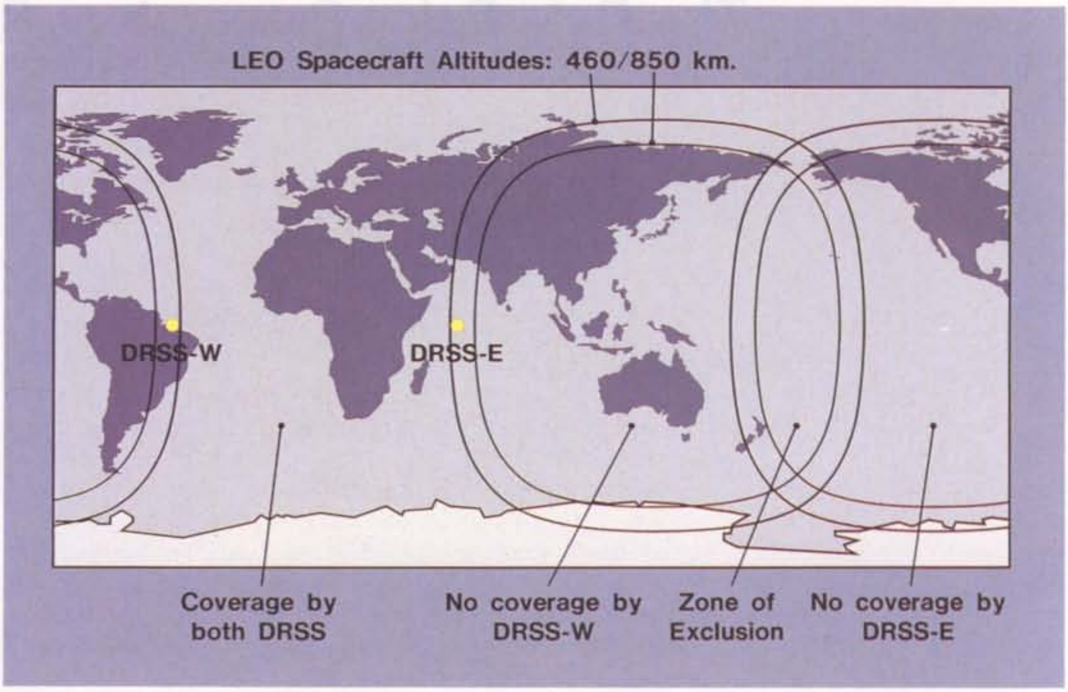


Figure 1. DRS coverage of Low-Earth-Orbiting (LEO) spacecraft

been selected for the 'feeder' links between the DRS satellites and the ground. There is a drawback here, however, in that atmospheric attenuation is significant at these frequencies.

Based upon all of the above considerations, the orbital positions of 44°W and 59°E have been selected for the two DRS satellites. The coverage afforded of spacecraft in LEO from these positions is summarised in Figure 1. It shows that full global coverage is achieved except for a small region (the so-called 'Zone of Exclusion') centred on the mid-Pacific Ocean.

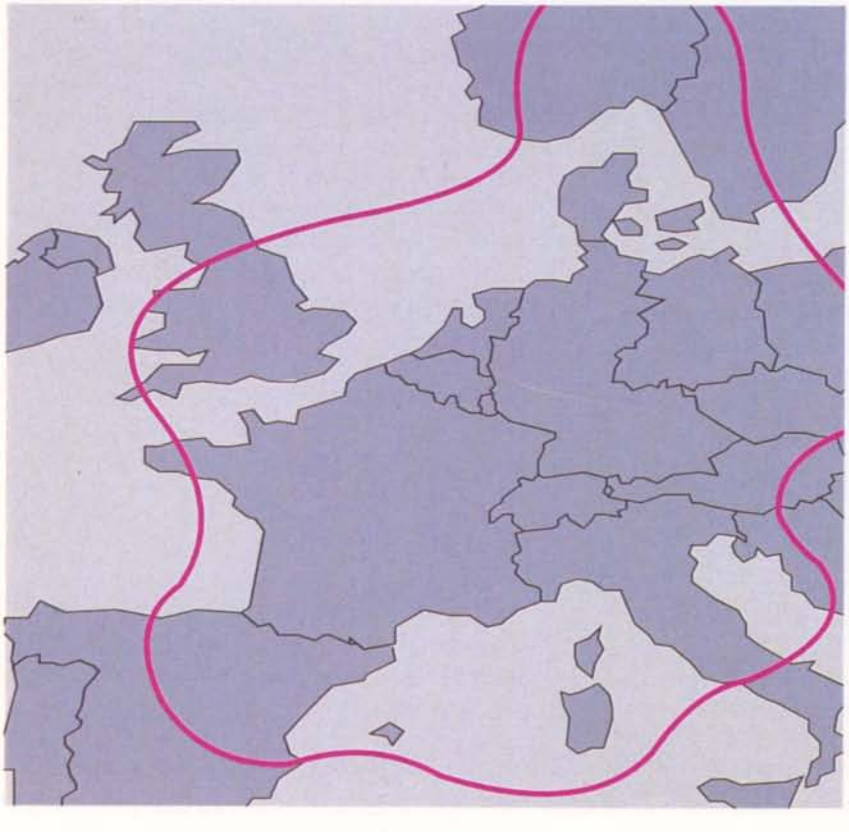


Figure 2. European feeder-link coverage

The feeder-link coverage achieved is sketched in Figure 2, where it can be seen that service can be provided to a wide region of central Europe.

In addition to a feeder link to cover Europe, it is proposed to provide a steerable feeder link able to serve any position visible from a DRSS. This feeder link can be used, for example, to provide a link to the Hermes Control Centre in Kourou during spaceplane launches, to distribute data to White Sands from American experiments on Columbus, or to serve non-European DRS users, including TDRS users during interoperability operations. It should be noted that the steerable feeder-link coverages for DRSS-E and DRSS-W differ, so that North and South America, Europe and Africa will be covered by DRSS-W, while Asia, Australia, Europe and Africa will be covered by DRSS-E.

For the link between the LEO user and the DRS satellite — the so-called 'Inter-Orbit Link' (IOL) — three frequency bands have been chosen: S-band, Ka-band and optical frequencies. The choice of band in a particular case will depend partly on the data rate to be transmitted between the LEO user and the DRS satellite, and partly on user preference and convenience.

The S-band is most suitable for users wishing to transmit data rates of less than 3 Mbit/s. It has advantages for users with 'omni-directional' antennas, such as the Columbus elements, in emergency situations, and Hermes when using its hemispherical or quadrant antennas. It also allows low-data-rate users to operate with directive antennas without the need for radio-frequency tracking systems. It is proposed to use this approach with the Hermes high-gain antenna. This frequency band is also used by the NASA TDRS and is foreseen to be used by the NASDA DRTS. Interoperability between the three systems is thus being actively pursued at S-band.

Ka-band (i.e. 23 GHz forward and 26 GHz return) and optical frequencies are both candidates for use by high-data-rate users. Ka-band technology is already quite mature, having been developed for Olympus and other European satellites. The Columbus elements are proposing to use this frequency band for normal operations. NASA and NASDA have also selected this frequency band for the high-data-rate links of their data-relay systems, to be implemented in the late 1990s, thus providing a further possibility for interoperability between the ESA, NASA and NASDA data-relay systems.

The alternative frequency band for the high-data-rate users is at optical wavelengths. This is an area of new technology and one which holds much promise for the future. With today's technology levels, the optical approach leads to link data rates, equipment masses and power consumptions that are not superior to those at Ka-band. However, this is a fast-moving field, and improvements in laser diode powers and receiver sensitivities over the next few years could radically change this situation.

The 'Silex' laser-optical communications experiment being developed within the programme for the Technology Mission Satellite, proposed for launch in 1994, will verify the characteristics of optical interorbit communications, and it is planned to continue using optical IOLs on the operational DRS satellites.

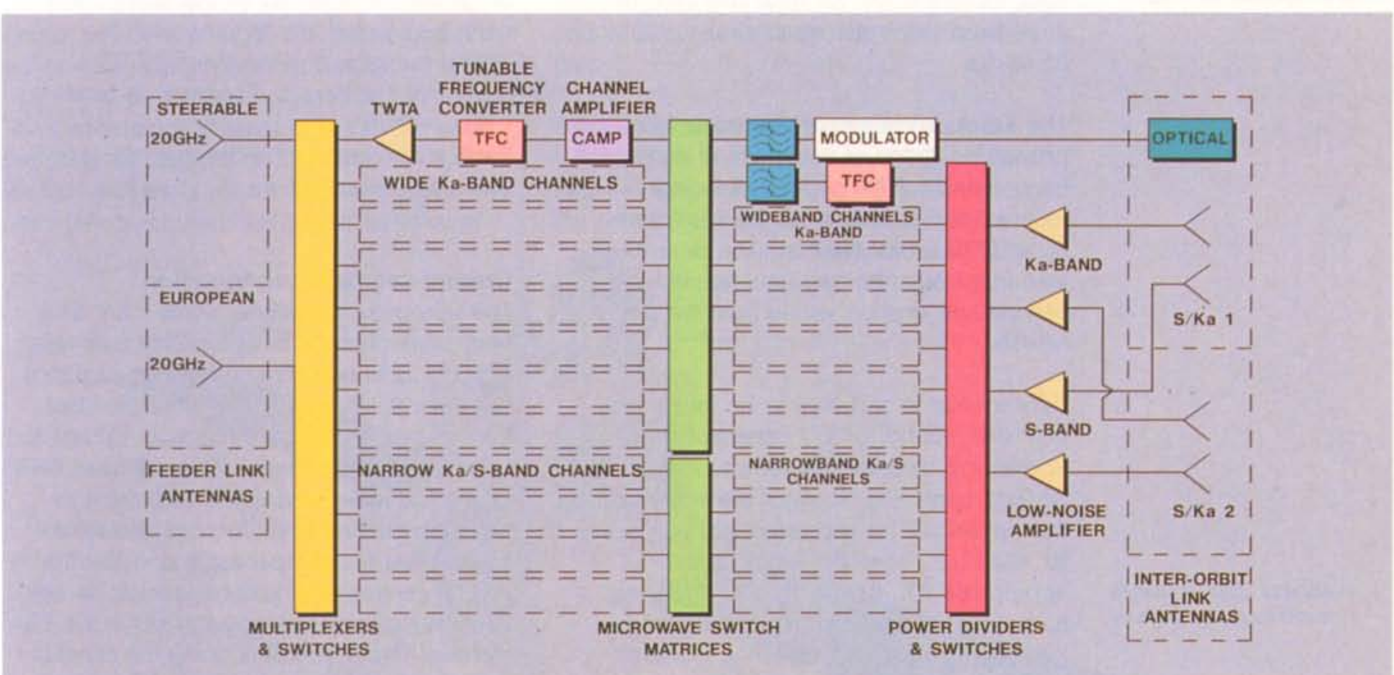
DRS satellite configuration

During the DRPP studies, a satellite configuration has been developed based on maximum use of available technology. In subsequent phases of the DRS programme, trade-offs will be made against alternative configurations, making increased use of advanced technology.

The satellite configuration defined within the DRPP is designed to provide two radio-frequency accesses on each satellite, each able to operate at either S- or Ka-band, and an optical access channel which will be used initially in a pre-operational mode.

The DRS satellite payload will be comprised of two interconnected elements, one handling return signals from user LEO spacecraft to the ground, and the other handling the forward signals from the ground to the LEO spacecraft (Fig. 3). The signals from S-band users will be upconverted on-board to the DRS satellite-to-ground frequency of 20 GHz and, after amplification, frequency-division-multiplexed with the other user return signals

Figure 3. DRS satellite return-repeater concept



prior to transmission to the ground. For the Ka-band users, a channelised system has been defined, with both narrow-band and wide-band channels.

A narrow-band channel provides a capacity of up to 10 Mbit/s, while a wide-band channel can carry up to 150 Mbit/s. After pre-amplification, these channels will be separated, frequency-converted and amplified individually, prior to being frequency-division-multiplexed with the other user return signals for transmission to the ground.

Optical IOL users' signals are received through a steerable telescope and (after detection and demodulation) are handled in the same manner as high-data-rate Ka-band data. Optical users will have a choice of three fixed data rates, at around 16, 32 and 65 Mbit/s.

The complete payload, including the optical package, is expected to weigh around 400 kg and to have a power requirement of 1.6 kW.

The spacecraft carrying this payload will weigh about 2.2 tons at lift-off, and will have a power consumption of approximately 2 kW. Its in-orbit configuration is shown in Figure 5. The two large S/Ka-band IOL antenna reflectors each have an aperture of 2.85 m, and are stowed for launch against the east and west faces of the spacecraft. When deployed, the antenna reflectors are steerable about two axes to track the LEO spacecraft. The associated antenna-pointing mechanisms are also mounted on the spacecraft's east and west faces.

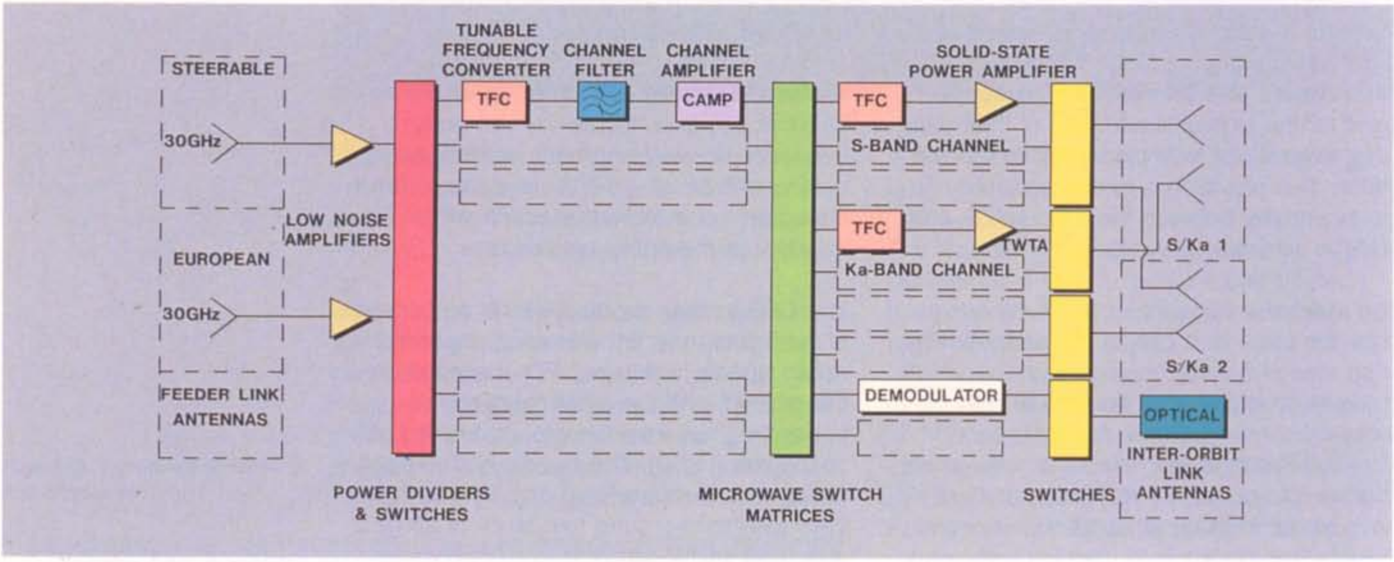


Figure 4. DRS satellite forward-repeater concept

The European feeder-link antenna will provide coverage of the whole of central Europe and will be capable of being reconfigured so that it can be used from either DRS orbital position. The steerable feeder-link antenna can be repointed to service any location visible from the DRS satellite.

Telecommands and data to be forwarded from the ground to LEO users will be uplinked at different frequencies in the 30 GHz band (Fig. 4). After pre-amplification, the signals will be separated into one signal for each LEO user, converted to the appropriate IOL frequency, amplified, and transmitted to the LEO user via the same IOL antenna used for receiving his return signals at the DRS satellite.

The European and steerable feeder-link antennas are mounted on the spacecraft's earth-facing platform, together with the optical package and the S-band TTC (telemetry, tracking and command) antenna.

Each spacecraft will be designed for a ten-year operational lifetime.

Ground-segment configuration

The European Data-Relay System will differ from other planned or operational data-relay systems in its decentralised communications architecture, which will allow multiple User Earth Terminals (UETs) throughout Europe to be served independently. This will allow DRS to provide wide-band video and high-rate data services via direct forward and return links between user spacecraft and satellite control centres of different agencies, as well as to multiple receive-only stations in the ESA Member States and also, using the steerable feeder link, to locations outside Europe.

For the ESA projects associated with the European In-Orbit Infrastructure (IOI), UETs are planned near the Hermes Flight Control Centre in Toulouse (F) and near the Columbus Free-Flyer Control Centre in Oberpfaffenhofen (D). These UETs will be interconnected to provide mutual back-up. Another earth terminal may also be built to serve the Polar Platform. Additional receive-only UETs may also be installed especially for Polar-Platform data reception. Further UETs can be expected to be constructed in the future for other ESA programmes and for other users.

DRS will be able to provide forward and return feeder-link Central User Facilities (CUFs) to users who do not wish to install their own facilities for either primary or back-up services. These CUFs will be co-located with the Hermes and Columbus Free-Flyer UETs mentioned above, to form ESA Earth Terminals (EETs).

DRS earth terminals in Europe serving more than one user spacecraft will have to be equipped with two antennas, one pointing at each DRS satellite, and be able to switch each user independently to either antenna.

DRS earth terminals in Europe serving only one user could, in principle, operate with only one antenna, which could be pointed at one DRS satellite or the other as required. However, a second fixed-mount antenna may be a cheaper and more reliable solution than a steering mechanism.

DRS earth terminals outside Europe (or western and central Africa) will only be able to obtain service via one DRS satellite, and so will need only one antenna.

The performance characteristics of the earth terminals will depend on the data rate and the link availability required, as well as on the performance of the User Space Terminal at the other end of the link. The DRS link design has ensured that UETs will need to be equipped with antennas of not more than 10 m-diameter to receive S-band or wide-band Ka-band channels, or 3 m to receive narrow-band Ka-band channels. The precise configuration of a UET will depend upon its exact location and the prevailing climate.

Although the DRS user communications architecture will be decentralised, the management of all Data-Relay System services is to be concentrated in the DRS Mission Control Centre (MCC), to be located at the Agency's European Space Operations Centre (ESOC), in Darmstadt (D). The MCC will provide facilities for both operational management and user support services, including:
- DRS operations management
- DRS engineering support and customer services
- operational interfacing with IOI (in-orbit infrastructure) and non-IOI users
- long-term planning
- arranging provision of DRS services
- management interfacing with IOI and non-IOI users
- user pre-launch certification.

The DRS-MCC will also control a network of DRS facilities at different geographical locations and in particular the DRS Operations Control Centre (OCC), the two EETs and the In-Orbit Test (IOT) facilities.

The control and monitoring of the DRS satellites, the generation of DRSS tele-commands, and the reception of DRSS telemetry will be performed by the DRS OCC and TTC stations to be located at Fucino, in Italy.

Back-up facilities will also be installed at Villafranca in Spain (back-up OCC) and at Redu in Belgium (back-up TTC), for use in the event of failures at the prime facilities during critical missions, especially those involving manned flight.

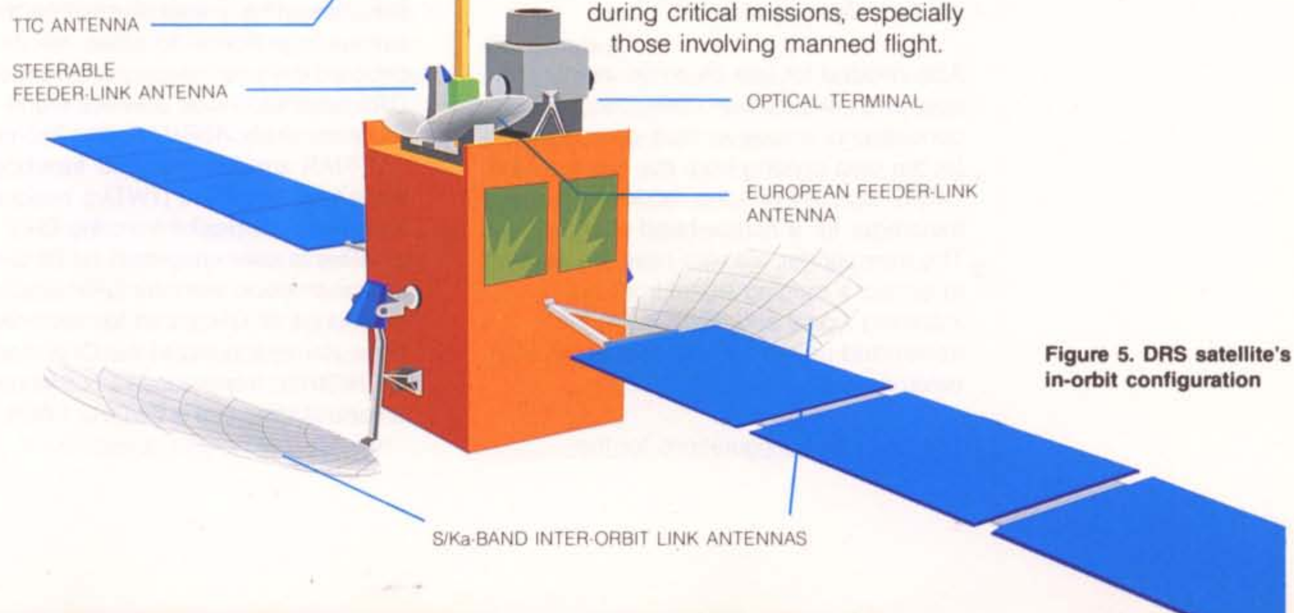


Figure 5. DRS satellite's in-orbit configuration

DRS TTC will normally operate in the 20/30 GHz feeder-link frequency bands, but during the launch and early-orbit phase (LEOP), and in an emergency, the 2 GHz frequency band will be used.

In-Orbit Test stations are planned in order to provide comprehensive test facilities for DRS satellites, User Space Terminals and User Earth Terminals. These are:
— a 20/30 GHz feeder-link IOT station, also known as the 'Reference User Terminal', which may be a modification of the Olympus TMS-6 test station at Redu
— a 23/26 GHz IOL IOT station (planned location also Redu)
— a 2 GHz (S-band) IOL IOT station, which could possibly be combined with the DRSS S-band (2 GHz) TTC station at Villafranca
— an optical IOL IOT station, which will probably have an optical test package which can be integrated into an astronomical telescope.

Technology developments
During the DRS system studies, several elements have been identified that could benefit from advanced breadboarding to verify design performance assumptions. Activities are underway on each of these items within the DRPP; they include:

— A High-Data-Rate Codec and Modem

To achieve adequate link performances with realistic transmit power levels and antenna sizes, data encoding will need to be used for the high-data-rate links. The data rates of these links can be up to 150 Mbit/s, and a breadboard operating at these rates has been developed of the encoder and modulator (by Newtec, B) needed onboard a user spacecraft, and of the demodulator and decoder to be installed in User Earth Terminals.

— Ka-Band Transponder

Also needed for use on some user spacecraft is a Ka-band transponder, consisting of a receiver and demodulator for the data coming from the ground via a DRSS, together with the modulator and transmitter for a narrow-band channel. The transponder will also have the ability to extract a ranging signal from the incoming signal and insert it into the transmitted carrier for user-spacecraft orbit determination.

The possible configurations for the Ka-band transponder are being studied in detail and some elements — particularly the demodulator and the system for ranging-signal processing — will be breadboarded.

— S-band Transponder

The S-band users will need transponders with similar functions to those of the Ka-band transponder. The development of this unit is being funded primarily under ESA's Advanced Supporting Technology Programme (ASTP). The development effort at Alcatel-Espace (F) is also being supported by the DRPP.

— Tunable Frequency Converter

A key feature of the DRS satellite repeater concept are the Tunable Frequency Converters (TFCs). These allow the onboard hardware to be used flexibly and allocated to users operating on any of the possible channels within the frequency band, by translating all incoming signals to a common frequency for routing and amplification and then upconverting them to the appropriate transmit frequency. Breadboarding of this unit is now in progress at Alcatel-Bell (B).

— Microwave Switching Matrix

Also critical to the performance of the satellite repeater are microwave switching matrices, which switch the signals, after their conversion to the common frequency by the TFCs, to their allocated transmitting channel. The switches have severe isolation requirements to avoid interference between signals. A breadboard of this unit is being constructed by ANT (D) and Plessey (UK).

— High-Power Amplifiers

Breadboarding is also planned for the various High-Power Amplifiers needed onboard the user spacecraft and the two DRS satellites. Three activities are in progress: firstly AEG/ANT and Thomson-CSF/FIAR are designing the Travelling-Wave-Tube Amplifiers (TWTAs) needed for Ka-band transmission from the DRS satellites to user spacecraft (at 23 GHz), for transmission from the DRS satellites to ground (at 20 GHz), and for transmission from user spacecraft to the DRS satellites (at 26 GHz). It is planned to continue with breadboarding of the 26 GHz TWTA.

Since, in the future, solid-state power amplifiers (SSPAs) will become more attractive at Ka-band, work has also been started with Siemens Italiana (I) on a 5 W amplifier operating at 20 GHz, which could be used for DRS satellite telemetry transmission. Development is also planned of a 1.5 W amplifier operating at 26 GHz, which could be used on user spacecraft in conjunction with a 1 m-diameter antenna to transmit data rates of up to 10 Mbit/s.

— Inter-Orbit-Link (IOL) Antennas

A significant feature of the DRS satellites are the large IOL antennas, which can operate at either Ka-band or S-band and whose beam is steered for S-band users, by means of an RF tracking system, to follow the low-Earth-orbiting user spacecraft. Breadboard activities are planned for several elements of these antennas, including the Ka-band feed with its RF tracking system, the tracking-signal receiver, and the steering mechanism.

— Feeder-Link Antenna

The European feeder-link antenna design has several novel features. Since a single antenna will be used irrespective of whether the DRS satellite is stationed at 44°W or 59°E, the antenna pattern must be switchable to serve Europe from either position. In addition, an optimised coverage/gain pattern is needed to partially compensate for the variation in atmospheric attenuation across the coverage area. Breadboarding of two different design approaches for this antenna by SES (I) and ERA (UK) is planned.

The DRS Development Programme

The overall planning for the DRS Development Programme is shown in Figure 6. The system of two satellites in orbit is planned to be fully operational in 1996, reflecting a time scale compatible with the needs of users. The two flight satellites will be launched in early and mid-1996, respectively.

The DRS Development Programme is proposed to be executed in two phases. Phase-1 will be synchronised with the decision schedule for the major Agency programmes Columbus and Hermes, which are expected to be reconfirmed in 1991. Phase-1 will include the industrial Phase-B2, leading to conclusion of the DRS detailed definition. In parallel with this phase, an invitation-to-tender will be issued for the satellite development phase (Phase-C/D).

The opportunity will be taken during the Phase-1 to trade-off the satellite configuration defined during the DRPP with others incorporating more advanced technology. Phase-2 is planned to start in 1991, after final selection of the DRS satellite configuration, and will include:

— development and manufacture of three complete sets of satellite subsystems;
— integration and testing of two flight satellites;

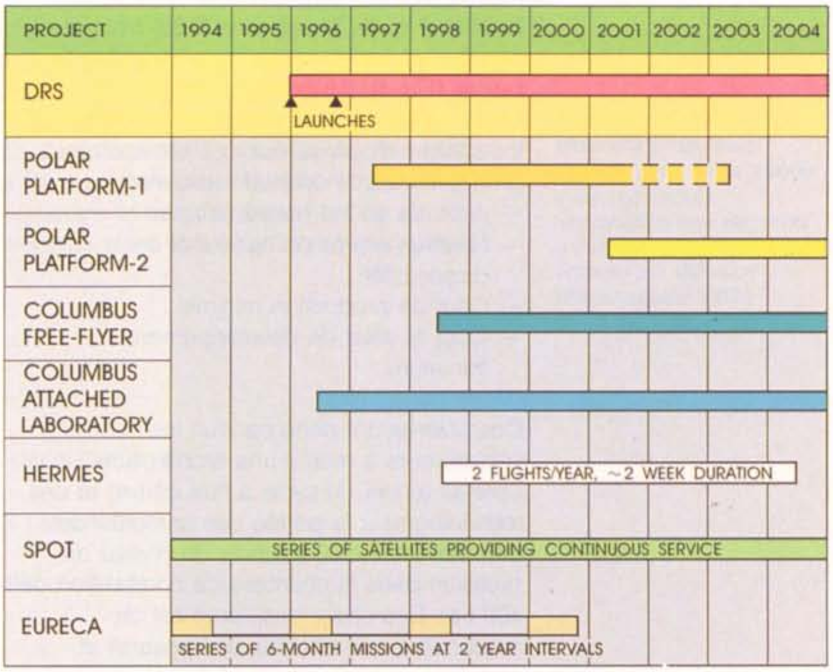


Figure 6. DRS and potential user schedules

— launch of two satellites;
— development of elements for user space terminals; and
— construction of the necessary ground infrastructure for system management, operations control and test.

Conclusion

The Data-Relay Preparatory Programme has successfully defined a cost-effective system that can serve the European In-Orbit Infrastructure that will be deployed in the late 1990s on an operational basis. The DRPP has also laid the foundations for the DRS Development Programme that will follow.

Le moteur Vulcain

— Travaux technologiques sur la chambre propulsive et le générateur de gaz

H. de Boisheraud
Département Ariane, ESA, Paris

Cinq ans se sont écoulés depuis le lancement, par l'Agence spatiale européenne, du programme préparatoire au développement du moteur cryotechnique 'Vulcain' devant propulser l'étage H155 du lanceur Ariane-5. Préalablement, des plans nationaux en France (SEP), en Allemagne fédérale (MBB) et en Suède (Volvo) avaient été engagés dès 1980 pour proposer une définition préliminaire du moteur.

Les performances demandées à ce moteur, comparées à celles des moteurs existants en Europe, imposaient d'engager dès le début du programme un effort technologique important dans les domaines aussi variés que les modélisations, la caractérisation des composants critiques, les procédés et outillages de fabrication.

D'autres activités majeures, comme la création de nouveaux bancs d'essai, la fabrication et les essais des premiers matériels ont également été engagées, mais elles ne rentrent pas dans le cadre de cette présentation consacrée aux activités technologiques les plus significatives.

Définition du moteur Vulcain

La configuration et les caractéristiques du moteur Vulcain, déjà décrites dans ce Bulletin (No. 44, Novembre 1985) n'ont que peu évolué, aussi contentons-nous d'un bref rappel (Fig. 1). En complément de ces caractéristiques il est important de préciser les critères d'optimisation qui ont contribué grandement à la définition actuelle:

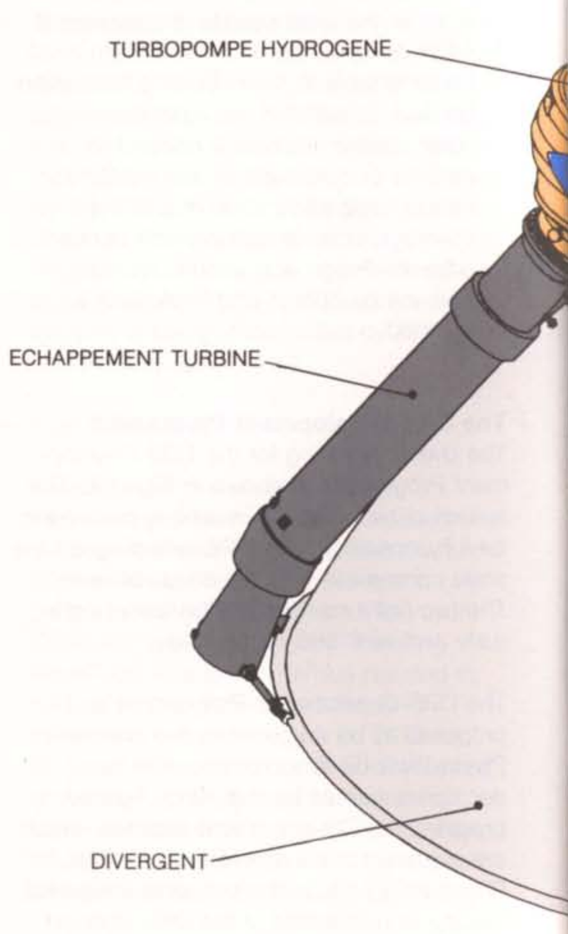
- Aptitude au vol habité (sûreté).
- Niveaux élevés de fiabilité et de disponibilité.
- Coût de production minimal.
- Coût et délai de développement minimum.

Ces critères ont donc conduit les concepteurs à retenir une architecture connue (choix du cycle à flux dérivé) et des technologies à la portée des compétences européennes, d'où le choix du niveau de pression dans la chambre de combustion de 100 bar. Ces choix faits, force est de reconnaître que certains composants et certaines technologies de fabrication devaient faire l'objet d'une attention toute particulière avant que ne soient figées les configurations définitives de la chambre propulsive et du générateur de gaz du moteur Vulcain.

La chambre propulsive

Trois actions principales ont été conduites au niveau de la fabrication: elles concernent l'injecteur, le corps de chambre et le divergent. De plus, des essais de performances à échelle réduite ont permis de valider les concepts retenus.

Figure 1. Configuration et caractéristiques du moteur Vulcain



Fabrication de l'injecteur
L'injecteur est un des composants les plus importants du moteur puisqu'il conditionne directement la performance de celui-ci. L'injection de l'oxygène et de l'hydrogène liquides dans la chambre de combustion s'effectue à travers 516 éléments d'injection de type coaxial, et toute fuite de l'un des ergols vers l'autre est prohibée. Pour respecter ce dernier impératif, deux technologies (brasure par diffusion et usinage par électroérosion) ont été développées, et la maîtrise des deux procédés de fabrication prouvée par la réalisation de pièces à échelle 1, chez MBB (Fig. 2).

Fabrication du corps de chambre
La durée de vie imposée et les contraintes rencontrées conduisent à envisager pour la paroi interne de la chambre de combustion un alliage de cuivre plus performant que celui mis au point lors du programme HM7 (3ème étage des lanceurs Ariane-1 à -4). La composition de cet alliage (Cu, Ag, Zr), le processus d'élaboration d'un lingot et les méthodes d'usinage sont aujourd'hui fixés. En complément de ces activités, des essais à feu sur chambre à échelle réduite ont démontré le bon comportement de ce matériau dans son environnement naturel.

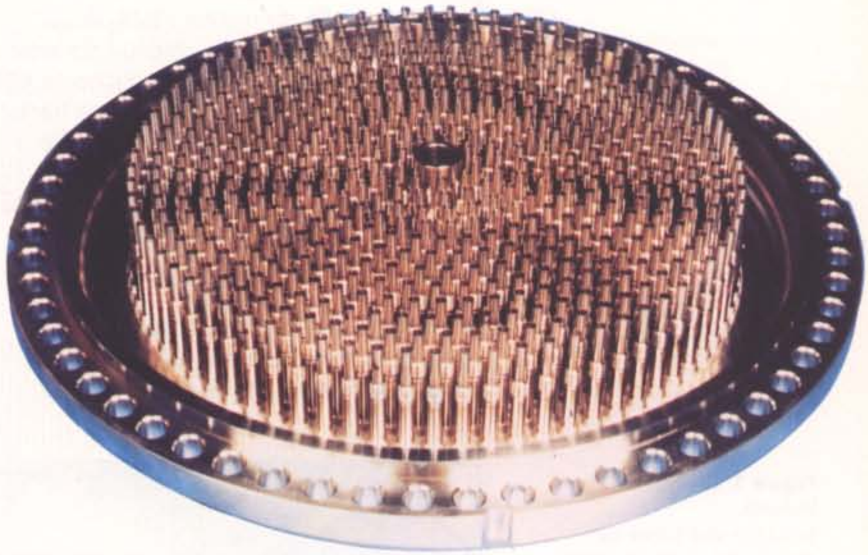
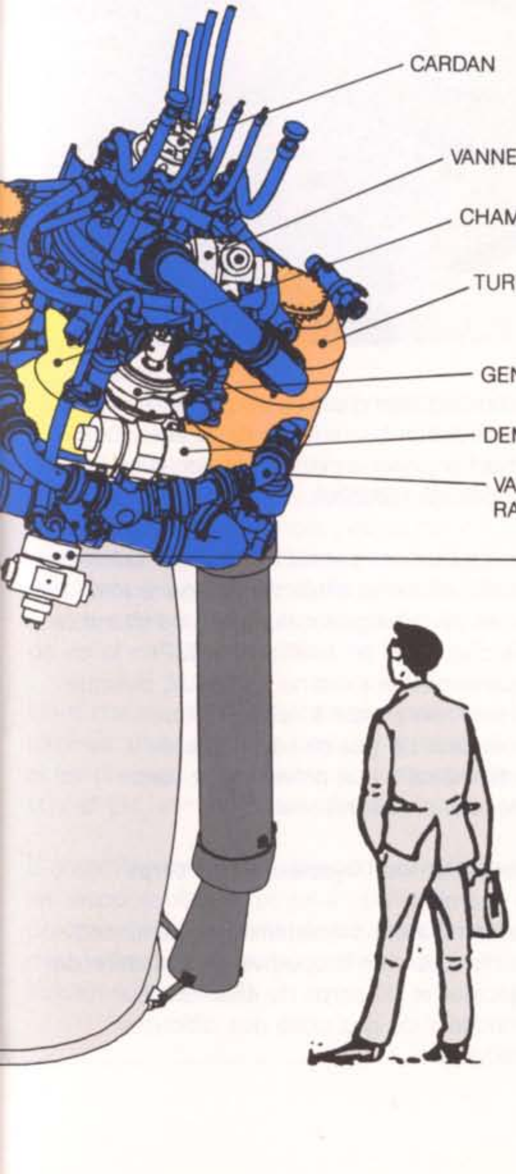


Figure 2. Injecteur de la chambre propulsive.
Configuration de la plaque d'injection après implantation des éléments d'injection par le procédé de brasure par diffusion (Photographie MBB)



Caractéristiques du Moteur Vulcain

Poussée vide	980—1070 kN
Rapport de mélange	4,9—5,3
Impulsion spécifique dans le vide	430 s
Pression d'aspiration	
—NPSP O_2	2 b
—NPSP H_2	0,5
Masse	1300 kg
Durée de fonctionnement vol	600 s
Durée de vie	
— nombre de démarrage	20
— nombre de secondes cumulées	6000 s

Fabrication du divergent

Déduite de celle du moteur HM7, la technologie de fabrication retenue consiste à souder côte à côte, 456 tubes d'Inconel 600 préalablement mis en forme. Ceci se traduit concrètement par l'exécution de plus de 1800 m de soudure par divergent ! L'automatisation du procédé est donc jugée indispensable pour assurer la qualité des fabrications.

Le robot de soudage, développé dans le cadre du programme, est aujourd'hui en activité chez Volvo, et ses performances (positionnement de la torche de soudage par un faisceau laser avec une précision inférieure à 0,1 mm) donnent entière satisfaction (Fig. 3).

Figure 3. Divergent Vulcain.
Soudage des tubes du divergent à l'aide du robot mis au point spécialement pour cette activité. Au deuxième plan, l'on peut voir le premier divergent après soudure des tubes, et en arrière-plan, la machine servant à former les tubes élémentaires (Photographie Volvo)

Essais de performance

La définition des éléments d'injection, géométrie, débits, pertes de charge, et la mesure des performances propulsives ont été exécutées lors d'essais à feu sur une chambre à échelle réduite. Ces campagnes d'essai ont également servi à recaler les modélisations du circuit régénératif de la chambre et du refroidissement 'dump cooling' du divergent. En outre, les dispositifs amortisseurs des vibrations de la combustion, telles que baffles et cavités acoustiques ont été mis en oeuvre avec succès.

Le générateur de gaz

Le rapport de mélange (débit massique oxygène/débit massique hydrogène, proche de 1) utilisé sur les générateurs de gaz rend très délicate la conception de ces matériels. Dès l'année 1984 deux thèmes de travaux ont donc été retenus : caractérisation d'un élément d'injection et procédés de fabrication de l'injecteur et du corps de chambre.

Caractérisation d'un élément d'injection

Les modélisations de la flamme issue d'un élément d'injection (Fig. 4) ont pu être ajustées lors d'essais à feu sur une chambre expérimentale munie d'un seul élément d'injection. Ces premières activités ont été accompagnées d'essais de pulvérisation et de simulation hydraulique de la tête d'injection, ceci en étroite relation avec les équipes de l'ONERA.

Ces travaux ont permis la définition précise des 60 éléments d'injection du générateur de gaz et de la longueur du corps de chambre. Ces choix faits en 1987 par la SEP apparaissent aujourd'hui judicieux, puisque les premiers essais à échelle 1 du générateur de gaz se sont déroulés conformément aux prévisions et sans détérioration du matériel.

Fabrication de l'injecteur et du corps de chambre

Comme il a été précédemment mentionné pour la chambre propulsive, la réalisation de l'injecteur et du corps de chambre du générateur de gaz pose des difficultés analogues.

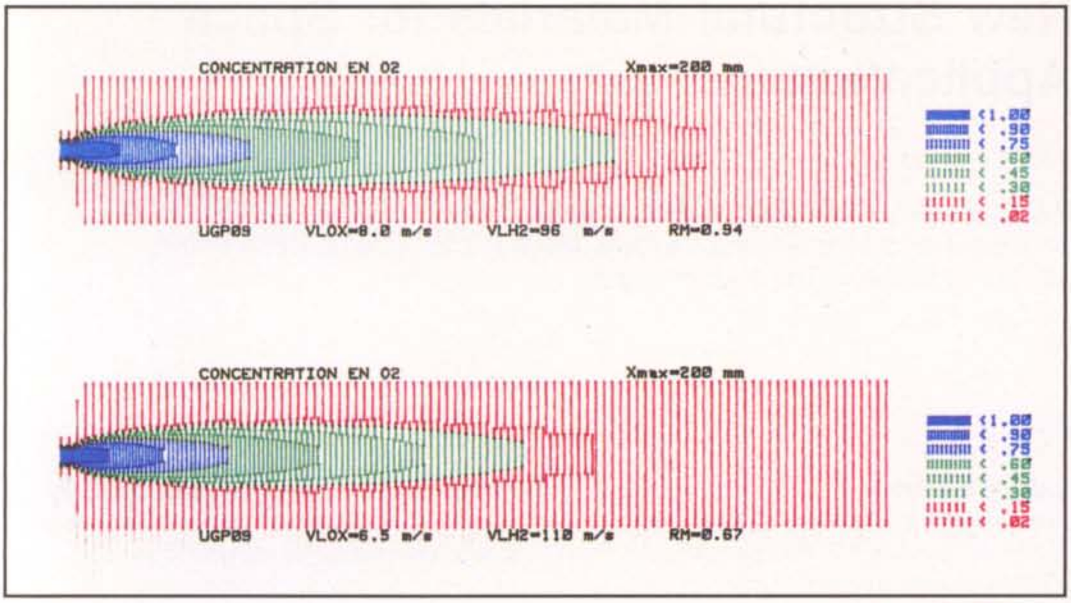


Figure 4. Générateur de gaz.
Exemple de modélisation de la flamme issue d'un élément d'injection du générateur de gaz (Photographie SEP)

Les procédés de fabrication des éléments d'injection, puis leur implantation par brasure dans la tête d'injection sont maintenant figés (Fig. 5). L'importance des travaux de caractérisation de cette brasure, réalisés aux cours de ces dernières années, permet de ne plus considérer cette technologie comme critique.

La forme particulière du corps de chambre, imposée par des contraintes d'aménagement du moteur, a nécessité une longue mise au point des procédés de réalisation. Cet apprentissage de mise en forme et de soudage du Waspaloy peut être considéré comme terminé, puisque plusieurs corps de chambre à échelle 1 ont déjà été livrés par la SEP.

Conclusion
Ces travaux, entrepris dès la phase de conception du moteur Vulcain, sont reconnus comme extrêmement positifs pour le programme. En effet, ces technologies, développées dès 1984, ont permis de réaliser en 1988 et 1989 les premiers essais de chambre propulsive et de générateur de gaz, sur des matériels représentatifs de ceux de vol et ce avec succès.

Dans d'autres domaines tels que pompes et turbines, une approche similaire a été suivie et les premiers exemplaires de turbopompe LOx et LH_2 sont en cours d'essai.

L' ensemble de ces résultats conduisent donc les responsables du projet à confirmer la prochaine date majeure du développement, c'est-à-dire la mise au banc du 1er moteur Vulcain en avril 1990.

Figure 5. Injecteur du générateur de gaz.
Démonstration de la tenue mécanique de la brasure des éléments d'injection à échelle 1. L'injecteur présenté a subi 24 essais à feu sans détérioration du matériel
(Photographie SEP)

New Structural Materials for Space Applications

D.C.G. Eaton, A. Pradier & M. Lambert
Structures and Mechanisms Division, Mechanical Systems Department, ESTEC, Noordwijk, The Netherlands

During the early evolution of the aeroplane, extensive use was made of wooden constructions relying on what might be termed a 'natural' composite material, including the familiar plywood form of construction. The greater strength, stiffness and fracture resistance of metals (for a given mass) eventually led to the replacement of wood with metal constructions, particularly those exploiting aluminium alloys. This, in turn, led to the development of the so-called 'light alloys' that are now used extensively in the construction of space vehicles. More recently, fibreglass composites have also come to be widely used in the construction of lightly-loaded structural components and, because of their good dielectric properties, for the first generation of space antennas. In the last ten years, the use of these now 'conventional' materials has been increasingly challenged by the emergence of new composite materials with potentially better specific-strength and stiffness properties (Fig. 1).

Today's materials

Until recently, carbon-fibre and aramid reinforced plastics (CFRPs) consisting of continuous uni-directional fibres reinforcing an epoxy thermoset resin matrix have been among the most widely used materials for aerospace and space applications. Their main drawback has been that they are more susceptible to impact damage than isotropic metals, due to the brittle behaviour of both fibre and resin.

The nature and spread of such damage is less well-charted than in metals, where flaws are usually visible. In the case of a composite, because of the laminated form of construction, the damage may well be hidden. With a thermoset resin, residual strains can develop during the cure cycle. These may be relieved by microcracking during environmental thermal cycles. Other factors such as moisture and ultraviolet light can also badly affect the resin, reducing the allowed design loadings by as much as 50% compared with typical material-failure values seen in practice.

As a result, first applications in the space industry exploited CFRP's stiffness rather than its strength, which, together with its low coefficient of thermal expansion, proved important assets in the development of dimensionally-stable CFRP/light-alloy honeycomb ('solid') reflector dishes. Subsequently, as confidence in the behaviour of CFRP has increased, it has begun to be used for major load-carrying structures, though with compression stiffness remaining the design driver. The Ariane launcher's Sylda and Spelda adapters and second/third interstage structure, and several telecommunications-spacecraft central-thrust cylinders, are typical examples.

As in the case of wooden structures, ply-laminates are often used. However, for many applications, increasingly sophisticated semi-automated processes have evolved, including the use of woven or knitted fabrics, filament winding and 'pultrusions' (analogous to metal extrusions). Such techniques can often be used to tailor the construction format to match the applied-load or directional-stiffness requirements.

Composites using the new 'thermoplastics' are less susceptible to impact damage and environmental effects. A thermoplastic resin softens on heating and hardens on cooling, but remains chemically unchanged. These reversible properties mean that such composites can be reworked and can be formed into complex shapes. Unfortunately, a thermoplastic resin has a much higher melting temperature than a thermoset. This, together with its greater viscosity, means that much higher processing temperatures and mould pressures are required than those used in existing autoclaves (sophisticated pressure cookers) for current thermoset-composite systems.

Other composites include the hybrid laminates. One well-established example, 'Arall' evolved at Delft University (NL),

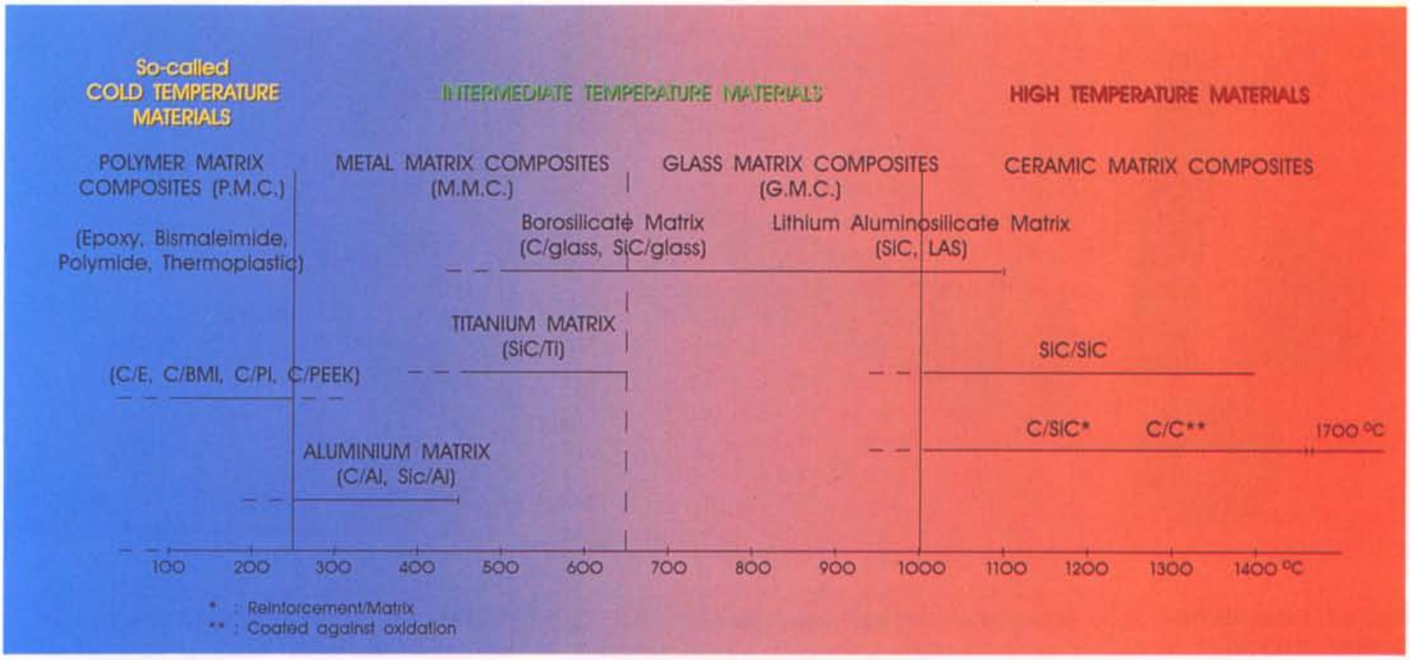


Figure 1. Temperature ranges of application for different advanced composite materials

The ability to evolve lighter structures, capable of working over a wide range of temperatures and other environmental conditions, relies on the development of new high specific strength and stiffness materials whose properties can be assured when using established manufacturing procedures.

consists of stacked alternate plies of light-alloy and aramid fibres. This configuration combines the attractive tensile properties of the aramid fibres with the compression properties of the alloy, to provide a fatigue- and damage-resistant lightweight plate material.

Whilst the existing epoxy- and thermoplastic-based composites may perform sufficiently well up to around 150°C, alternative materials are required to achieve similar structural performances at higher temperatures.

In the aircraft industry it has already been demonstrated that it is technically feasible to build an airframe almost entirely from composite materials and still fulfil all the load-bearing, load-transfer and stiffness-sustainment requirements. To keep its mass as low as possible, the Hermes spaceplane could have a largely all-composite primary structure. Such a structure has of course to be protected from the very high skin temperatures incurred during re-entry.

Importantly, the mass of the thermal protection system can be reduced if the primary structure can be made to work at higher operating temperatures than are currently possible with established thermoset resins. To this end, the emerging high-temperature thermoset resins are being extensively investigated. In particular, bismaleimide and polyimide composite systems, capable of working up to around 250°C, are being studied in detail. The work has included assessments of their thermal-mechanical properties, the effects of moisture, and the feasibility of manufacturing large complex structural components.

Care also has to be taken to ensure compatibility between the work underway at different industrial centres, and that the toxicity problems inherent in some of these materials can be avoided.

Metal-matrix composites

In the last few years metal-matrix composites have begun to emerge, in which the resin matrix is replaced by a metal such as aluminium or titanium. In addition to carbon, other continuous fibres such as silicon-carbide (SiC) and boron have been introduced. When compared with reinforced plastics, a number of potential advantages are evident. The matrix is stronger and more ductile, providing the opportunity for enhanced mechanical properties, particularly compression strength. Greater damage tolerance is also to be expected.

Eventually, forming and joining techniques could be similar to those used for isotropic metal constructions. However, exploitation of the full potential of such materials awaits improvements in costly material-processing techniques, particularly in assuring good fibre/metal bond strength, which is quickly reduced by the presence of impurities. Further developments are also needed in manufacturing methods, including machining, forming and joining techniques.

In the short term, it seems probable that metals containing reinforcements in the form of particulates or short fibres, known as 'whiskers', will constitute the first generally available forms of metal matrix. Their

Figure 2. Experimental fastener designed to operate at high temperatures whilst withstanding thermal shocks and high mechanical loads
(photo courtesy Aerospatiale)

Designing and manufacturing practicalities dictate that an aerospace structure is made from many components, which have to be joined together. Such joints are often key elements with many of the load-transfer, stiffness, fatigue and mass problems arising at these discontinuities. Application-dependent techniques, such as bolting, riveting, bonding and welding, exist to connect these joints. The use of advanced materials and effects such as thermal shocks and large gradations in temperature, pose new problems for joining techniques.

intermediate strength but good ductility properties, when compared with reinforced plastics, may see them used in regions of high load transfer such as certain classes of joint and attachment rings (Fig. 2).

High-temperature materials

In the cases of propulsion systems and hypersonic space vehicles, materials capable of sustaining considerably higher temperatures are required. These can be loosely catalogued as intermediate temperature material requirements up to around 1000°C (for example, metal matrices), and short-duration ceramic material requirements up to around 1700°C.

The use of different types of glass as a matrix is enabling the development of a range of composite materials reinforced with carbon or silicon-carbide fibres. These composites have intermediate mechanical properties, but they retain them up to as high as 1000°C. The use of these composites for hot secondary (i.e. not main load-carrying) structural items therefore appears feasible.

The production of carbon-carbon material involves the embedding of carbon fibres in a matrix of pitch or a similar substance, which is subsequently fired under pressure. This composite material has been used in the construction of motor nozzles for some years (Fig. 3), that of the Agency's Mage Apogee Boost Motor being just one example (its motor case, incidentally, is an intricate combination of filament-wound aramid, carbon and glass fibres, which is able to sustain a sequence of high static, dynamic and thermal loads).

However, apart from the manufacturing complexity and the associated high manufacturing costs, the other major problem of using carbon-carbon in constructing an airframe is its poor resistance to thermal oxidation during hypersonic flight. This means that all surfaces have to be coated with a protective material; silicon carbide is a popular choice and is currently being tested. At present, the use of carbon-carbon appears likely to be mainly constrained to leading edges, as in the case of the Hermes spaceplane (Fig. 4).

The materials offering really attractive thermal-protection properties are the ceramics, with their strong resistance to high temperature, oxidation and other environmental effects, combined with good dimensional stability and wear characteristics. They are, however, very brittle and usually require reinforcement, for which various techniques are under development, including the incorporation of silicon-carbide continuous fibres, particulates and whiskers. For certain applications, carbon fibres are also being considered.

Ceramic shingles or silica tiles will be used for much of Hermes' external thermal-protection system. Carbon–silicon-carbide is being used for the movable control surfaces, which have to be small and therefore require use of high-temperature material throughout (Fig. 5).

Developments with metals

Whilst the application of composites is growing rapidly, it is not entirely to the detriment of metals and their further development. Some manufacturing processes such as forging and casting are still unique

Figure 3. Carbon-carbon nozzle unit
(photo courtesy SEP)

The use of carbon-carbon as a nozzle material is illustrated by this example in which the three-dimensional composite is used in a fully automated process to produce a nozzle with an integral interface ring. This lightweight nozzle facilitates a high specific impulse, whilst having a low erosion rate and good resistance to thermal shock.

Figure 4. Reinforced carbon-carbon structure for the leading edge of Hermes' wing
(photo courtesy Aerospatiale)

During re-entry this aerodynamically loaded fairing reaches a temperature of around 1700°C. Care has to be taken with the design of the discrete load-transfer attachments to the cold primary structure because of thermal effects.

to metals and are particularly efficient for certain specific applications, such as highly loaded adapter rings.

In the field of light alloys, advancements have been made in producing new versions with higher specific strength and stiffness. For example, the latest aluminium/lithium alloys are expected to provide a mass saving of around 15% compared with their traditional counterparts, provided some of remaining fracture-toughness problems can be fully resolved.

Other material processes, such as rapid quenching of aluminium, can enhance mechanical properties and help sustain them up to temperatures approaching 300°C, thereby providing alternative alloys.

Titanium alloys continue to offer highly efficient structures for many applications, for example using superplastic-forming and diffusion-bonding techniques. Some of these aspects may be repeated in superplastically forming aluminium-lithium.

Although beryllium can be a highly toxic material, it has very high specific-stiffness properties and a high conductivity and thermal capacity. However, it is brittle, which somewhat restricts its application. It is, and will continue to be, used for rather specialised equipment applications, and is currently baselined for the heat shield of the Cassini-Huygens Probe.

The way ahead

Based on the samples presented, which are in no way exhaustive, it could be said that there is a near plethora of existing or emerging structural materials. There are, however, a range of common problems that have to be addressed before such materials can augment or fully replace traditional isotropic metals in aerospace construction.

It is sometimes said that 'the best news on hearing of a new material is the first news!' Certainly, it has taken many years to establish the industrial standards for commercial light alloys and other isotropic metals. There has been a cautious acceptance of the first thermoset CFRP materials, but, in Europe at least, the potentially attractive thermoplastics still seem to be in their infancy.

The Hermes spaceplane project, with its envisaged use of high-temperature thermosets and ceramic structural materials, illustrates the range of problems that have to be tackled in achieving a safe but lightweight structure. The procurement and processing of these materials must comply with very demanding specifications and standards, which must be adhered to by all suppliers and manufacturing centres.

The number of design-load cases and their complexity, together with accompanying environmental factors, is substantially greater than for conventional rocket launchers and their payloads. This, in conjunction with the complications inherent in a layered composite as opposed to an isotropic material, requires consideration of a wider range of failure modes and accompanying failure criteria.

Similarly, the establishment of design-allowable strengths and the resolution of fracture-toughness problems require extensive test programmes, together with the demonstration of adequate means of interpolation to cover the many composite lay-up configurations and the influence of environmental effects.

Figure 5. A carbon–silicon-carbide thermo-mechanical protection shingle, which retains its mechanical properties up to about 1450°C
(photo courtesy SEP)

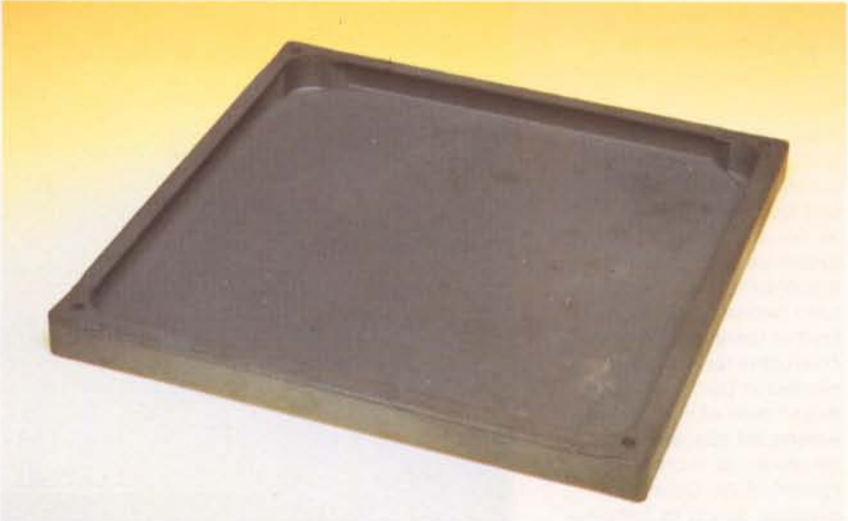
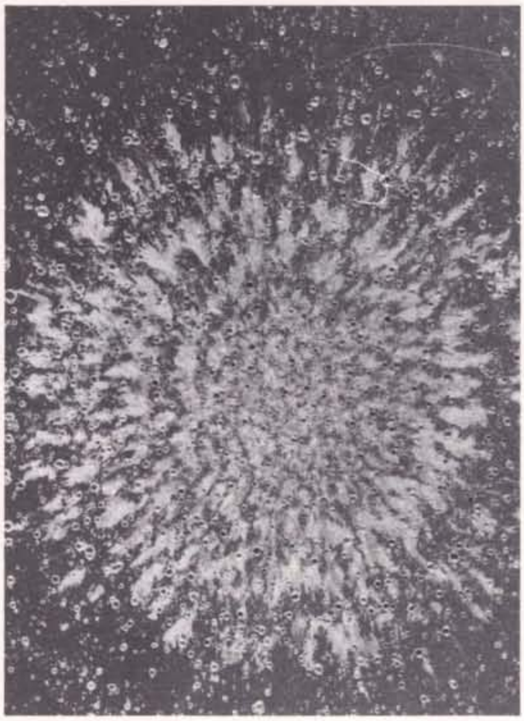
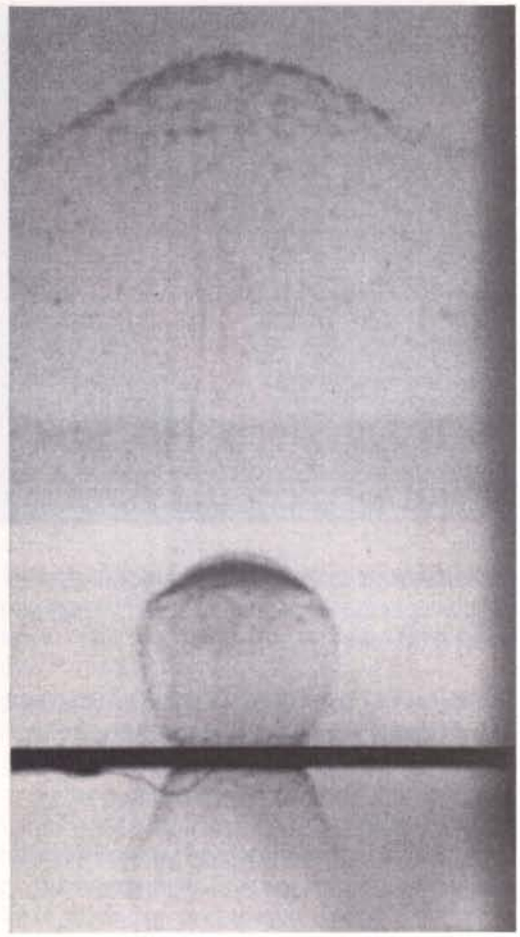


Figure 6. Impact by meteoroids or space debris represents a hazard for space vehicles such as Columbus and Hermes, and possible protection-shield materials are therefore being investigated
(photo courtesy Ernst Mach Institute)

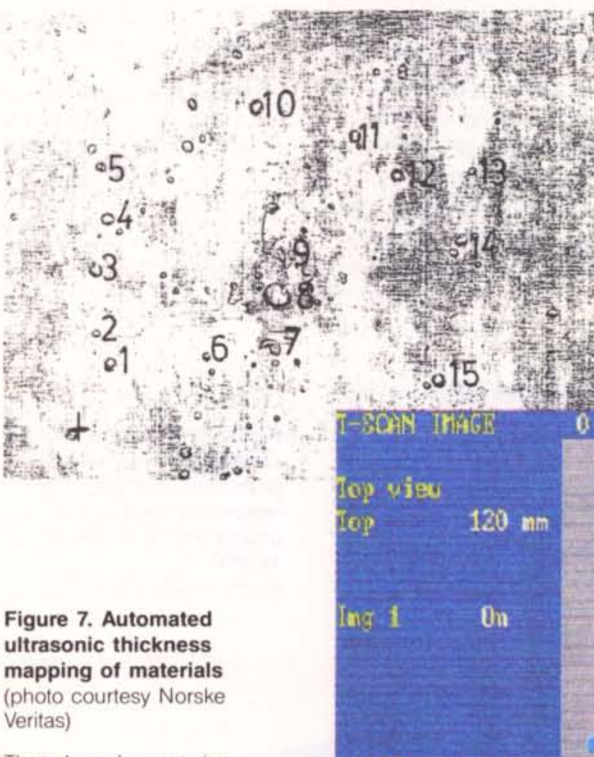
In this ground simulation, a 4-micron diameter aluminium pellet impacts the outer shield at a speed of 5.8 km/s. The cloud of plasma and debris that ensues causes the damage shown on the face of the inner plate.



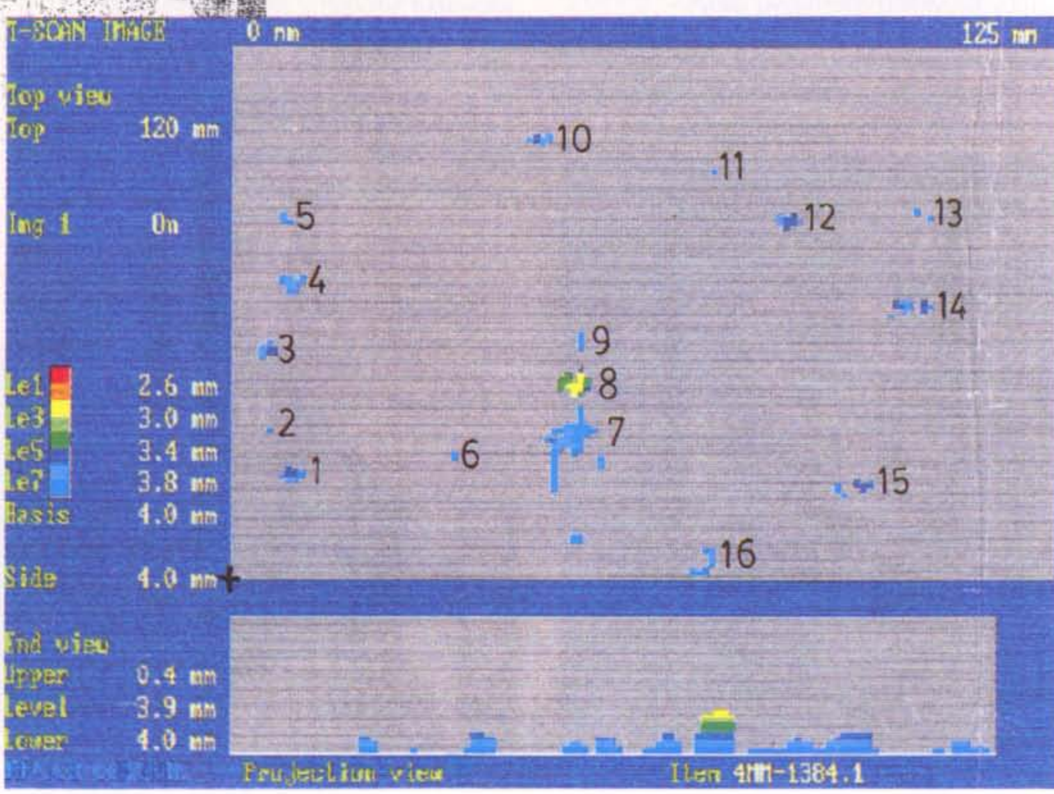
6a



6b



7a



7b

Figure 7. Automated ultrasonic thickness mapping of materials
(photo courtesy Norske Veritas)

There have been major developments in the non-destructive testing methods available to ascertain the size and location of defects, such as this automated ultrasonic system used to obtain a topographic map of simulated meteoroid damage. Further developments in non-destructive testing are needed to permit detailed examination of inaccessible assembled spaceplane structures, or in-orbit investigations of the Columbus structure during its thirty-year lifetime.

This complexity extends into the final verification programme. Extensive tests must be conducted on fully representative structures. Of particular concern is the nature and extent of inherent flaws and damage induced, for example, by low-energy impacts. Other factors that have to be considered include the effects of meteoroids (Fig. 6) and lightning strikes. The degree to which such damage can be tolerated without having an adverse effect on the residual strength and stiffness of the structure is a crucial issue. Clearly, the ability to locate the presence and extent of such defects in an assembled airframe is of equal concern and imposes severe demands on current non-destructive testing methods (Fig. 7).

Conclusion

Structural-materials problems will certainly continue to manifest themselves in the next generation of spaceplane developments. Propulsion systems, for example, are likely to include an airbreathing engine with a complicated air-intake and heat-exchange system. Cryogenic tanks fuelled with liquid hydrogen will become integral parts of the airframe. The materials used in such systems will be subjected to even greater extremes of load and temperature, and for longer periods (Fig. 8). Susceptibility to more severe oxidation and hydrogen enbrittlement could become fundamental issues in material selection in many instances.

In order to achieve the greatest structural and thermal efficiency, it seems likely that the emerging range of metals, together with the new metallic and ceramic composites, will have to be introduced into appropriate parts of the spaceplane structure and powerplant. Since these materials are likely to be required in rather small quantities, perhaps the greatest problem lies in ensuring adequate investment in their development and ensuring that this investment is appropriately directed.

Figure 8. A carbon–silicon-carbide turbine wheel (photo courtesy SEP)

Future developments will involve the use of rapidly-rotating parts operating at high temperatures, such as this turbine wheel manufactured from carbon–silicon-carbide. This low-density structure leads to lower centrifugal forces and avoids the need for a cooling system.

Figure 9. The Far Infra-Red Space Telescope's inflatable space-rigidised thermal shield structure

The inflatable skeleton supports thermal-control blankets to reduce the thermal load on the high-precision antenna and other parts of the FIRST spacecraft. It is basically constructed from a Kevlar prepreg with an outer foil of Kapton (selected for its high resistance to bending). The impregnation resin is optimised for low tackiness and long shelf-life.

The ESOC Spacecraft Performance Evaluation System (SPES)

J.C. Guillaumé, J.F. Kaufeler & F. Sell
ESA Computer Department, European Space Operations Centre (ESOC), Darmstadt, W. Germany

The need for spacecraft performance-evaluation tools has been strengthened by the advent of missions carrying complex items of equipment that have variable performances during their mission lifetimes. This has introduced an additional element of complexity into routine mission-operations activities, prompting ESOC to develop a performance-evaluation tool that is both multi-user and multi-mission oriented.

The SPES provides user-friendly and flexible access to all mission data stored in a central repository. Data of interest can be retrieved from this repository and transferred to the local storage of the user's workstation, where they can be presented in a variety of ways.

The SPES environment is decoupled functionally from the mission-control systems and thus its use can be opened up to a potentially large user community without any inherent risk. The SPES is currently being used for the Agency's Hipparcos scientific-satellite mission and will be used in the future for its ERS-1, Eureca and other missions.

Introduction

Data from the Agency's satellites arrive at the appropriate control centre in form of telemetry, and the satellites themselves are controlled by sending telecommands from those control centres to the satellites. The incoming telemetry data, which are currently handled by the same real-time systems used to control the satellites, carry the fundamental information needed to fully understand the performance and behaviour of all the components and subsystems that make up a spacecraft.

Unfortunately, the sheer volume of the telemetry (TM) and telecommand (TC) data generated by each spacecraft means that these 'historical' data can only be kept on-line in the real-time control systems for a limited period, normally about one week. Hence the need for systems that are able to archive large volumes of satellite data and subsequently retrieve and present it to the spacecraft engineers and operators in an easily manipulatable form. The ultimate goal must be to store all the satellite's house-keeping data — both telemetry and tele-commands — generated throughout the mission, which, depending on the nature of the satellite, can involve several gigabytes of data.

In the late 1970s, ESOC developed a system called the 'Engineering Data Service' (EDS) which provided the facilities described above. It was to be used in combination with the Multi-Satellite Support System (MSSS), which was the spacecraft control system in use at that time. EDS provided data-presentation facilities similar to those of the online system (i.e. printouts, plots and tapes). Data were stored on tape on the real-time system, and subsequently retrieved from the archived tapes. The system supported the conven-tional time-division-multiplexed type of telemetry and was operated in batch-mode from a user terminal.

EDS was used successfully for many ESA missions, including the OTS, Marecs-A and B, Exosat, Giotto and all the Meteosat satellites, but its architecture was based on late 70s technology, which has long been super-seded. It was a purely batch system, with very basic data-selection possibilities, and the tape manipulation involved made the data-gathering process very tedious.

Objectives of the SPES

Based on the above, ESOC decided to develop a new Spacecraft Performance Evaluation System (SPES) using modern software-engineering techniques and offering the user an interactive and flexible means of working, with better response times. The basic objectives for the system were established during the project's requirements definition phase.

The aim was to provide a service whereby all interested parties — spacecraft engineers, spacecraft controllers and manufacturers — can be afforded remote access to the satellite's entire history of housekeeping and other data. Applications already foreseen include, for example: long-term analysis of the performance of a particular component or subsystem; and the retrieval of data to support an anomaly report. Such fundamental investigations are not feasible based on the online system's history files, because of their short-term nature.

The SPES had to be designed to be used in conjunction with the new Spacecraft Control and Operation System (SCOS) developed at ESOC for the Dedicated Mission-Support Systems (DMSS) that are now replacing the MSSS (see ESA Bulletin No. 56, pp. 19–24). Consequently, it can support all the SCOS data structures (CCSDS telemetry packets or traditional time-division-multiplexed telemetry).

To maintain full compatibility with the SCOS structures and avoid duplication of data descriptions, the SPES uses the SCOS data description files directly, i.e. ORACLE tables directly exported from SCOS to SPES (ORACLE is the relational-database management system that supports SCOS). All the mission data were to be stored centrally on a fast-access medium, and the users were to be able to work interactively in a remote environment with data selected and extracted from the centralised mission database. Facilities had to be provided to retrieve individual parameters from the archived data, based on a number of different time-related strategies. It had to be possible to incorporate the resulting output data into a working file, or to display it on the terminal in either tabular or graphical form.

Finally, data transfer from the online system (DMSS based on SCOS) to the SPES and from the SPES to the users was to be performed via communication lines and not via tape.

The first candidates to use the SPES were the Agency's Hipparcos, Eureca and ERS-1 projects.

Functionality

Archiving

One of the prime functions of the SPES is to archive the satellite data for the entire lifetime of the missions that it is used to support. The data of interest for evaluation purposes consist of the spacecraft raw telemetry and telecommands, as well as data processed on the ground by the dedicated SCOS systems (one per mission), such as the out-of-limit checks. The archiving is achieved by regular transfer of the SCOS history files to the SPES mass-storage medium, the so-called 'repository'.

Moreover, the SPES must be able to interpret the archived data in order to deliver it to the end-user in a processed format. For this purpose, the SPES has to maintain a data-description database that is identical to the SCOS ORACLE-based one, and is regularly updated whenever changes are made to the SCOS.

Both the source- and the control-data transfers (Fig. 1) have to be made in an auto-

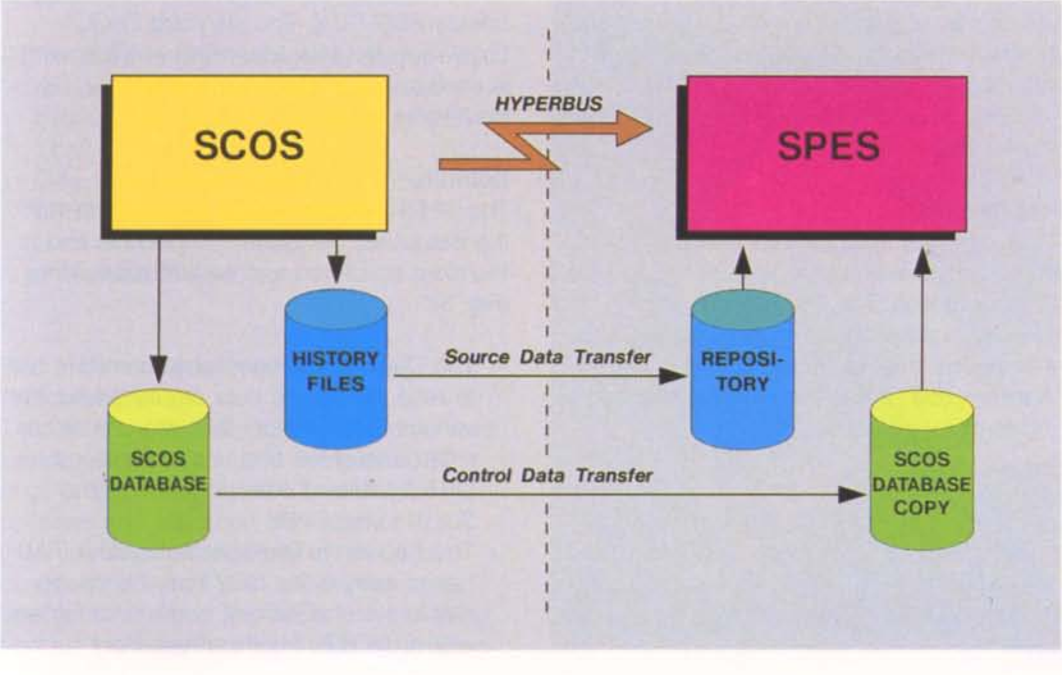


Figure 1. SCOS — SPES interactions

mated manner, interacting with the SCOS via dedicated functions, thereby permitting the SPES to be multi-mission-oriented.

Retrieval

Any data in the SPES repository have to be made available to the user according to high-level selection criteria and processing rules. The data selection is defined by 'time' and 'parameters':

- the 'time' criterion is controlled by access strategies defining interesting time patterns for retrieval
- the 'parameters' criterion is controlled by access structures and defines which parameters of the packets have to be extracted.

In addition, the SPES supports a tape-production facility permitting the retrieved data to be stored for further processing or delivery to external users.

Architecture

Hardware

The overall SPES hardware environment is shown in Figure 2. The source and control data for the various missions are received from dedicated VAX computers. The SPES itself runs on the ESOC offline mainframe computer (Comparex 8/90, under MVS/XA). The computers are linked by Hyperbus hardware.

The SPES users work remotely on IBM-compatible workstations running under DOS

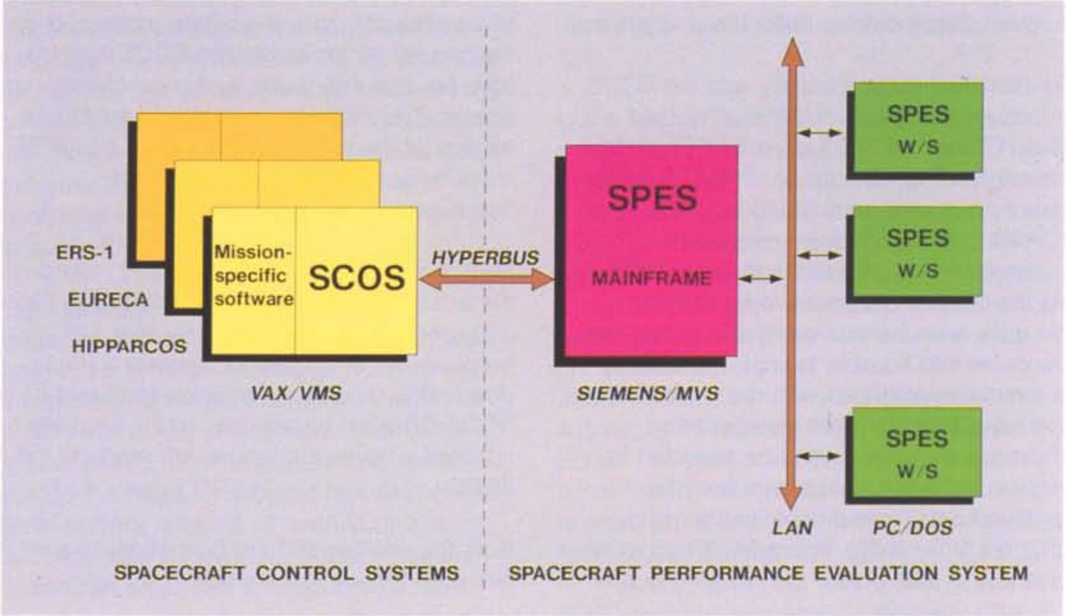


Figure 2. The SPES hardware environment

(ideally PS/2 PCs). The standard ESOC Local-Area Network (operating at 9.6 kbaud) is used to link the workstations to the mainframe.

The processing of the selected data contains standard functions like validity checking or calibration of raw parameters, and advanced functions involving user-defined SPES-derived parameters.

Presentation

Once retrieved from the repository, the data will be made available to the user for presentation purposes. The SPES offers great flexibility in defining the form of the displays, allowing the user to specify both the subset of parameters of interest and their display and formatting attributes.

The SPES supports the local displays on the user's workstation for the rapid analysis of critical parameters, and central printouts and plots allowing more voluminous data to be produced either on demand or on a routine basis.

Software

The SPES software design has to cope with the distributed hardware components and is therefore structured into several subsystems (Fig. 3):

- The Data-Acceptance Subsystem (DA) has to read the source data regularly from the various SCOS history files into one strictly time-ordered file, and has to transfer the ORACLE-based control data from the SCOS to the SPES.
- The Repository-Manager Subsystem (RM) has to archive the data from the transfer files into the repository, and has to retrieve requested data from the repository.

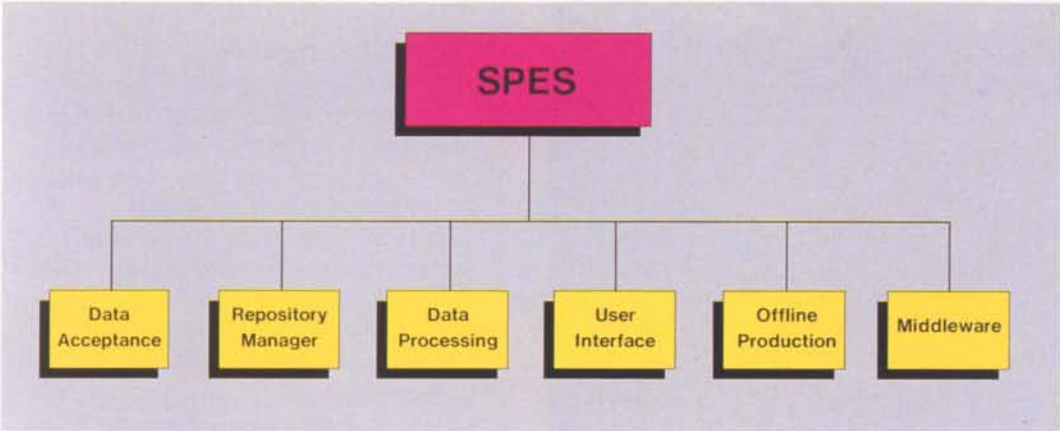


Figure 3. Architectural breakdown of the SPES software

- The Data-Processing Subsystem (DP) selects data according to the access strategy, using the RM subsystem as a server. It then processes the data with respect to a given access structure and prepares the results for transfer to the requesting subsystems.
- The User Interface Subsystem (UI) is distributed between the mainframe and the workstation. The UI element on the mainframe is mainly responsible for the protocol handling of the connectivity between the mainframe and the workstations. The UI element on the workstation covers — in addition to the corresponding protocol — the user interface, the data presentation, and the derived-parameter compiler.
- The Offline Production Subsystem (OP) is responsible for the autonomous production of printouts, plots and tapes on the mainframe devices.

In addition, so-called 'middleware' subsystems provide general support to the SPES:

- The Event-Logger Subsystem (EL) is responsible for routing all messages between the different cooperating SPES jobs.
- Other middleware subsystems support the SPES by providing commonly used functionalities like time and date handling or standard file access.

The man/machine interface

Principles

The SPES can be fully piloted and accessed interactively from any IBM-compatible PC (Fig. 4) supporting the SPES workstation software, and equipped with at least a graphics card, a hard disk, and a serial connection to the ESOC LAN. This simple configuration allows the SPES to be installed and run from any location in ESOC, and will also allow the SPES service to be extended to external users at remote sites with minimum cost.

The SPES workstation provides a multi-user integrated environment within which all SPES commands can be activated. Privacy and security are guaranteed using hierarchical levels of privileges granted to registered users, under the SPES system manager's authority.

Modern concepts have been employed to provide the end user with a friendly interface. The system can be commanded either via a menu-forms-based interface (Fig. 5) oriented towards the novice user, or by SPES User Interface Language (UIL) commands. An online help facility (Fig. 6) can be activated at any stage to obtain more information on command details.

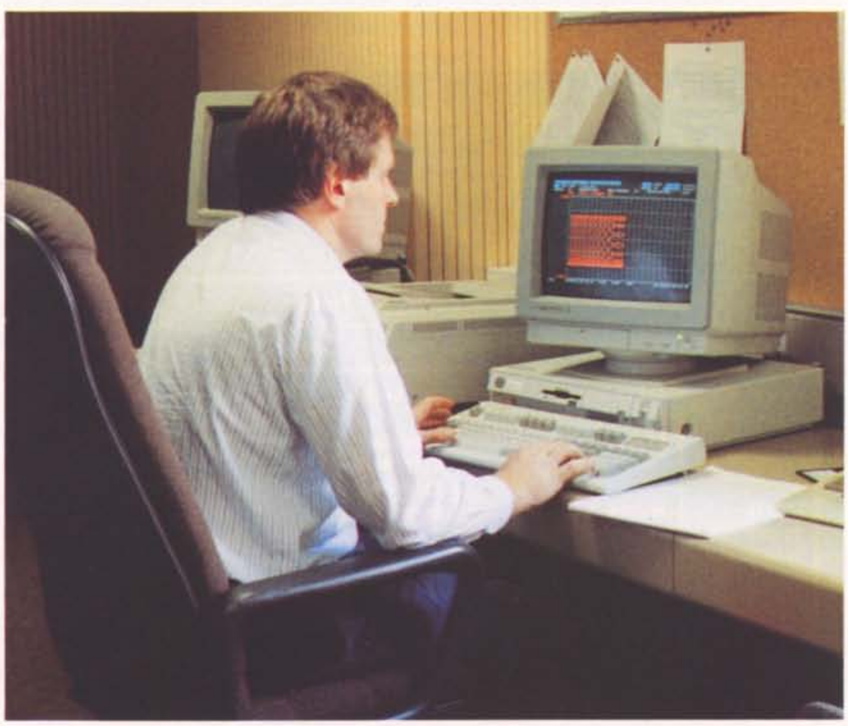


Figure 4. A SPES workstation installation

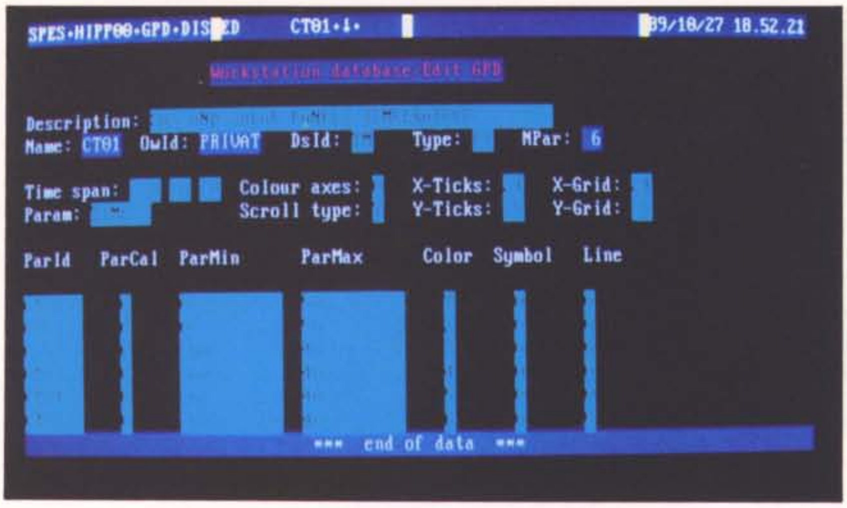
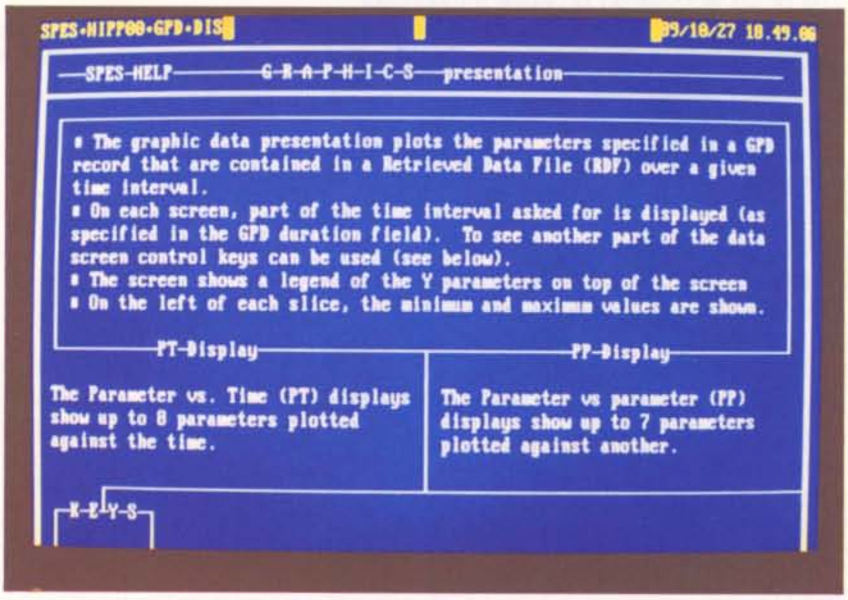
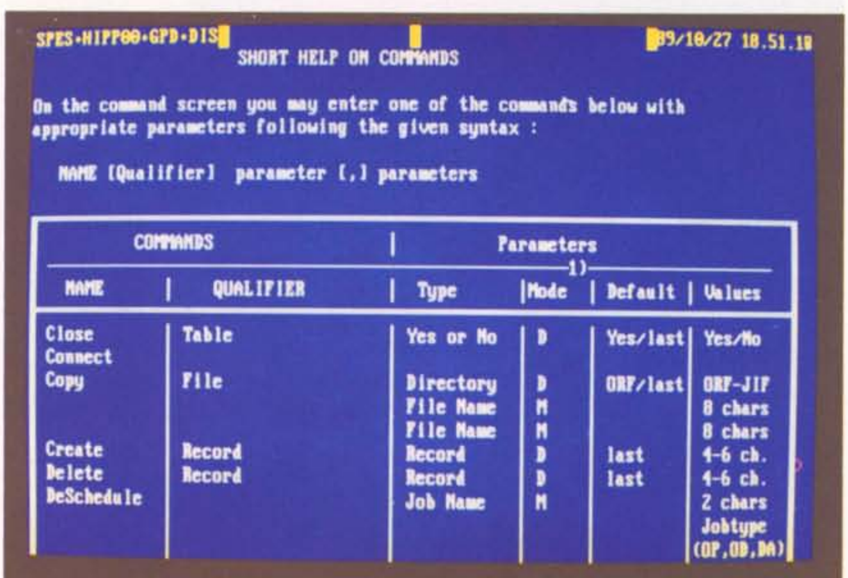


Figure 5. Example of the SPES menu-driven interface



a



Figures 6a,b. Examples of the SPES on-line HELP facility

b

The SPES commands

To begin a session, the user must first log-in to SPES locally on the workstation. After access rights have been checked, the user is authorised to perform any local function. Activation of the mainframe functions is only allowed once the user is connected to the SPES mainframe, which is a separate stage in the SPES access procedure.

Local commands

Local commands deal with those functions that can be entirely processed locally on the SPES workstation, without requiring any connection to the mainframe. They include:

- the workstation database-management commands, allowing the creation, editing or display of records from the workstation database. Every user has their own set of objects in their private database, but also has the possibility of importing objects from the mainframe public database for their own use;
- the mainframe job-preparation commands, permitting the building of mainframe request files for the subsequent activation of mainframe jobs;
- the derived-parameter compilation command, permitting the correctness of user-defined derived-parameter source programs to be checked. They can then be debugged on the workstation prior to operational use on the mainframe as part of the access structure;
- the data-presentation commands, which are the final step in the data-processing chain and cover the activation of displays, plots or printouts of repository data previously retrieved from the mainframe.

Mainframe commands

All mainframe tasks are activated and controlled from the workstation, and the mainframe commands allow one to initiate and schedule mainframe processes, and to monitor them via messages displayed in a dedicated area on the workstation screen.

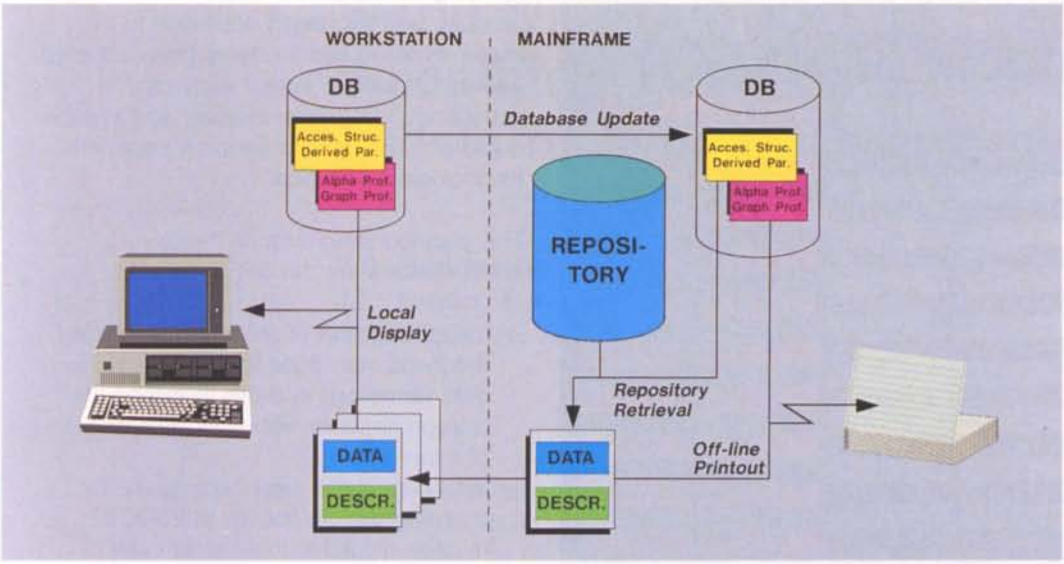


Figure 7. Schematic of a typical SPES session

Typical session

The SPES has the attractive feature of being able both to deliver to the user's PC selected data gathered at any time during the satellite mission's lifetime, and to display it in a user-defined layout. The fulfilling of such a request involves several complementary steps (Fig. 7):

- Building of the access structure: the access structure describing the selection of parameters to be retrieved from the repository needs to be specified using the database-management facilities on the workstation. Similarly, the derived parameters (if any) contributing to the access structure need to be created and compiled on the workstation. The access structure will then be stored on the mainframe for further retrievals. It is important to note that at this stage all derived parameters and access structures created can be reused later.
- Retrieving the data: the data-retrieval request is satisfied by the initiation of an online repository-retrieval job after having specified the particular retrieval parameters (access structure, access strategy, and time selection). Such a retrieval will produce a data file and a separate data-description file. This concept of isolating the data from its interpretation method has been retained throughout the system, and contributes greatly to its flexibility and performance.
- Displaying the data: the data and description files produced in the previous step serve as input for the presentation processes, which can take place either on the workstation (local displays and printouts) or on the mainframe (offline printouts). At this stage, a subselection of the parameters retrieved, or a shorter time slot, can be specified.

Typical outputs

The final goal of the SPES is to present the user with the data that he is interested in, in a form suitable for easy interpretation. The system offers two types of outputs:

- alphanumeric format (Fig. 8), whereby the parameters are presented in the form of a table of values against the packets in which they occurred
- graphical format (Fig. 9), where the variation in the parameters with time or as a function of another parameter is presented pictorially.

The displays are driven by the definition of so-called 'user-defined proformae', which are held on either the workstation database for local outputs, or on the mainframe database for offline prints. (A proforma basically specifies the display type, the set of parameters contributing to the display, as well as the display characteristics: colours, external representation, raw or calibrated values).

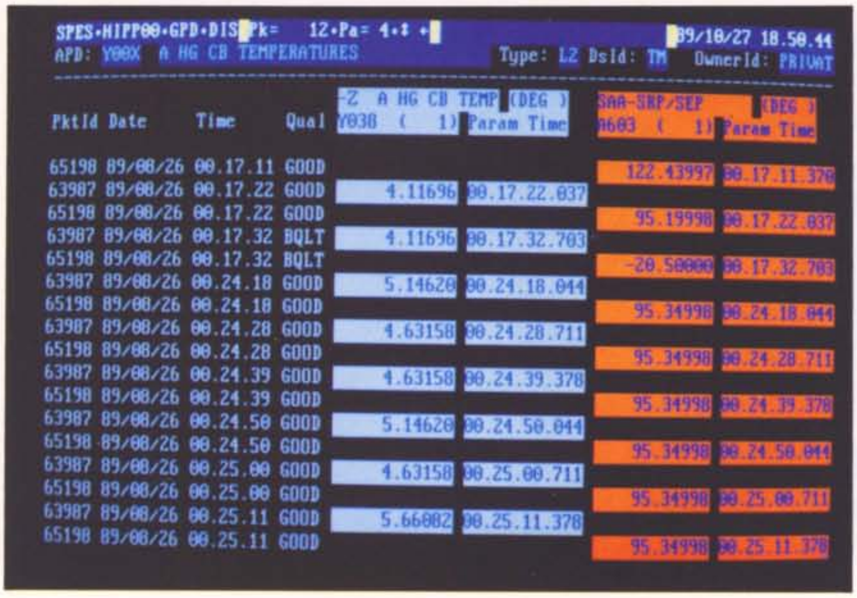
Initial experience

The SPES was used operationally for the first time during the launch of the Agency's Hipparcos satellite. It was made available on several workstations at ESOC, and was used by the mission-support team to monitor the in-flight behaviour of some onboard equipment during the early life of the spacecraft.

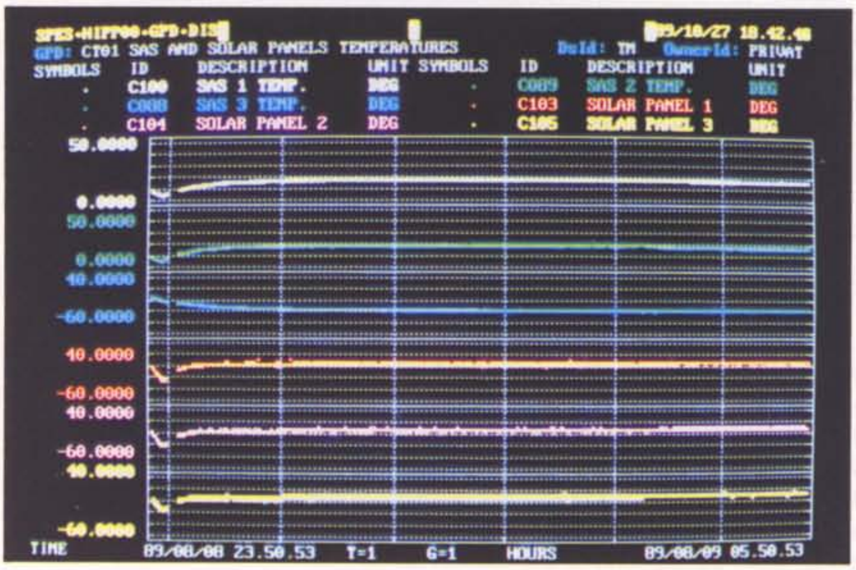
Since then, the mission data has been routinely archived in the SPES repository (an average of 32 Mbyte per day) and the system is being used regularly for mission-evaluation purposes.

Future developments

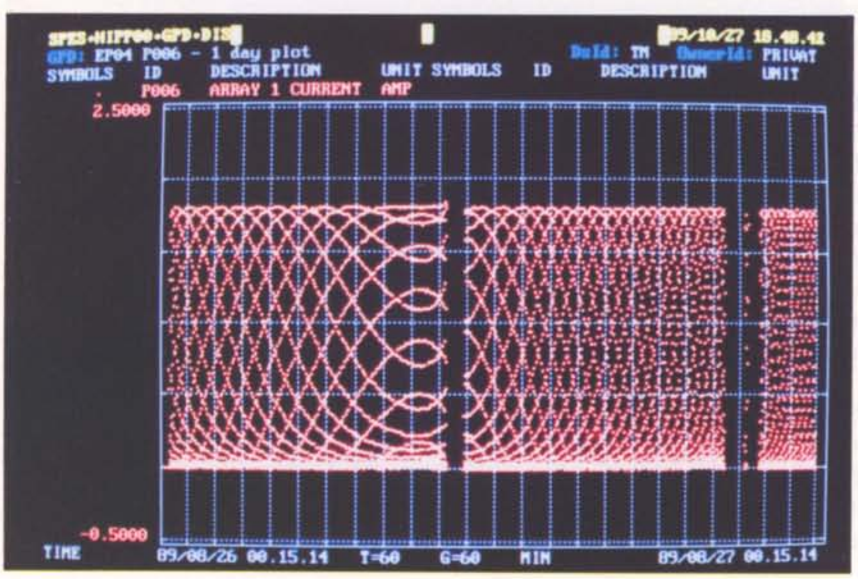
The SPES is an ambitious, long-term-oriented



Figures 8. Example of an alphanumeric display on the SPES workstation



a



Figures 9a,b. Examples of graphical displays on the SPES workstation b

product, and a phased approach to its implementation has therefore been adopted, both to be able to exploit early user experience in the later phases, and to allow a growth capability for keeping pace with technological evolution.

The planned short-term (in 1990) enhancements for the SPES include:

— the introduction of automatically-loaded magnetic cartridges to hold the mission data repository, in order to extend the storage capacity with least compromising of access time;
— extension of the 'user community' by affording remote access to ESOC's mission database to external users (e.g. projects at ESTEC, spacecraft manufacturing industry, etc.);
— further improvement of the man/machine interface based on user experience.

A number of longer-term expansion possibilities are also under investigation:

— handling of telecommand data in either packet or conventional form, ready for when these data become available as a standard feature of the SCOS;
— provision of a user interface based on more advanced and more powerful workstations, with additional and faster presentation facilities combined with greater local storage (the PC interface will, however, be retained);
— utilisation of expert-system techniques to assist the mission performance evaluation process itself.

Conclusion

The Spacecraft Performance Evaluation System is expected to have an operational lifetime of at least ten years, supporting an increasing number of missions and a progressively larger user community. Its modular concept will allow it to be adapted in accordance with the latest technological trends, especially in the man/machine-interface domain. The effort expended on further development of the SPES will, of course, depend on the user's perception of and interest in the facilities now being offered.

World-Wide Interactive Access to Scientific Databases via Satellite and Terrestrial Data Network

T.R. Sanderson, M.A. Albrecht, K. Blank, M. Brett, A. Ciarlo, J.L. Green, H.K. Hills, P.M.T. Hughes, T. Kamei, A. Kiplinger, R.E. McGuire, J.H. Waite Jr. & G. Wallum

During the Ninth Meeting of the Inter-Agency Consultative Group (IACG) for Space Science held in Prague, Czechoslovakia, during the week of 18—22 September 1989, a temporary satellite network link was installed between Prague and ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, to demonstrate the latest possiblities for scientific networking and data transfer. This was the first time that scientists in the East and West have been linked via such a network.

Affiliations:

M.A. Albrecht* A. Ciarlo* M. Brett	ESIS, ESRIN, Frascati, Italy
K. Blank* P.M.T. Hughes G. Wallum	ESOC, Darmstadt, W. Germany
H.K. Hills J. L. Green* R.E. McGuire	NSSDC, Goddard Space Flight Center Greenbelt, Maryland, USA
T. Kamei	WDC-C2 for Geomagnetism, Kyoto University, Kyoto, Japan
A. Kiplinger	NOAA, Boulder, Colorado, USA
J.H. Waite Jr.*	Southwest Research Institute, San Antonio, Texas, USA
T. R. Sanderson*	ESA Space Science Dept., ESTEC, Noordwijk, The Netherlands

* Members of IACG Working Group 2.

The temporary satellite link between ESOC and Prague, using the Agency's ECS satellite, was installed by ESOC's Computer Department, with the full cooperation of Deutsche Bundespost and the Czechoslovakian PTT. The link consisted of a Dornier Personal Earth station, installed on the roof of the Prague hotel where the meeting was being held, and IBM PS/2 computers in the conference room. The computer's display was projected onto a large wall screen.

The computers in Prague were connected via ESOC to the Space-Physics Analysis Network (SPAN) and the European Space Information System (ESIS), both of which were used to connect to all the databases used in the demonstration.

The capabilities of the network connection were demonstrated in real time during a live 45-min presentation to the IACG Meeting by members of the IACG Data Working Group.

Features demonstrated

Electronic mail to Japan

The first demonstration was to send an electronic mail message to a colleague in the World Data Center in the Geophysical Institute at Kyoto University in Japan, using the SPAN. A short message was composed on the screen of the terminal in the meeting room, and despatched at 11:20:04 h to Japan, travelling by satellite link to ESOC, by submarine fibre-optic cable across the Atlantic to Goddard Space Flight Center (GSFC) near Washington, and from there on to Japan. A reply from Japan was received in the meeting room at 11:21:14, approximately 1 min later (Fig. 1).

Orbit prediction

NASA's Satellite Situation Center is located in the National Space Science Data Center at GSFC in Greenbelt. The Center contains data and software for plotting spacecraft orbits, both on site, and remotely via network connections. Both graphical and textual summaries can be produced. One of the aims of the Center is to enable users to predict advantageous positions for a spacecraft, relative to the position of magnetospheric or interplanetary features, to the position of other spacecraft, or to the position of ground facilities.

Figure 1. The message sent from Prague to Kyoto, and the response received 1 min 10 s later

```
From:   ESIS::MIGUEL      22-SEP-1989 11:20:04.32
To:     KYOTO::TOYO
Subj:   demo

greetings from the iacg meeting in prague
trevor
```

```
From:   KYOTO::TOYO       "Toyohisa Kamei, Kyoto Univ." 22-SEP-1989 11:21:14.90
To:     ESIS::MIGUEL,TOYO
Subj:   RE: demo

Dear Trevor and friends,
I have received your message from the IACG meeting.
Sugi gave me a message to you all.

Message from him: I wish you will have a successful meeting. /M. Sugiura/

How is the demo going?   Best regards, Toyo Kamei from Kyoto, Japan
[ISAS]--span--[NASA]--span--[ESA]--span--[IKI]  IACG
```

The demonstration consisted of showing how to predict the orbit of the recently launched Japanese satellite 'Akebono', and compare that with the orbit of the US 'Dynamics Explorer' satellite, and the predicted orbit of the Soviet 'Activnyi' satellite (which had not yet been launched at that time). A time period of interest was chosen and the commands sent from the meeting room by network to the computer in the USA, which responded by calculating the orbits of the satellites, and then sending the results over the network to Prague for plotting on the screen back in the meeting room (Fig. 2a).

The interactive nature of the facility was demonstrated in real time by moving the cross hairs on the screen and requesting the time at which a spacecraft would be at a particular position (the position selected interactively, denoted by the tick mark on the Akebono orbit, is recorded on the left-hand side of the plot).

Purely to demonstrate the capabilities of the system, two other hard-copy plots prepared prior to the meeting were also shown: a heliocentric plot of the the Halley encounter (Fig. 2b), and a geocentric plot showing the Earth, the bow shock, the magnetopause, and the orbit of the IMP spacecraft (Fig. 2c).

Near-real-time solar X-ray data

Next, near-real-time data from a scientific satellite were displayed — in this case data from the X-ray instrument on the GOES geostationary satellite held in the National Oceanographic and Atmospheric Administration's database (MAX91) in Boulder, Colorado.

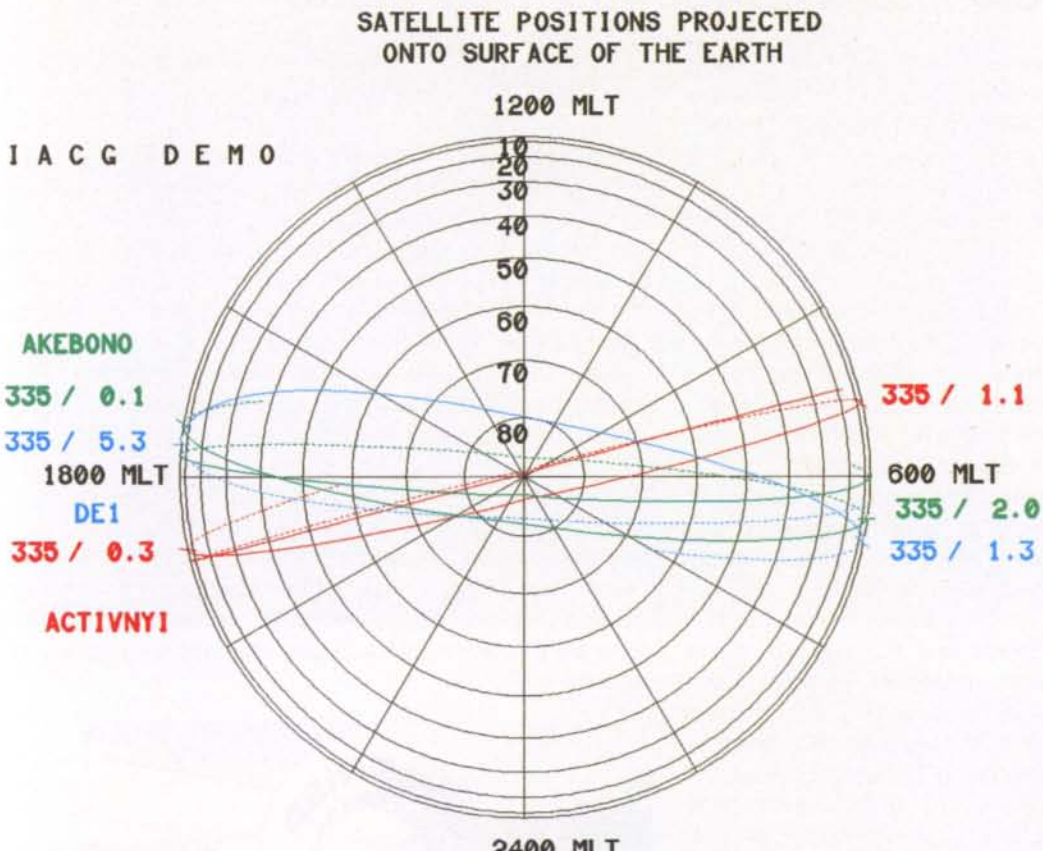
The GOES spacecraft carries a solar X-ray experiment which continually monitors the Sun and measures the solar X-ray flux integrated over its disk. It is therefore a very effective means of detecting the presence of solar flares. Each day's data is processed and then placed in the database at 3 a.m. in the morning in Boulder, which is 11 a.m. Central European Time. By coincidence, the demonstration in Prague started at 11 a.m., which allowed one-day-old GOES satellite data to be accessed and displayed on the screen there.

The GOES-based plot showed that a solar flare had occurred on the Sun on the previous day at 0300 UT, giving rise to an enhancement in the X-ray flux measured by the satellite's X-ray instrument (Fig. 3). During the demonstration, it was possible to predict that this flare would cause a magnetic storm on the Earth one or two days later. During the week of the meeting, plots from this source were copied automatically over the network and displayed as posters in the meeting room.

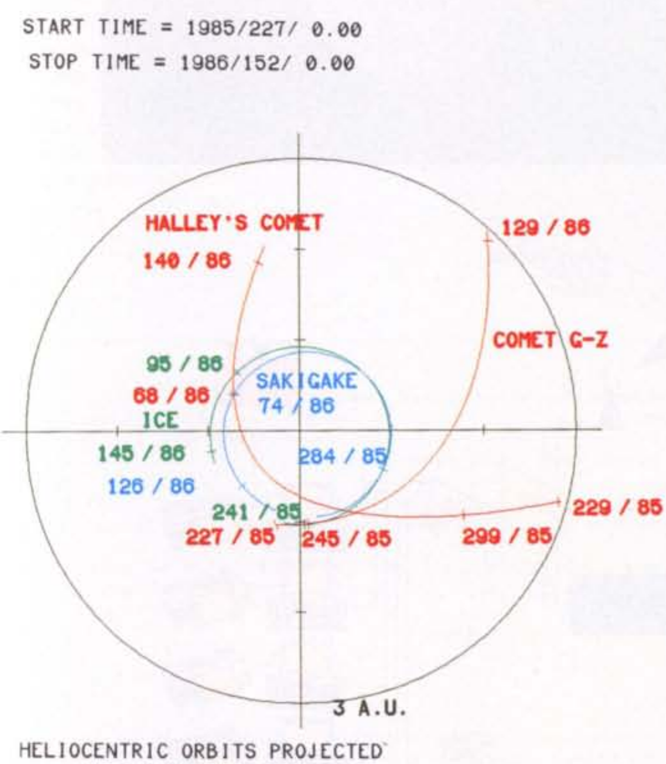
Southwest Research Institute Database and NASA Master Directory

Next, the NASA Master Directory was demonstrated, and used to show how to access the Southwest Data Display and Archive System (SDDAS).

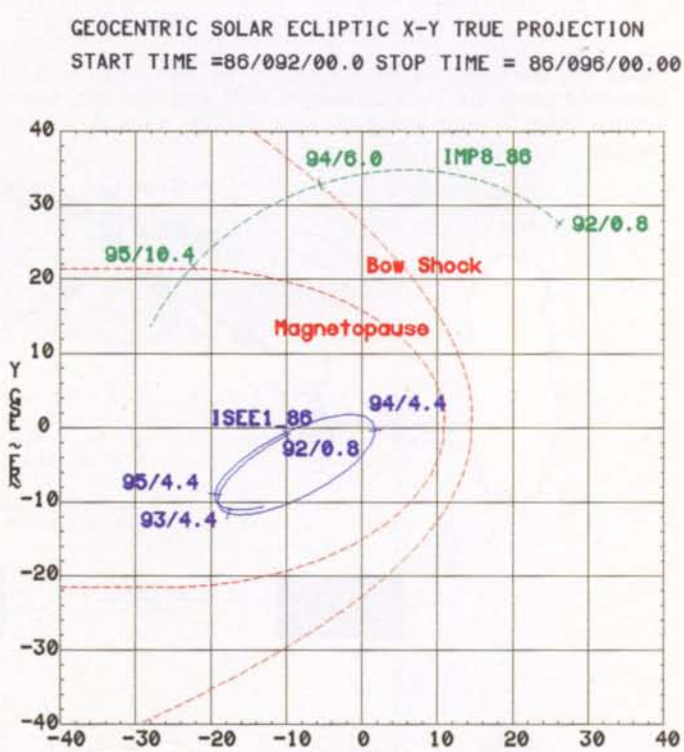
The NASA Master Directory is an online information system devoted to earth- and space-science data, based at the National Space Science Data Center, which acts as a starting point for computer-aided searches of data for both NASA and non-NASA scientists. It includes brief, high-level information about existing data sets, including the archive location and how to obtain more information. In addition, automated connection links are available to connect the user, via a network such as SPAN, to databases included in its directory. One such database is the Southwest Research Institute's database in San Antonio, New Mexico, which was accessed in this part of the demonstration.



(a)



(b)



(c)

Figure 2

(a) Geocentric plot of the predicted orbit for Japan's Akebono satellite for 1 December 1989 (day 335), and the orbits of the USA's Dynamics Explorer-1, and the Soviet Activnyi spacecraft

(b) The bottom left-hand panel shows predicted orbits for the spacecraft involved in the Halley encounter

(c) The bottom-right hand panel shows the predicted orbit of the IMP spacecraft and the positions of the Earth, the bow shock and the magnetopause

— How the Connection was Made —

Several international computer networks are in use today in support of scientific data analysis. These include the Space Physics Analysis Network (SPAN), the European Academic Research Network (EARN), its US counterpart BITNET, the NASA Science Network (NSN), of which SPAN is a part, as well as many national research and academic networks in Europe.

The network chosen for the world-wide communication from Prague was SPAN, which links together several thousand scientific computers in Europe, the USA and Japan, via which many of the databases and services related to space research are accessible. One such information system able to use SPAN is ESA's own European Space Information System (ESIS). The European connections made use of ESAnet, the Agency's general-purpose communications network, which also provides gateway services to a variety of public and private networks, such as SPAN.

The connection between SPAN and Prague was made using a satellite link between a Dornier Personal Earth Station installed on the roof of the hotel (Fig. A1), and the Eutelsat ground station in the Deutsche Bundespost-Telekom Technical Headquarters (FTZ) in Darmstadt. A 64 kbit/s land-line connected the Eutelsat ground station to ESOC. Suitable X.25 switching equipment was installed in the hotel to enable the PCs to be used as terminals and log-on remotely to the SPAN node in Darmstadt, or the ESIS nodes at ESRIN in Frascati, Italy (Figs. A2 - A4).

Several types of software emulators were used to emulate either a VT100 terminal for text, or a Tektronics 4000/4100 series terminal for graphics. These included the Kermit terminal emulator from Columbia University, the EM 4010 terminal emulator from Diversified Computer Systems Inc., and the TNET-07 terminal emulator from GrafPoint Inc. All three support VT100 text and Tektronics 4010 graphics emulations. The latter also includes a Tektronics 4107 graphics emulation, which gives the possibility of using cross-hairs interactively on the screen.

To make the entry of commands into the computer user-friendly, the so-called 'user-shell' of ESIS, was used extensively during the demonstration. As part of the ESIS pilot-project phase, a user shell (a program which can be installed on any computer) is being developed which provides a uniform, menu-driven interface to a variety of databases (Fig. A5).

Figure A1. The Dornier Personal Earth station installed on the roof of the Forum Hotel in Prague

Figure A2. The ECS satellite, connecting the ESA network in Darmstadt to Prague. An X.25 switch, PAD, IBM PS/2 PCs and a Barco projector were installed in the meeting room in Prague

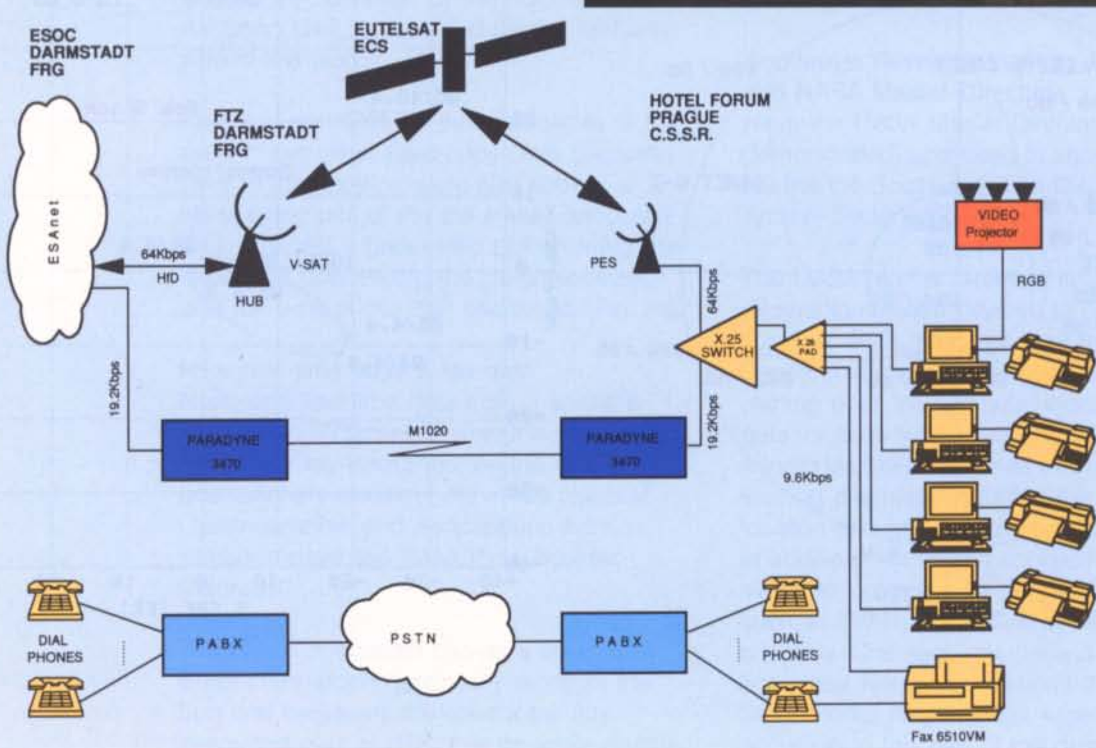


Figure A3. The interconnection between Prague and the ESAnet network connections in Europe

Figure A4. The Space Physics Analysis Network connection from ESAnet in Europe to: the National Space Science Data Center in Greenbelt, Maryland; the Southwest Research Institute in San Antonio, Texas; and the World Data Center at Kyoto University, Japan, used during the demonstration

```
         ESIS : European Space Information System - USER SHELL V1.0
Context:  Solar-Flares                              Thu 21 Sep 1989 15:02:22
---------------------------------------------------------------------------
:                  The prototype ESIS User Shell - Version 1.0              :
:                                                                           :
: This  prototype of  the ESIS  User Shell  is aimed  at providing  users with:
: connectivity to access remote databases and some basic support functions. :
:                                                                           :
: Help on Help tells you how to use the Help system;                        :
: help on User Shell gives you some hints on the functions implemented in this:
: version.                                                                  :
:                                                                           :
:                                                                           :
:                                                                           :
:                                                                           :
---------------------------------------------------------------------------
---------------------------------------------------------------------------
: Help ........ H  Databases ... D  Info-Services I  Solar-Flares  S        :
:                                                                           :
---------------------------------------------------------------------------
: Quick-look ... Q  Forecasts .... F  Daily-Events . E  Exit ......... X    :
---------------------------------------------------------------------------
```

Figure A5. The European Space Information System (ESIS) prototype 'user-shell' menus used during parts of the demonstration

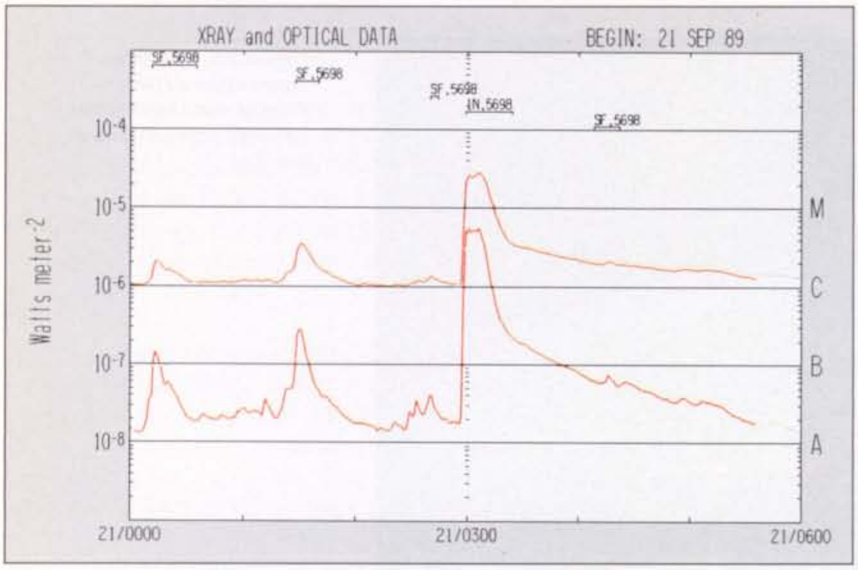


Figure 3. X-ray data from the GOES geostationary orbiting satellite for 21 September 1989. The plot shows an enhancement in the X-ray flux at 03:00 UT due to a solar flare

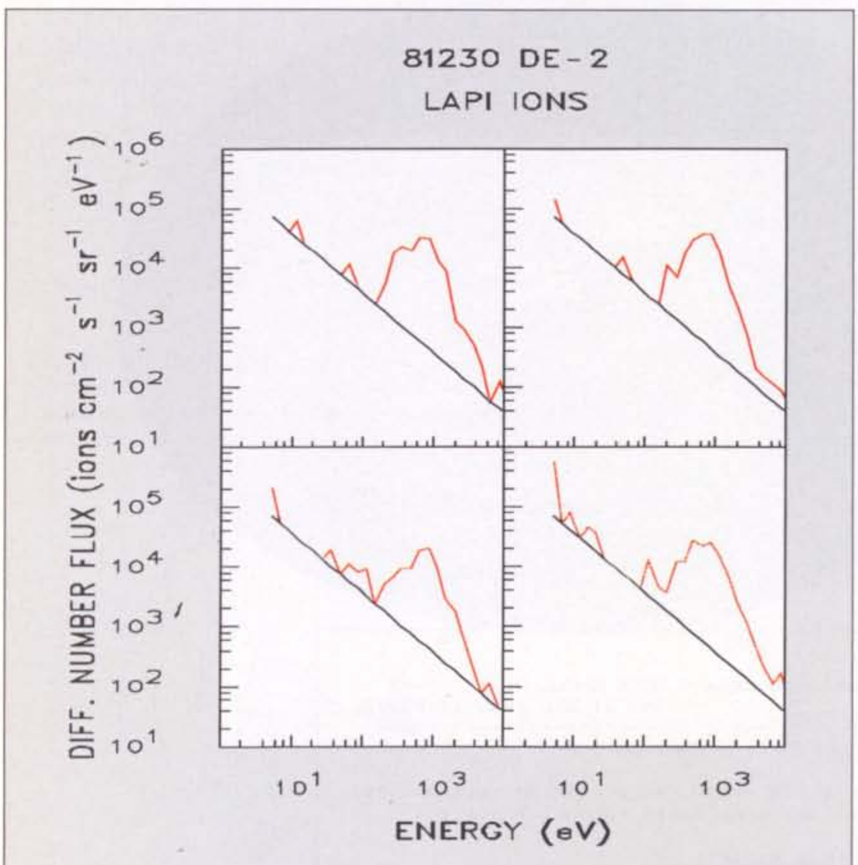


Figure 4. Dynamics Explorer-2 ion spectra observed on 19 August 1981 (day 230). The four spectra were recorded when the spacecraft was passing through the cusp region, and show enhancements in differential flux at energies around 10 keV

The SRI database was established to support the analysis of the Dynamics Explorer Satellite plasma data, and now includes data from several particle and field instruments. The original aim of establishing the database was to enable scientists to access the data and produce colour plots from it at their own institutes without having to write computer programs. The database can be accessed not only through the NASA Master Directory, but also directly on SPAN and via the Internet network.

The terminal in Prague was used to log-on to the database and to select data from several instruments on DE-2, which was then transmitted over the network to be displayed on the screen (Figs. 4, 5).

Co-ordinated Data-Analysis Workshop

Finally, the database of Coordinated Data-Analysis Workshop-9 (CDAW-9) was accessed. This database was assembled specifically for the Polar Regions Outer Magnetosphere International Study (PROMIS), which was in the process of being run from GSFC. Data from several instruments on eleven spacecraft and from many ground stations had already been assembled in a common database for this Workshop.

This database was accessed during the demonstration, and the data plotted on the screen in Prague. Data from three instruments were selected, transmitted via the network and displayed within just a few minutes of accessing the database (Fig. 6).

Press demonstration

The demonstration to the IACG was followed by a Press Conference at which the demonstrations of mail transfer to Kyoto, and of accessing the NOAA database were repeated for the Czechoslovakian press.

Conclusion

The Prague demonstration was performed to show members of the IACG what is possible with modern technology, using a link installed specifically for the meeting. Minor political and technical problems had to be overcome to make the connection possible, but during the presentation all the planned demonstrations could be conducted in real-time, despite the temporary nature of the installation.

In addition to showing what is currently feasible with today's technology, the demonstration provided valuable insight into the possibilities for data exchange for future

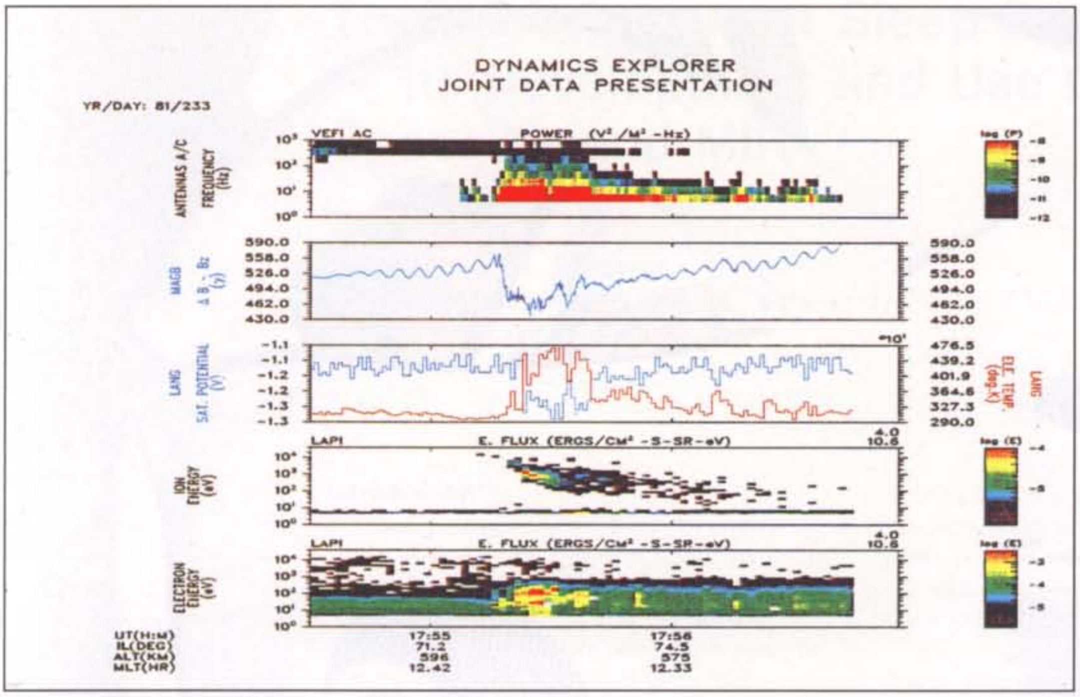


Figure 5. Colour spectrogram of data from the Dynamics Explorer-2 electron, ion, magnetic field, and wave experiments, plotted prior to the meeting on a colour display

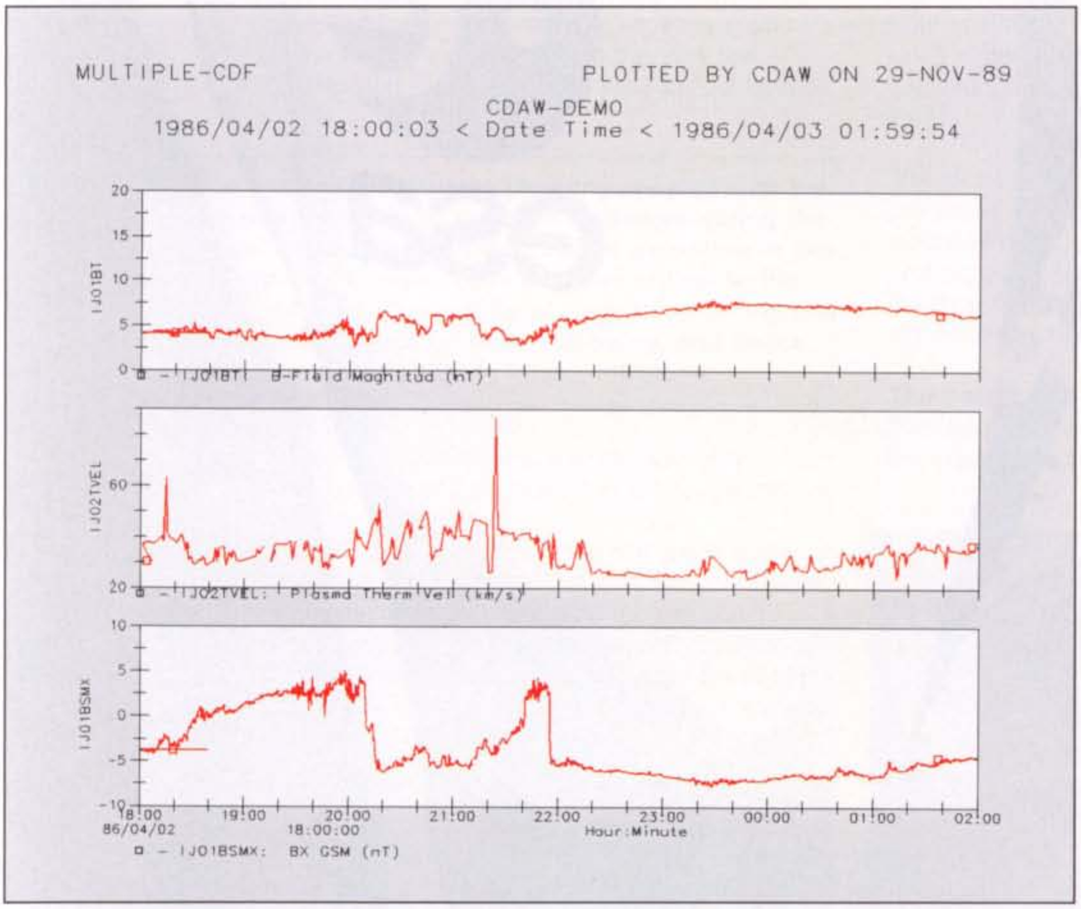


Figure 6. Sample CDAW plot, showing data from the magnetic-field and plasma experiments on the IMP-8 spacecraft. The data show a possible bow-shock crossing

cooperative programmes to be undertaken under the aegis of the IACG.

Acknowledgement

The temporary nature of the link to Prague on this occasion meant that considerable manpower and expertise had to be made available to support the network. This is to some extent reflected in the list of the authors of this article, each of whom played a significant part in the demonstration, either in Prague, or at one of the remote sites, in some cases working unsocial hours due to the time differences.


esa

The ESA Astronaut Sleep Restraint — Its Development and Use Onboard Spacelab and MIR

W. Ockels & H. Stoewer
European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands

Manned space missions call for intricate planning coupled with the careful exploitation of a minimum of precious resources during the flight. The astronauts' capabilities and time are no exception in this respect, and the health and fitness of the crew are critical to the success of a manned mission. The quality of their sleep during rest periods in orbit has a direct effect on their well-being, and hence on their performance, particularly during longer missions.

Introduction

Achieving a comfortable sleeping position in space is not as easy as one might think. The lack of gravity means, of course, that the 'bed' is never too hard and the body's muscles can completely relax. However, the absence of the gravitational force that normally holds one down and restrains the limbs also eliminates any knowledge about one's whereabouts when the eyes are closed. It is then all too easy to float towards, and collide without warning with, any number of hard objects in the spacecraft.

On Earth one can move both body and limbs relatively freely during sleep, but each time the covers are lifted the perceived pressure increases. This smooth application of pressure extending over large areas of the body has a comforting effect. This feedback to the body is also important in space. In practice, astronauts often tie themselves to walls, or even wedge themselves into narrow corners, looking for the comfort of feeling confined and protected (Fig. 1a,b).

It was this realisation that prompted the idea, after the experience of the first Spacelab flight in 1983, of developing a new 'astronaut sleep restraint' that could provide a comforting resting place similar to a bed on Earth.

The idea was to create a sleep restraint producing some kind of spring-like pressure feedback over body and limbs. Knowing the problems of stowage and safety in orbit, the first thoughts were of air tubes or air mattresses tied together at the seams.

The design and development stages

The design principle that emerged from the first discussions of a practical device foresaw

Figure 1a,b. Astronauts' chosen sleeping places on earlier missions

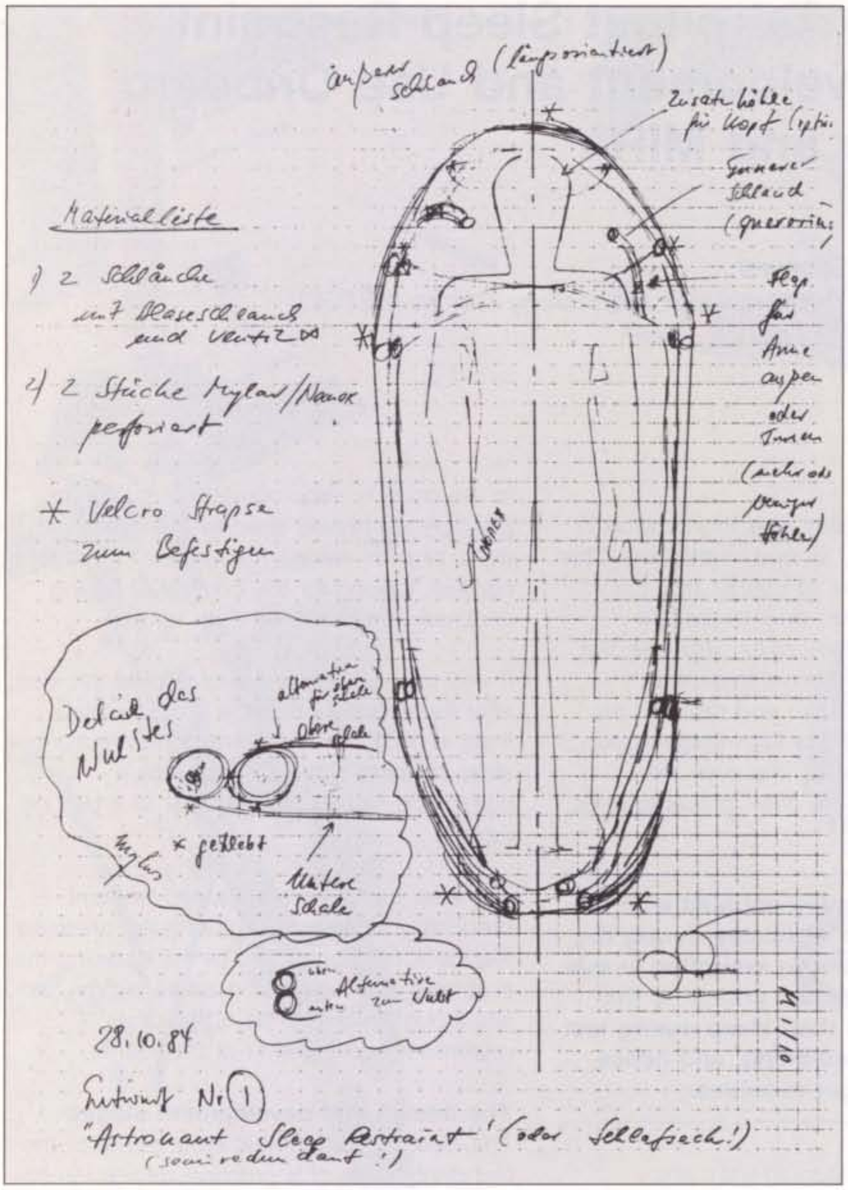


Figure 2. The first design sketch, made on 28 October 1984

Figure 3. The first attempt at building a full-scale model by the ESTEC Workshop, using ordinary cloth and an extra-long bicycle-tyre inner tube

two sheets of cloth-like material stretched by a tubular tensioning device. The sheets would give sufficiently for the astronaut to get in and out, and would provide a feedback pressure roughly proportional to the degree of stretching, and hence varying with sleeping position.

A sketch of an arrangement that it was thought would deliver a satisfactory pressure equation/distribution via a combination of its dimensions and shape, was made on 28 October 1984 (Fig. 2). The first design drawing, prepared just a few days later, was scaled by ESTEC's Design Office to full size and used as a pattern by the Workshop staff to cut and stitch the cloth material (Fig. 3). An elongated bicycle-tyre inner tube served as the tensioning device. The final result was totally unsatisfactory, due largely to the excessive flexibility of the tube, but enthusiasm prevailed!

The TNO Fibre Research Institute's Textile Application Department in Delft (NL) was subsequently asked for help with prototype manufacturing. They had already successfully produced textile items for the Agency for Spacelab, and their ability to produce an updated prototype in a matter of days contributed substantially to the overall success of the ensuing development effort. Figures 4 and 5 show successive stages in the prototyping process.

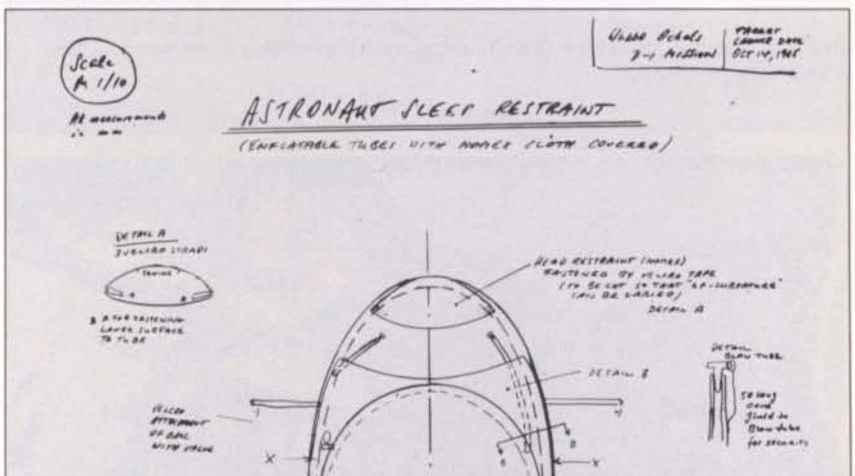
The problems of working with multi-dimensionally flexible material were new to most of those involved (space engineers are much more familiar with stiff, lightweight materials like aluminium, carbon fibre, etc.) and the sleep restraint's design and make-up were adjusted several times before the final flight-ready concept was arrived at (Fig. 6). Nevertheless, just six months had elapsed since the first sketch had been made.

One of the greatest difficulties lay in the selection of proper parts and materials. Nomex® cloth was an obvious candidate for the covering, due to its safe flammability and offgassing characteristics. The tubes and valves were more difficult choices. Eventually, the 9 cm-diameter plastic liner for a fire hose was found to possess the right stiffness, strength, mass and ease-of-manufacturing properties for the peripheral pressure tubes.

Another particular problem was that of finding a flexible adhesive that would stay leak-tight through a succession of inflation/deflation/folding cycles during the mission.

Figures 4 and 5. Progressive stages in the prototyping process

Figure 6. The final design update, made on 24 April 1985



Selection of the inlet/outlet valves needed in the fill and drain tubes was even more difficult. Aeronautical and aerospace hardware proved too heavy and complicated, and the designers eventually turned to chemical-laboratory and medical types of components. Blood-pressure measurement device valves proved to have the right mass, operability and technical properties for the purpose and could be purchased very cheaply over the counter (DM 3.50 each!).

These valves had the added advantage of being compatible with an elastic-ball pressurising device that would allow the astronaut to test the sleep restraint using various high (in excess of lung-produced pressure) and low pressure settings. Their only drawback was that their flow rates had to be increased to provide a convenient inflation/deflation time. This was achieved via a simple hardware modification using an electric drill!

The final prototype was tested in late May 1985, after which the flight unit, weighing a total of 2.05 kg, including all attachment straps, pump, and head restraint, was manufactured (Fig. 7).

All supporting 'paperwork', namely an 'Acceptance Data Package' (just 19 pages), produced by M. Judd of ESTEC Product Assurance Division, and a 'Certificate of Compliance/Acceptance' for Spacelab-D1, signed jointly by A.C. de Boer of ESTEC Test Division and H. Schürmanns of DLR for

Figure 7. The first prototype (fourth attempt) that provided confidence in the overall design concept

Table 1 — Design and development milestones

First discussion on requirements and possible solutions	Mid-October 1984
First design sketch	28 October 1984
Design update	5 November 1984
Manufacture and test of first model by ESTEC Workshop	9 November 1984
Manufacture of second model by TNO and test at ESTEC	29 November 1984
Manufacture of third model by TNO and test at ESTEC	4 April 1985
Final design update	24 April 1985
Prototype available	31 May 1985
Flight and training units available	3 July 1985
Acceptance Data Package signed off	11 July 1985
Certificate of Compliance/Acceptance for the Spacelab-D1 flight signed off	5 September 1985
First flight (Spacelab-D1)	October 1985

the D1 authorities, was presented for approval at Kennedy Space Center on 5 September 1985.

The few ESA and TNO staff involved had done a most commendable job in developing the 'ESA Astronaut Sleep Restraint' in less than nine months (Table 1), and at a cost substantially below that customary for space 'flight hardware'.

This novel Astronaut Sleep Restraint was subsequently granted a patent on 10 February 1987 (US Patent No. 4 641 386, in the name of the two authors), based on an application filed by ESA on 1 July 1985 (see accompanying panel).

The patent that has been granted is quite broad, covering all general 'pressure-feedback zero-gravity-type' sleep restraints, the particular model patented being the prototype used to establish proof-of-concept.

Flight experiences aboard Spacelab and MIR

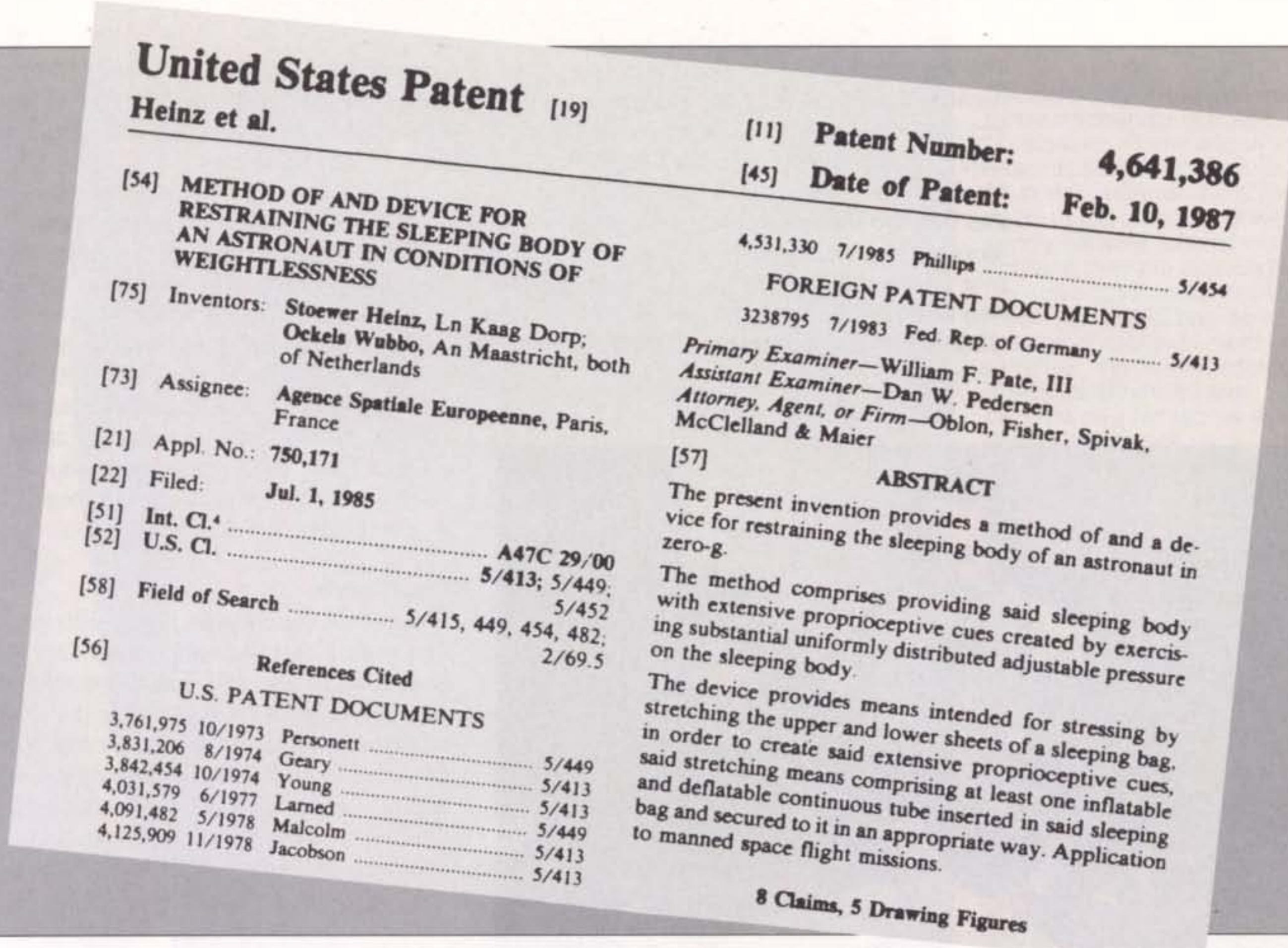
The ESA Astronaut Sleep Restraint has been tested in orbit on two space missions; the German Spacelab-D1 mission, lasting from 30 October until 6 November 1985, and the USSR's MIR mission, from 22 July until 29 December 1987.

As one of the three Scientist Astronauts in the Spacelab-D1 crew, one of the authors (W.O.) was able to carry the ESA Astronaut Sleep Restraint as part of his personal stowage allocation (granted to allow crew members to perform some experiments of their own during leisure time). It was stored in one of Spacelab's overhead lockers.

Although taken on board as a personal experiment, the Astronaut Sleep Restraint turned out to provide a welcome solution to a shortage of sleep stations during the D1 mission, with only four bunks available for a crew of eight. Six of the crew worked in two teams of three, in two 12 h shifts. The third Scientist Astronaut worked a rotating shift. As one bunk was permanently reserved for the Shuttle Commander, the three Scientist Astronauts on board had to share one bunk between them. The ESA Astronaut Sleep Restraint therefore provided a much needed extra sleeping berth (Fig. 8) throughout the D1 flight.

Quoting from the D1 mission report:

> 'At the end of a long mission-day one . . . I (W.O.) unstowed 'my' sleeping bag. I had to leave Spacelab in order not to



United States Patent [19]

Heinz et al.

[11] **Patent Number:** **4,641,386**

[45] **Date of Patent:** **Feb. 10, 1987**

[54] **METHOD OF AND DEVICE FOR RESTRAINING THE SLEEPING BODY OF AN ASTRONAUT IN CONDITIONS OF WEIGHTLESSNESS**

[75] Inventors: **Stoewer Heinz**, Ln Kaag Dorp; **Ockels Wubbo**, An Maastricht, both of Netherlands

[73] Assignee: **Agence Spatiale Europeenne**, Paris, France

[21] Appl. No.: **750,171**

[22] Filed: **Jul. 1, 1985**

[51] **Int. Cl.**[4] **A47C 29/00**

[52] **U.S. Cl.** **5/413**; 5/449; 5/452

[58] **Field of Search** 5/415, 449, 454, 482; 2/69.5

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,761,975	10/1973	Personett	5/449
3,831,206	8/1974	Geary	5/413
3,842,454	10/1974	Young	5/413
4,031,579	6/1977	Larned	5/449
4,091,482	5/1978	Malcolm	5/413
4,125,909	11/1978	Jacobson	5/413
4,531,330	7/1985	Phillips	5/454

FOREIGN PATENT DOCUMENTS

3238795 7/1983 Fed. Rep. of Germany 5/413

Primary Examiner—William F. Pate, III
Assistant Examiner—Dan W. Pedersen
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

The present invention provides a method of and a device for restraining the sleeping body of an astronaut in zero-g.

The method comprises providing said sleeping body with extensive proprioceptive cues created by exercising substantial uniformly distributed adjustable pressure on the sleeping body.

The device provides means intended for stressing by stretching the upper and lower sheets of a sleeping bag, in order to create said extensive proprioceptive cues, said stretching means comprising at least one inflatable and deflatable continuous tube inserted in said sleeping bag and secured to it in an appropriate way. Application to manned space flight missions.

8 Claims, 5 Drawing Figures

interfere with the next shift. I looked for a place to sleep in the airlock, which is dark and relatively quiet. Blowing up the sleeping bag was easy and I tied it to the forward wall of the airlock, with the 'head' close to the top hatch. It was difficult to keep the lower part away from the tunnel, so a few times other crew members inadvertently bumped into me. But I had a very good night's sleep of 6 h. The bag felt very good, I could move around and my head was held against the airtube, which gave the feeling of lying on a pillow.

Before the mission, Reinhard Furrer and I had agreed to swap between the bunk and the bag regularly. I only used the bunk once, on the third night, because I felt much more comfortable in the bag. The other astronauts who tried it — Reinhard Furrer, Ernst Messerschmid and Commander Hank Hartsfield — were all positive about the ESA sleeping bag, although Hank Hartsfield did not spend a whole night in it. Overall, the sleeping bag was a success.

Based on our experiences, a few improvements are suggested, such as ventilation holes below the top air tube, and a strap to pull the two air tubes together at the top for head pressure'.

Figure 8. Scientist Astronaut Wubbo Ockels floats into the ESA Astronaut Sleep Restraint aboard Spacelab-D1

The Astronaut Sleep Restraint was later demonstrated to a Russian Delegation, which included Cosmonaut Alexander Alexandrov, during a visit to ESTEC in April 1986 (Fig. 9). Mr. Alexandrov expressed so much interest that one model was subsequently sent to Moscow for evaluation. It was learnt some time later from Star City that the cosmonauts had arranged to transport the Restraint to the USSR's MIR Space Station on the Progress 32 mission.

Figure 9. The authors demonstrate the ESA Astronaut Sleep Restraint at ESTEC to Soviet Cosmonaut Alexander Alexandrov, in April 1986

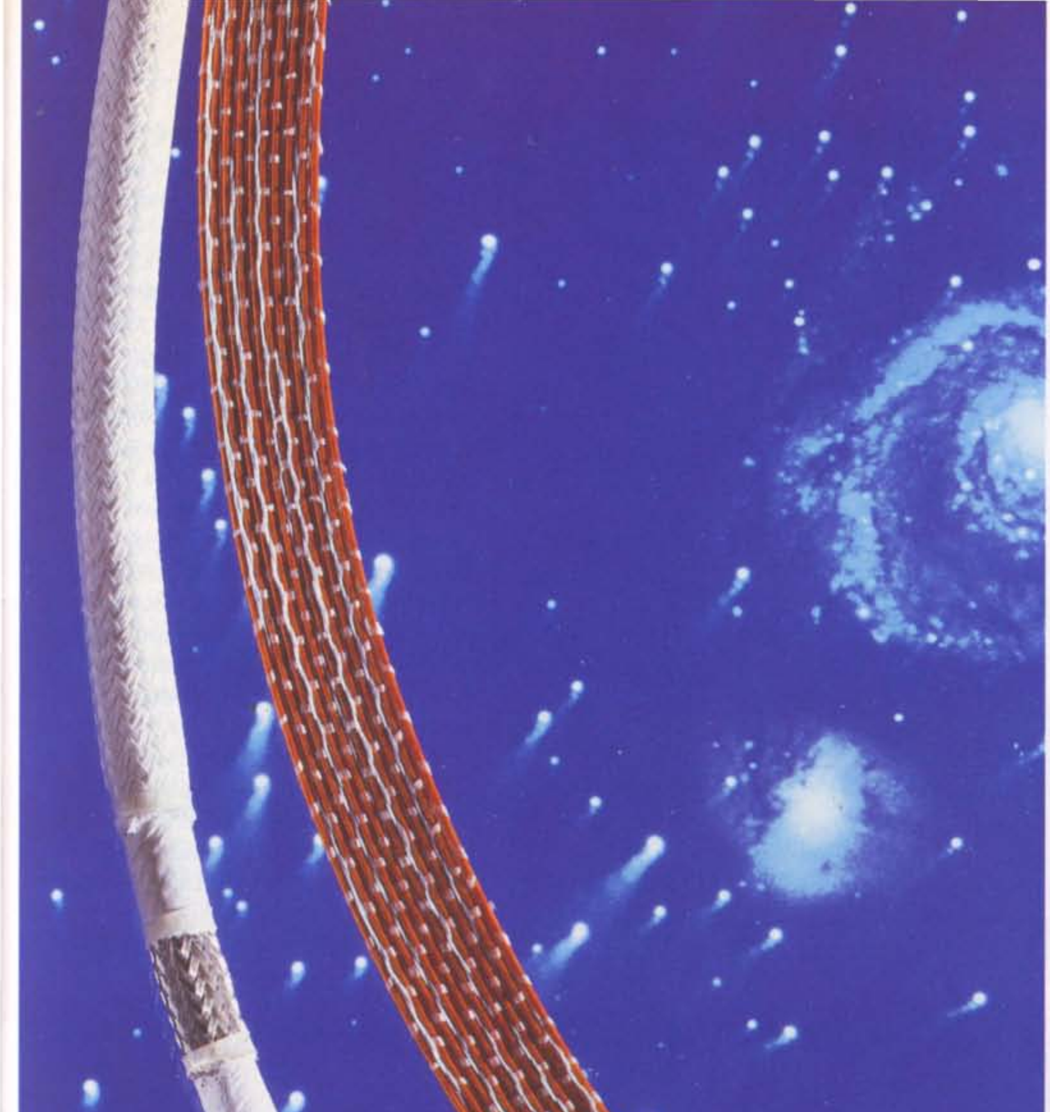
Cosmonaut Alexandrov evaluated the device during his stay on board MIR, between 22 July and 29 December 1987 (Fig. 10). His report reads as follows:

'I mark the ESA sleeping bag positively. The tight cover allows a good body warming, which creates an imitation of sleep in gravity. The thin cover helps to keep the normal temperature. The bag construction provides freedom of movement when resting inside it. There was not enough place in MIR to keep the bag inflated. So crew time was spent on folding up, etc. The sleeping bag provides indispensable comfort for cosmonauts and can be used in a Space Station.'

Conclusion

The in-orbit experience gained with the ESA Astronaut Sleep Restraint during both the Spacelab-D1 and MIR space missions was very encouraging. It has clearly demonstrated itself as a novel concept that should be evaluated further during future manned space missions. It may eventually become the preferred means for sleeping in space, especially on longer duration flights.

Figure 10. The ESA Astronaut Sleep Restraint being prepared for use aboard the USSR's MIR Space Station



Product Information:

Power Supply Cable Assemblies for Space Technology

Standard cable solutions are totally inadequate in space applications. Power supply cable assemblies connect individual on-board systems and components to the on-board power supply network. Like all interconnections, they are exposed to the aggressive space environment. W.L. GORE has developed a range of cables to meet these extremes, the performance characteristics of which have become an international standard of excellence.

The GORE cables complying to specifications SPA, SPB and SPC 2110 are approved to ESA standard ESA/SCC 3901/007, 3901/008 and 3901/009. GORE offers the designer an extensive, approved range of products for the entire spectrum of signal and power supply cables. GORE cables use combinations of the GORE-TEX® expanded PTFE, PTFE and Polyimide. Mechanical and electrical performance is met with additional weight savings. Our manufacturing processes allow continuous colour coding. GORE power supply cable assemblies are easy to strip, handle and install. Shielded and unshielded constructions are also available and have been used on a number of missions – in a number of SPACELAB payloads, the ROSAT X-ray satellites and the EURECA experimental retriever platform. GORE Special Cables assure outstanding performance in tough everyday use. GORE believes in application-oriented development. Cables should be considered as fundamental construction elements and vital working parts at an early development stage of any space project. Frequently it's thanks to GORE Special Cables that technically innovative concepts become reality. So contact us right now. We'll design your individual special cable, provide a prototype, test and begin manufacturing within the shortest period of time.

GORE

W.L. GORE & ASSOCIATES GMBH
Nordring 1 · D-8835 Pleinfeld
West-Germany
Phone: (09144) 601-429

Hermann-Oberth-Straße 22
D-8011 Putzbrunn · West-Germany
Phone: (089) 4612-507

In brief

ESA/UK Agreement on Ascension Island Ariane Ground Station

The Agency recently signed an agreement with the United Kingdom on the establishment and use of an Ariane down-range telemetry reception station on Ascension Island, in the South Atlantic Ocean.

The Ascension Island station will be operational by March/April and forms an essential link in the chain of ground stations required to monitor Ariane launches (Kourou and Cayenne in Guiana, Natal in Brazil, Ascension Island and finally Libreville in Gabon). Operational qualification of the new station is scheduled for the Ariane V37 launch in April.

The ceremony took place at the Foreign and Commonwealth Office in London on 27 November 1989 and the Agreement was signed by ESA's Director General, Prof. Reimar Lüst, and the United Kingdom's Minister of State for Foreign and Commonwealth Affairs, the Honourable William Waldegrave MP.

The occasion also provided the first opportunity since the British Government reshuffle in July for informal exchange between ESA's Director General and the three new ministers most closely associated with space affairs. In addition to discussions with Mr Waldegrave, Prof. Lüst met the Right Honourable Nicholas Ridley MP, Secretary of State for Trade and Industry, and the Minister for Industry, the Honourable Douglas Hogg MP.

Signing of the ESA/UK Agreement on the Ascension Island Ariane station, by the Hon. William Waldegrave, Minister of State for Foreign and Commonwealth Affairs (right) and Prof. Reimar Lüst, the Agency's Director General (London, 27 November 1989)

New ESA Director of Telecommunications

At the ESA Council meeting of 13 and 14 December 1989 Dr René Collette was appointed Director of Telecommunications Programmes. Dr Collette took over from Mr Giorgio Salvatori, who is retiring, on 1 January.

René Collette, who is Belgian, has been with the Agency since 1964. He has headed the Communications Satellite Department since 1977 and in this capacity was responsible for the development of the Orbital Test Satellite (OTS); the European Communication Satellite (ECS) series; the Marecs maritime communications satellites; and Olympus.

Pending a review of the organisation of the Telecommunications Directorate, Dr Collette will, per interim, retain the function of Head of the Communications Satellite Department.

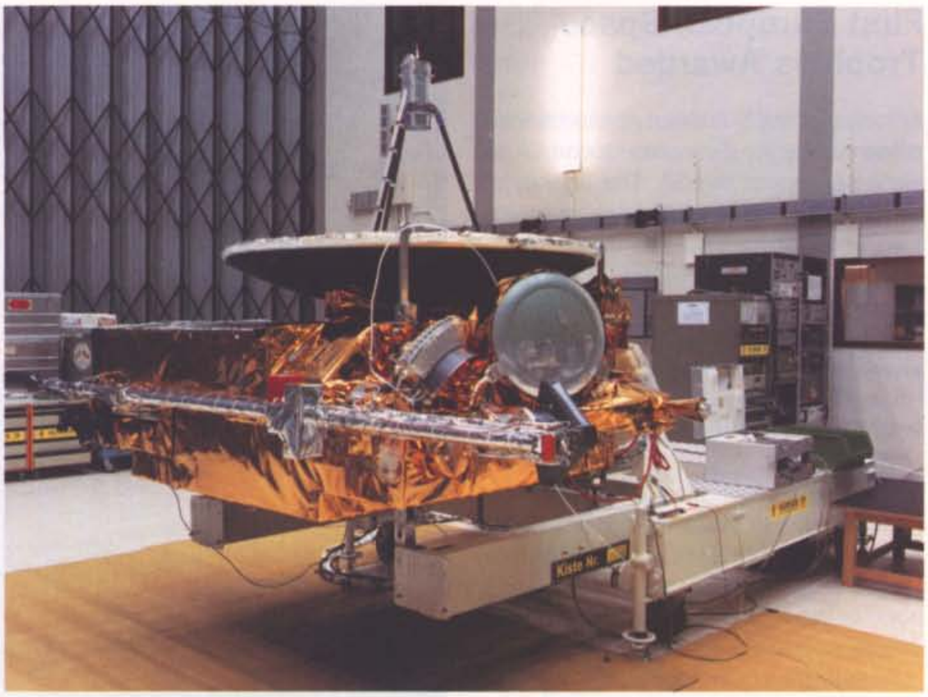
Ulysses' Final Testing at ESTEC

The Ulysses spacecraft has been undergoing a series of tests at ESTEC, prior to shipment to the United States for its Shuttle launch in October 1990.

Ten days of tests in ESTEC's Heat Balance Facility (HBF-3), simulating the deep vacuum and low temperatures of the deep space environment, began on 15 November last year. The spacecraft then underwent Integrated System and Operations Compatibility Testing.

Ulysses is currently (mid-January) in the second phase of Mission Operations System Tests with ESOC, the Agency's operations centre in Darmstadt, Germany. Spin-Balance and Mechanical Property Tests will be conducted in the week beginning 22 January. After final calibrations in the first week of February, the spacecraft will be ready for shipment to the Cape Canaveral launch site on 17 May.

A special issue of the ESA Bulletin on the Ulysses mission will be published in August 1990.



Ulysses undergoing operational testing at ESTEC, Noordwijk, The Netherlands (November 1989)

The Ulysses spacecraft en route to the Heat Balance Facility (HBF-3) in ESTEC, Noordwijk, The Netherlands (November 1989)

Ariane's Tenth Anniversary

The first Ariane launch took place at 17:14:38 UT on 24 December 1979 and was a complete success. Ten years on, the total number of launches has now reached 34 (just 4 of which have run into difficulties). Under the auspices of ESA, which delegated industrial responsibility for the launcher to CNES, the programme has achieved all its objectives, the main one being to give Europe its own space transportation system.

On the occasion of Ariane's tenth anniversary a celebratory dinner, hosted jointly by ESA and CNES, was held on 15 December 1989 at Paris La Défense.

The Arianespace company, which took over the marketing of the launcher at ESA's request, currently has a further 74 launch service contracts on its books.

Hermes Crew Escape System Selected

At the end of an intensive study programme, ESA and CNES have presented to the ESA Member States their choice of escape system for the crew of the Hermes spaceplane – an advanced ejectable-seat concept.

Crew safety is obviously a key issue in the design and development of the spaceplane. The Hermes crew of three will play a crucial role in tending the scientific experiments on the Columbus free-flying laboratory, as well as undertaking maintenance work.

During the Programme's detailed definition phase several crew-safety options have been studied, including several ejectable seats and two concepts entailing the ejection of the full front cabin. The latter turned out to be more difficult than expected, requiring a complex development and qualification programme. Ejectable seats, on the other hand, have long been built and tested by industry, primarily for high-speed aircraft.

The concept selected will now be defined in more detail by industry, in preparation for inclusion in the second phase of the Hermes development programme.

First European Space Trophies Awarded

Among the first European space trophies presented by the European Space Club were two awards to ESA. The Agency's Director General, Prof. R. Lüst, received the award 'Space European of the Year'. The scientific team of ESA's Hipparcos Programme was given the 'Leading Scientific Issue of the Space Year' award, which was accepted by Prof. Roger Bonnet, the Agency's Director of Scientific Programmes.

On behalf of the scientific team of the Agency's Hipparcos Programme, Prof. R. Bonnet, Director of Scientific Programmes, accepts the European space trophy for 'Leading Scientific Issue of the Space Year', presented by Prof. H. Curien, the French Minister for Research and Technology (Paris, La Défense, 16 November 1989)

The ceremony took place on 16 November 1989, following the first Apogee Dinner of the European Space Club, in Paris, La Défense. A total of five trophies were presented to individuals, groups and companies that had made outstanding contributions to the development of European space activities. The award 'Major European Space Project Manager of the Year' went to Mr Roger Vignelles, CNES Deputy Director General, Space Transportation Systems. 'Best marketing effort of the year' went to Arianespace, and the European association 'Youth and Space' received the 'Youth Prize of the Space Year'.

The second Apogee Dinner and presentation of the 1990 European Space Trophies will take place in Germany at the end of this year. It is to become an annual event, hosted by each of the member countries in turn, providing a forum for the space community to meet and to honour those who have contributed most to the future of European space endeavours.

Mayor of Frascati Visits ESTEC and Noordwijk

On 20 November 1989 the Mayor of Frascati (I), Dr G. Romani, and his deputy, Dr F. Posa, paid a visit to ESTEC. A tour of the facilities included a comprehensive introduction to the work taking place at the establishment.

The following day the Mayor was taken on an extensive tour of the Noordwijk area, culminating in a meeting with the Noordwijk municipal authorities. The purpose of the visit was to strengthen relations between the communities of Noordwijk, host to ESTEC, and Frascati, the host town of ESRIN, ESA's information retrieval centre.

From right to left: Mr G. Giorgi-Alberti, Head of Administration at ESRIN, Dr G. Romani, Mayor of Frascati and his deputy, Dr F. Posa, and Mr F. Bonacina of ESTEC's Public Relations Office

Hipparcos Commissioned

Hipparcos has now been fully commissioned and has begun its routine scanning of the sky. Since the start of the revised mission on 4 September 1989 operations have proceeded smoothly and, due to the intensive work of the ESOC Operations Team and the Hipparcos Project Team, the outlook for the mission is far better than first appeared in the days following the occurrence of the apogee boost motor firing problem.

On 1 November the satellite's spin axis was manoeuvred from the Sun-pointing direction to an angle of about 43° from the Sun, around which the spin axis will slowly gyrate throughout the satellite's lifetime. This means that the satellite is now following its nominal scanning law (its predefined scanning of the celestial sphere). Further payload calibrations were carried out between 1–25 November and, after an accuracy review with representatives of the Hipparcos Science Team and the Data Reduction Consortia, the nominal mission commenced on 26 November 1989.

Observations are now proceeding routinely. More than 10 000 stars are observed each day, along with some minor planets, and even Venus has already been observed.

Ground station coverage is being supplied by a combination of the Odenwald (Germany), Perth (Australia) and Kourou ground stations, and the satellite is now being tracked for about 80% of the time, with reliable scientific data being acquired 50-60% of the time. An arrangement has been made to use a NASA ground station at Goldstone, California, from where the data will be transmitted to ESOC via three satellite links. Use of this fourth station will begin in March, increasing coverage to 93%, with valid data acquisition for perhaps 70% of the time.

The most critical parameter in assessing the scientific accuracy of the revised mission is the satellite's expected lifetime, which will be determined by the degradation of the solar panels due to the high-energy proton radiation environment in the present highly elliptical orbit. Estimates now suggest that a total lifetime of about 30 months may be achievable.

A further complication of the present orbit is that the satellite will have to endure much longer periods of eclipse than the 72-minute maximum originally expected. The first such extended eclipse period will be encountered around February/March and plans are being formulated to ensure the survival of the satellite and to maximise data acquisition and engineering checkout during this eclipse.

The scientific data (1 – 2 gigabits per day) are now being routinely stored on magnetic tape at the ESOC ground station and then transmitted to the European scientific institutes responsible for data reduction. It is already evident that the payload performance in all areas is extremely good, with the instrumental parameters and (along-scan) star positions already being determined to milli-arcsecond precision.

Meanwhile the Hipparcos Enquiry Board, commissioned by ESA's Director General, and chaired by an independent expert, has completed its preliminary report. Board members include a number of European specialists in solid propulsion and electrical systems, as well as representatives of the national space and other government agencies. Their preliminary conclusion is that the most probable cause of failure lies in the pyrotechnic chains. The Board has now recommended a test programme, likely to last several months, prior to issuing its final report.

M.A.C. Perryman, Hipparcos Project Scientist & H. Hassan, Project Manager

Main control room at ESOC, Darmstadt

Ulf Merbold IML-1 Payload Specialist

ESA astronaut Ulf Merbold has been named as payload specialist for the first International Micrograviity Mission (IML-1) that will be flown on the Space Shuttle Columbia in December 1990.

Dr Merbold was born in Greiz, Germany, in 1941, and received his doctorate in science from the University of Stuttgart in 1976. Prior to joining ESA he worked as a solid-state physicist at the Max-Planck Institute for Metals Research. As Mission Specialist on the first Spacelab in November 1983, Dr Merbold made history as the first non-American to fly on a US manned mission.

IML-1 is the first of a series of microgravity missions to perform life sciences and materials investigations using the Spacelab module. Included in the 15 experiments aboard IML-1 are two ESA experiments, Biorack and the Critical Point Facility.

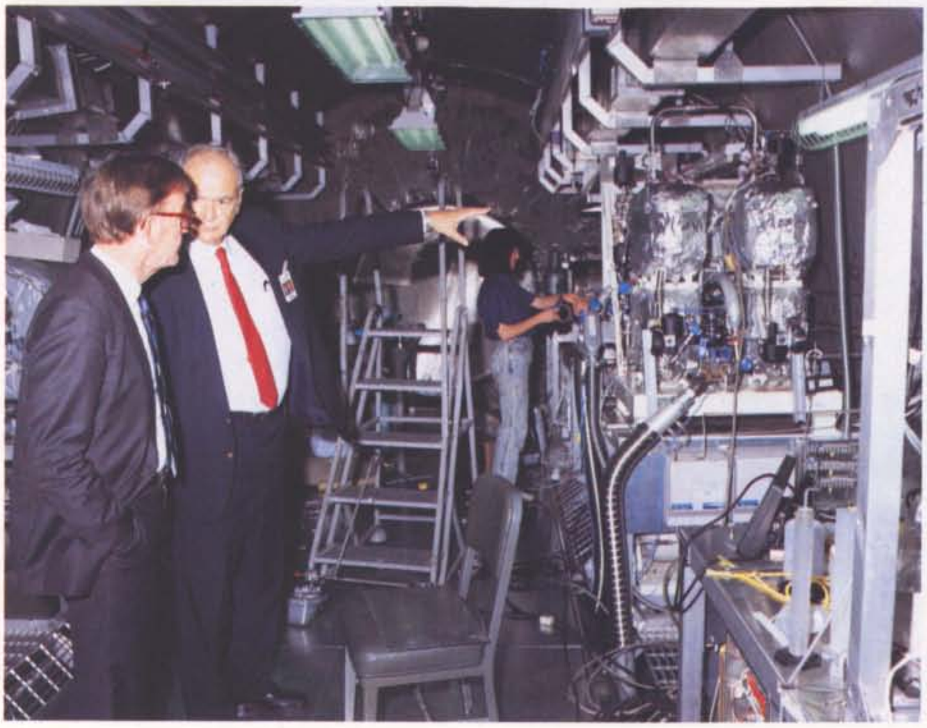
ESA' Director General, Prof. R. Lüst, visiting Marshall Space Flight Center (MSFC) on 31 October 1989. From left to right: Mr G. Hopson, Manager of the MSFC Space Station Projects Office, Mr I. Pryke, Head of ESA's Washington Office, Prof. R. Lüst, and Mr C. Gregg, Deputy Manager of the MSFC Space Station Projects Office.

DG Visits Marshall Space Flight Center

During a visit to the United States in October last year, to deliver the annual A.W. Quick/B.H. Goethert lecture at the University of Tennessee, the Agency's Director General, Prof. R. Lüst, took the opportunity to visit NASA's Marshall Space Flight Center (MSFC). As well as meeting the Director of MSFC, Mr J-L. Lee, Prof. Lüst was given a briefing on the Center's activities and a tour of the various laboratories and other facilities.

In the course of the tour Prof. Lüst had the opportunity to inspect a full-scale mock-up of the International Space Station manned base. He also spent time in discussion with MSFC staff on the forthcoming Spacelab missions for which the Center is responsible.

Prof. Lüst was accompanied on his visit by Mr I. Pryke, Head of ESA's Washington Office.



Prof. R. Lüst being shown around the Space Station mock-up by Mr C. Gregg (centre), Deputy Manager of the MSFC Space Station Projects Office

ESA-IRS at the 13th International Online Information Meeting

For the 13th consecutive year ESA-IRS, the Agency's Information Retrieval Service, was among the exhibitors at the International Online Information Meeting, held every year in London during the first half of December and the most important event in the world of information providers and users. The 1989 Meeting had a record attendance of over 6 850 visitors, with 167 exhibitors. The ESA-IRS stand (pictured below) was once again a focal point for informal meetings, information exchange and hands-on demonstration.

This year ESA-IRS received an award for its 'outstanding achievements as a distributor in 1989', a tribute to the difficult task of marketing its services throughout the ESA Member States.

Located at ESRIN, the Agency's establishment in Frascati, Italy, ESA-IRS offers online data collections mainly in the scientific/technological fields but also on business, administration, finance etc, catering for the information needs of managers as well as project scientists, researchers and engineers.

The ESA-IRS stand at the 13th International Online Information Meeting

Seven Passengers on Ariane V35

The first Ariane flight of the year was launched in the early hours of Monday 22 January. Lift-off took place at 02:35 h European time, at the very beginning of the launch window. The launch was of particular interest because it is the first time an Ariane-4 rocket has been launched without strap-on boosters and with the Ariane Structure for Auxiliary Payloads (ASAP). This allowed flight V35 to carry no less than seven satellites, all of which have been safely injected into polar orbit.

The main passenger was Spot-2, the second in a series of French Earth observation satellites, developed by CNES for Spot Image.

The first auxiliary payload comprised six very small satellites, namely UoSAT-D and -E, and Microsat-A, -B, -C and -D. UoSAT-D and -E are carrying experimental communications and technology payloads for the University of Surrey. Two of the experiments aboard UoSAT-E were developed at ESTEC, within the framework of the In-Orbit Technology Demonstration Programme (TDP), namely the Gallium-Arsenide Solar-Array Panel and the Transputer and Single-Event Upset Experiment.

The Microsat series was developed by Amsat for amateur radio communications (A and D) and educational purposes (B and C).

UoSAT-E

Corrigendum

In an article in ESA Bulletin No. 60, entitled 'ESA Support for the Italian SAX Astronomy Satellite Mission', there was an editorial error of omission. Regrettably, the article failed to mention the responsibility of Laben SpA, Italy, for the following aspects of the SAX Programme:

- Payloads and related test equipment
- On-board data handling
- Checkout
- Ground station.

Inter-mountain Laser Communications Experiment

ESTEC's Instrument Technology Division has just taken part in a joint laser diode experiment between two mountain observatories on the islands of Tenerife and La Palma in the Canary Islands. The test was performed in collaboration with the 'Universidad Politecnica de Cataluna', with the support of the 'Instituto de Astrofisica de Canarias'. It involved the establishment of a one-way link between the two mountain-top observatories located at an altitude of 2400 m. The link was required to cover a distance of 145 km, 110 km of which was over the sea. Semiconductor laser diodes with powers as low as 10 mW were used in conjunction with small-diameter telescopes.

The test was in support of the Semiconductor Laser Intersatellite Experiment (SILEX) that will be flown on ESA's Payload and Spacecraft Development and Experimentation (PSDE) Programme Technology Mission (formerly Sat-2). The objective of the test was to characterise the atmospheric conditions at this location and establish its suitability as a site for an optical ground station and for testing future satellite optical communication equipment.

The SILEX experiment was described in more detail in Bulletin No. 54, pp. 62–65.

Receiver telescope on La Palma, Canary Islands

ESTEC Hosts Joint European SPAN/ESIS Users' Meeting

Around 80 scientists and computer engineers from each of the ESA Member States and the USA attended a joint European Space Physics Analysis Network (SPAN)/European Space Information System (ESIS) meeting held in ESTEC's new conference centre from 27–29 November 1989.

The meeting was divided into a scientific networking session and an applications session.

Various aspects of networking were presented, including the current status of SPAN in the USA and the High Energy Physics Network, the Reseaux Associés pour la Recherche Européenne, the International X.25 Interconnect, and ESA's own ESANET in Europe. Status reports on networking in each of the Member States were also given. Other topics included security and future X.400/X.500 applications.

The applications session covered various scientific databases and associated activities, both in Europe and the USA. ESA's own Space Information System ESIS and the associated databases, Exosat, IUE, and the Space Telescope European Coordinating Facility, as well as the proposed Cluster data centre were described. One of the highlights of the meeting was a live, on-line, data-analysis session using first the Exosat database in ESTEC, then using the ESIS user shell to access scientific abstracts from IRS, and scientific data from the Space and Environment Laboratory database in Boulder, Colorado.

American applications were described by representatives from NASA's Goddard Space Flight Center and Jet Propulsion Laboratory.

T. Sanderson
ESA Space Science Department

Participants of the joint SPAN/ESIS meeting held in the new conference centre at ESTEC, Noordwijk, The Netherlands, 27–29 November 1989

Tribute to Dr. Ernst Trendelenburg

It is with much sadness that we have to record the death, on 4 November 1989, of Ernst Trendelenburg, one of the earliest and longest serving of Europe's space-science pioneers.

Dr. Trendelenburg took up duty at the end of 1964 as Director of ESRO's European Space Research Laboratory (ESLAB), which was to form the base for the project scientists liaising between national groups flying experiments on the organisation's early satellites and sounding rockets and the engineering groups at ESTEC. He was instrumental in the setting up of a host laboratory that was to become a temporary home for young visiting scientists from all the ESRO Member States, who came to acquire skills in the then emerging fields of space research that were still lacking at their parent institutes.

The fruits of Dr. Trendelenburg's initiatives were soon manifested in a quick succession of highly successful sounding-rocket and satellite-based scientific missions. ESRO's first scientific satellite was put into orbit in May 1968 (ESRO-2).

In 1975, when ESA came into being, Ernst Trendelenburg was appointed its first Director of Scientific and Meteorological Programmes, a post which he was to hold until his retirement from the Agency in 1983.

Ernst Trendelenburg will long be remembered in the space-science communities not only in the ESA Member States, but also around the World, for as the Agency's Director of Science he forged cooperative links with space scientists in many countries, including the Soviet Union. The culmination of the latter was reflected on the World's television screens in March 1986, as we watched Giotto pass within 600 km of the nucleus of Halley's Comet, helped by data provided by the Soviets from their two Vega spacecraft, which had passed the Comet some days earlier.

Not least, Ernst Trendelenburg will be remembered by his many ESRO and ESA contemporaries and by his staff, whose scientific thinking he shaped and whose careers he guided. The accompanying selection of tributes reflect the high regard in which we all held him.

We mourn him, and we offer his family our deepest condolences. Those of us who knew him will live with personal memories of him which we treasure, and ESA will always be thankful that Ernst Trendelenburg was there to play a major role in making sure that Europe is the force in space that it is today.

R. Lüst

Dr. E.A. Trendelenburg

Ernst Trendelenburg was an intellectual, an intellectual aristocrat, with the greatest contempt for mediocrity and conformism, the greatest enjoyment of provocation.

The seduction of the excess, the thrill of the extreme, the amusement of the paradox, the noise of sarcasm, were just some of the motivations of a rich personality which derived its major strength from a profound humanity and a sparkling intelligence.

He was among the few in the sixties to realise that a great era was starting for European scientists in the domain of space research, and he was from then on one of the strongest defenders of the interests of the European community and a great encouragement for their ambitions. The conflict with the establishment, whether in Noordwijk, in Paris or Washington, was his power-supply for driving his creative work. He showed us all that the establishment could indeed be challenged and glasnost and perestroika anticipated.

We feel a great gratitude to him, and also a great sorrow that he could not be in Berlin on 9 November 1989.

M. Trella

Ernst Trendelenburg was the best sort of boss one could have. He made clear delegations of responsibility to his staff; he backed up their actions with support at his level when necessary; he was available to his staff to discuss problems; he expected his staff to argue with him — as fiercely and as long as necessary — in order to get to the heart of an issue and reach a conclusion

One of my most vivid memories is of his unique rendering of 'When the Saints Come Marching In', accompanied by an excellent Intourist jazz/rock band playing late into the night in Samarkand after an official banquet, after one of the regular coordination meetings with IKI.

G. Haskell

I started working for ESLAB (later Space Science Department) in October 1966. The day I took up duty, Ernst Trendelenburg informed me that I would be responsible for the scientific part of the ESRO sounding-rocket programme, and then added: 'by the way, you will also have to be Project Scientist for the TD-2 satellite, because we are short of people'. All this represented quite a challenge for a young scientist with limited experience!

Ernst Trendelenburg delegated responsibility and trusted people to solve the problems. He would help with the big problems, but did not want to be bothered with minor details.

Some people may have found him unapproachable, but his staff did not think so. He could be approached, and he would listen and also — if necessary — admit his own mistakes.

Ernst Trendelenburg was a fighter for European space science, and he also was a European in his thinking and when talking about life in general. He loved to joke about the oddities of the different European characters, but this did not hinder him in sitting down and establishing good contacts with his European staff and the many international visitors.

We who worked with him from the early years of ESRO will remember him both as a good boss and a good European.

A. Pedersen

The first time I met Ernst Trendelenburg was in 1974 during an ESLAB Symposium in Frascati. Purely by chance, we were seated next to each other at dinner. I remember that I was very impressed by this personality, and in particular by his style. He had a very simple but effective way of classifying people. Once you had demonstrated that you deserved his confidence, his support for your initiatives was unlimited.

For me he was not only a good boss, but also a good friend.

H. Olthof

I joined ESLAB in 1967 at the age of 26. Trendelenburg's approach with such young staff was to throw them into the deep end to see if they could swim. Once you had proved your worth, Trendelenburg was your ally and mentor and I, like many others in the Science Directorate, owe him a great debt.

He was keen to make ESLAB/SSD a place of scientific excellence with staff in the mainstream of project and research work. In the early days, there was a great pressure against ESLAB/SSD taking flight opportunities away from national groups. He always stressed the collaborative nature of our work to avoid this ever becoming a real issue.

In large part it was Trendelenburg's single-mindedness that put Giotto into the ESA Programme almost at the last minute, when NASA pulled out of a joint mission that had been under study for some time.

It was also Trendelenburg who began forging links with the Soviets from the early 1970s, through contact with their Space Research Institute (IKI). No doubt the new ESA — Soviet Agreement owes much to 'Perestroika' and the changes taking place in the Soviet Union, but Trendelenburg helped plant the seed many years ago.

Personally, I shall remember and be grateful for his professional support and friendship. He had a certain disregard for authority, but Trendelenburg always appeared as a 'leader' to his troops, though he would have hated to have been thought of as a 'manager'.

B.G. Taylor

Dr. Trendelenburg was a man of character. Among his many qualities, I would like to mention in particular his extraordinary ability to judge people for what they were, and not for what they believed themselves to be. His initial judgement was so sound that he rarely had to modify it, but on the rare occasions when it was necessary he had a very boss-like way to reluctantly admit that he might have misjudged. That was part of his intellectual honesty, another pleasant trait of his personality.

M. Delahais

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

In Orbit / En orbite

	PROJECT (1990–1996)	COMMENTS
SCIENT. PROG.	IUE	
SCIENT. PROG.	HIPPARCOS	LAUNCHED 9 AUGUST 1989
APPLICATIONS PROGRAMME	MARECS-A	LEASED TO INMARSAT FOR 10 YEARS
APPLICATIONS PROGRAMME	MARECS-B2	LEASED TO INMARSAT FOR 10 YEARS
APPLICATIONS PROGRAMME	METEOSAT-3	LIFETIME 3 YEARS
APPLICATIONS PROGRAMME	METEOSAT-4 (MOP-1)	LIFETIME 5 YEARS
APPLICATIONS PROGRAMME	ECS-1	LIFETIME 7 YEARS
APPLICATIONS PROGRAMME	ECS-2	LIFETIME 7 YEARS
APPLICATIONS PROGRAMME	ECS-4	LIFETIME 7 YEARS
APPLICATIONS PROGRAMME	ECS-5	LIFETIME 7 YEARS
APPLICATIONS PROGRAMME	OLYMPUS-1	LAUNCHED 12 JULY 1989

Under Development / En cours de réalisation

	PROJECT (1990–1996)		COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
SCIENTIFIC PROGRAMME	ULYSSES		LAUNCH OCTOBER 1990
SCIENTIFIC PROGRAMME	SOLAR TERRESTRIAL SCIENCE PROG. (STSP)		LAUNCHES: SOHO MARCH 1995 CLUSTER DEC. 1995
SCIENTIFIC PROGRAMME	ISO		LIFETIME 1.5 YEARS
COMMS PROG.	DATA-RELAY SATELLITE (DRS)		SYSTEM OPERATIONAL 1996
COMMS PROG.	PSDE TECH. MISSION		READY FOR LAUNCH BEGIN 1994
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	ERS-1		OPERATIONAL 2 YEARS
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	EARTH OBS. PREPAR. PROG. (EOPP)		
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	METEOSAT OPS PROG.	MOP-2, MOP-3	MOP-1 LAUNCHED MARCH 1989
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	MICROGRAVITY	IML-1, D2, IML-2	
SPACE STI. & PLATF. PROG.	EURECA		LAUNCH MAY 1991
SPACE STI. & PLATF. PROG.	COLUMBUS	PHASE 1, PHASE 2	3 YEAR INITIAL DEVELOPMENT PHASE
SPACE TRANSPORT. PROG.	ARIANE-4	V37, V38/39/40, 41/42, 43	OPERATIONAL UNTIL END 1998
SPACE TRANSPORT. PROG.	ARIANE-5		FIRST FLIGHT APRIL 1995
SPACE TRANSPORT. PROG.	HERMES		3 YEAR INITIAL DEVELOPMENT PHASE
TECH. PROG.	IN-ORBIT TECHNOL. DEMO. PROG. (PH-1)		SEVERAL DIFFERENT CARRIERS USED

= DEFINITION PHASE · > PREPARATORY PHASE · ▨ MAIN DEVELOPMENT PHASE · ▪ STORAGE · HARDWARE DELIVERIES

~ INTEGRATION · LAUNCH/READY FOR LAUNCH · ▪ OPERATIONS · - ADDITIONAL LIFE POSSIBLE · RETRIEVAL

Olympus

Tous les sous-systèmes et charges utiles du satellite Olympus-1 continuent à bien fonctionner depuis son lancement de Kourou, le 12 juillet 1989, sur le vol Ariane V-32.

Les essais de recette de la charge utile ont été menés à bonne fin et suivis d'un programme détaillé d'essais en orbite (IOT). Ce programme de vérification a fait intervenir l'ensemble du matériel et du logiciel IOT des stations sol. Il a confirmé le bon fonctionnement de tous les éléments en tant que système global; en fait, les résultats ont montré que les caractéristiques de fonctionnement du satellite étaient supérieures aux spécifications dans presque tous les domaines.

La conduite opérationnelle du satellite a été officiellement transférée le 14 octobre 1989 au personnel de Telespazio, au Centre de contrôle des opérations (OCC) de Fucino (Italie). Pendant les trois mois précédents, le satellite était resté sous l'autorité de l'ESOC (Darmstadt).

La phase opérationnelle a commencé comme prévu le 16 octobre et le satellite a été mis à la disposition des utilisateurs. Pendant la première semaine, les utilisateurs y ont eu accès les uns après les autres jusqu'à ce qu'ils puissent tous travailler simultanément avec les différentes charges utiles.

Télescope spatial Hubble

Le lancement du Télescope spatial Hubble (HST) a été reporté du 26 mars au 18 avril en raison de difficultées provenant de la Navette. Le véhicule spatial a été transporté de Californie au Centre spatial Kennedy le 4 octobre 1989. Après le transport, la chambre de prise de vues pour objets faibles (FOC) a subi des essais de fonctionnement complets qui n'ont révélé aucune anomalie. Un essai système entre le HST et le secteur au sol (GST8) a également été mené en impliquant le principal instrument, la FOC. Des séances d'entraînement à la mission pour le lancement du HST et du déploiement des réseaux solaires ont eu lieu. Quelques défaillances des matériels du HST, dont la chambre de prises de vues planétaires à grand champ et le système de commande des instruments et de traitement des données, ont été constatées. Celles-ci seront corrigées avant d'intégrer les instruments sur le site de lancement.

Les travaux sur la deuxième série de panneaux solaires se poursuivent. Ils sont destinés à une fonction de soutien de la mission de maintenance du HST prévue six ans après le lancement.

A TDS-4 ground station being installed at the Polytechnic of the South-West, Plymouth, UK

Installation d'une station sol TDS-4 à l'Institut polytechnique de South-West, Plymouth, R-U

Ulysse

Les activités du projet Ulysse se déroulent désormais à un rythme soutenu. Le modèle de vol du véhicule spatial a été retiré de son lieu d'entreposage pour que l'on procède à la réintégration de l'ensemble des expériences et sous-systèmes. Les essais d'ambiance en vue de sa nouvelle qualification pour le lancement sont presque terminés. Aucun problème sérieux ne s'est posé et le programme continue à se dérouler conformément au calendrier.

Les prochaines étapes consisteront à mener à bien les essais de compatibilité des liaisons de télécommande et de télémesure des stations sol avec le véhicule spatial et à établir les propriétés de masse et l'équilibrage définitifs, ce qui sera fait d'ici début février. Il restera ensuite une brève période-tampon avant le démarrage de la campagne de lancement en mai.

La préparation de la Navette et des étages supérieurs se poursuit elle aussi normalement et on ne prévoit aucune difficulté pour l'intégration des divers éléments, préalablement au lancement le 5 octobre 1990.

STSP

Les propositions industrielles relatives à Soho et Cluster ont été reçues et évaluées conformément au calendrier. La réunion finale de la Commission d'évaluation des offres a eu lieu fin juillet 1989.

Les propositions d'approvisionnement, attribuant à Matra la maîtrise d'oeuvre de Soho et à Dornier celle de Cluster, ont été approuvées par le Comité de la politique industrielle (IPC) de l'Agence fin septembre 1989, en temps utile pour la réunion de lancement des travaux prévue début octobre 1989.

Certaines activités de pré-phase B ont été conduites sur Soho et Cluster; elles

Olympus

All subsystems and payloads of the Olympus-1 satellite have continued to perform well since its successful launch from Kourou on 12 July 1989 on Ariane V-32.

The payload-commissioning tests were completed successfully and were followed by the detailed In-Orbit Test (IOT) programme. This measurement programme involved all the IOT earth station hardware and software. It confirmed that all elements were working correctly as an overall system and in fact the results showed that the satellite performance was better than specified in nearly all areas.

Operational control of the satellite was formally handed over to Telespazio personnel at the Operations Control Centre (OCC) at Fucino, Italy, on 14 October 1989. For the ninety days prior to this the satellite had been controlled from ESOC, Darmstadt.

The operational phase began on 16 October 1989 as planned, and the satellite was made available to users. During the first week the users were introduced in sequence until all payloads were being accessed in parallel.

A TDS-4 ground station has been handed over to the Polytechnic of the South West, Plymouth, UK, for use in tele-education.

Hubble Space Telescope

The Hubble Space Telecope launch date has been delayed from 26 March to 18 April due to Shuttle problems. The spacecraft was transported from California to Kennedy Space Center on 4 October 1989. After the journey the Faint Object Camera (FOC) underwent a full functional test and no changes in performance were recorded. A system test between the HST and the Ground System (GST-8) has also been conducted, with the FOC the main instrument involved. A series of mission-training sessions for the HST launch and solar-array deployment has also been conducted. There are some hardware shortages on the HST, including the Wide-Field Planetary Camera and Instrument Command and Data-Handling System. These are being reworked and will be fitted at the launch site.

Work continues on the second set of solar arrays which are being built to support the HST maintenance mission, planned for six years after launch.

Ulysses

Events on the Ulysses Project are now moving swiftly. The flight spacecraft has been taken from storage and all the experiments and subsystems reintegrated. It has now almost completed environmental testing to recertify it for launch. No significant problems have been encountered and the programme is continuing on schedule.

The next major events are the completion of proving compatibility of the ground-station command and telemetry links with the spacecraft and the determination of final mass properties and balancing. These will be completed by early February, after which there is a short buffer period prior to the start of the launch campaign in May.

Preparation of the Shuttle and the Upper-Stage rockets is also proceeding normally, and no difficulties are anticipated in bringing together the various elements for a successful launch on 5 October 1990.

STSP

The industrial proposals for Soho and Cluster were received and evaluated on schedule. The final meeting of the Tender Evaluation Board took place at the end of July 1989.

The procurement proposals, with Matra as the Prime Contractor for Soho and Dornier as the Prime Contractor for Cluster, were approved by the Agency's Industrial Policy Committee (IPC) in late September 1989, in time for the intended kick-off in early October 1989. Some pre-Phase B activities have been carried out for both Soho and Cluster to allow a better definition of system-critical areas, including payload interfaces.

Soho

In the process of formalisation of the ESA/NASA Agreements, there has been a delay in formal confirmation of the Memorandum of Understanding (MOU). In addition, NASA has experienced some problems in formalising its contribution to the Soho payload as scheduled.

The start of the Soho Phase-B was therefore delayed to 1 December 1989, by which time these difficulties had been resolved.

The pre-Phase B activities with Matra were expanded during the interim period with a view to continuing the system activities necessary for payload-interface definition.

A series of Experiment Conceptual Design Reviews took place in the period April—July 1989. In the light of these reviews, it is clear that the mass and power resources requested by the Experimenters cannot be accommodated in full, and judgements will have to be made on a case-by-case basis.

Cluster

Following approval by the IPC of the Phase-B Contract Proposal, the formal kick-off meeting with Dornier took place at ESTEC on 2–5 October 1989. With only a few minor points still to be clarified, the kick-off meeting was deemed successful and the contract has been signed.

The intention is still to synchronise Soho and Cluster industrial development. In order to accommodate the two-month postponement of the Soho Phase-B kick-off, the Cluster Phase-B will be extended by two months. Various options are being studied with the objective of maintaining the Cluster launch-readiness date of December 1995.

Spacecraft design is continuing in Industry, with major subsystem contracts awarded to Contraves for structure, Fokker for thermal control, BAe for attitude-and-orbit control and propulsion, CRI for electrical ground-support equipment and FIAR for power. The industrial team is expected to be complete by September 1990.

During the summer of 1989 the Experiment Conceptual Design Reviews (ECDRs) were held. The experiment interface definition has progressed significantly and has resulted in an updated issue of the Experiment Interface Documents for the Principal *visaient à améliorer la définition de secteurs critiques du système, notamment les interfaces de la charge utile.*

Soho
Certaines difficultés rencontrées au cours de la mise au point définitive des Accords ESA/NASA ont retardé la confirmation officielle du Mémorandum d'Accord (MOU). En outre, la NASA a éprouvé quelques dificultés à arrêter définitivement, dans les délais prévus, sa contribution à la charge utile de Soho.

Le démarrage de la phase-B de Soho a donc été reporté au 1er décembre 1989, date à laquelle ces difficultés devraient être résolues.

Chez Matra, les activités de pré-phase B se sont prolongées dans l'intervalle afin de poursuivre les activités système nécessaires à la définition des interfaces de la charge utile.

Les Revues de définition conceptuelle des expériences ont eu lieu d'avril à juillet 1989. Il en ressort que les ressources en matière de masse et d'énergie demandées par les expérimentateurs ne peuvent être entièrement satisfaites et qu'il faudra faire des arbitrages cas par cas.

Cluster
A la suite de l'approbation de la proposition de contrat de phase-B par l'IPC, la réunion officielle de lancement des travaux a eu lieu avec Dornier à l'ESTEC du 2 au 5 octobre 1989. Seules quelques questions mineures restant à résoudre, la réunion de démarrage des travaux a été jugée concluante et le contrat signé.

Il est toujours prévu de synchroniser les travaux industriels de Soho et de Cluster. Pour compenser le report de deux mois du démarrage de la phase-B de Soho, la phase-B de Cluster sera prolongée de deux mois. Plusieurs solutions sont à l'étude pour que la date d'aptitude au lancement de Cluster soit maintenue en décembre 1995.

La conception du véhicule spatial se poursuit dans l'industrie, les principaux travaux de sous-systèmes étant confiés à Contraves pour la structure, Fokker pour la régulation thermique, BAe pour les systèmes de correction d'attitude et d'orbite et de propulsion, CRI pour le matériel électrique de soutien au sol, et FIAR pour les systèmes d'énergie. L'équipe industrielle devrait être mise en place en septembre 1990.

Les Revues de définition conceptuelle des expériences (ECDR) ont eu lieu au cours de l'été 1989. La définition des interfaces des expériences a beaucoup progressé et a donné lieu à la mise à jour de documents d'interface des expériences à l'intention des chercheurs principaux (PI) et des industriels. A la suite d'entretiens techniques détaillés avec les PI, il a été convenu d'une attribution révisée des ressources en masse et en énergie; bien que les demandes soient supérieures à la formule de référence interne, ce compromis est acceptale pour l'ensemble du système. Il faudra veiller au suivi et à la maîtrise des ressources pendant toutes les phases du projet, car les marges sont peu importantes.

A la troisième réunion de l'Equipe de travail scientifique tenue du 6 au 8 novembre 1989, IKI/Intercosmos a présenté les aspects scientifiques et techniques du projet Regatta. L'ESA et IKI/Intercosmos poursuivent leurs entretiens sur les possibilités d'associer au plan scientifique les missions Cluster et Regatta. L'atelier prévu à Graz (Autriche) du 20 au 22 février 1990 portera sur la définition des objectifs scientifiques de la mission coordonnée.

Les prochaines grandes étapes du projet Cluster sont les suivantes: Revue des impératifs système à la fin de la Phase-B, fin avril 1990, et Revues intermédiaires de conception des expériences pour chaque expérience, au cours de l'été.

ISO

Les premiers éléments du module de charge utile (cryostat à l'hélium liquide) et du module de service ont été intégrés. Le module de charge utile a été fermé et mis sous vide, prêt à être rempli d'hélium liquide. Les essais de charge statique sur la structure du module de service ont eu lieu avec succès. Les deux modules subiront des tests mécaniques et thermiques en parallèle durant le premier semestre 1990.

Les essais du montage sur table des sous-systèmes électriques sont en grande partie terminés et l'autorisation de fabriquer les unités de qualification a été donnée. Des efforts particuliers sont faits pour accélérer les travaux sur le sous-système de commande d'orientation pour garantir sa livraison dans les délais.

Comme il est prévu de mener en parallèle les essais thermiques du module de service et du module de charge utile, on procédera aux essais de compatibilité des instruments scientifiques dans un autre cryostat réalisé dans le cadre d'un programme national allemand antérieur. Cette décision présente des avantages techniques, car elle permettra de disposer un an plus tôt des résultats des essais. L'avancement de la date de ces essais donne plus de souplesse au calendrier en vue d'un lancement fixé en mai 1993.

Les quatre groupes responsables des instruments scientifiques travaillent dans de bonnes conditions à la fabrication des modèles de qualification et d'identification, dont la livraison est prévu au milieu de l'année; l'équipe ISOPHOT étudie les moyens d'avancer la date de livraison du modèle de vol.

PSDE

Le Programme de développement et d'expérimentation de charges utiles et de véhicules spatiaux (PSDE) de l'Agence est un programme décennal qui vise à faire progresser la technologie européenne en matière de télécommunications.

La Mission de technologie (Sat-2)
Les études préparatoires de la Mission de technologie, auparavant dénommée Sat-2, sont terminées et la configuration de référence de la charge utile a été choisie.

Les charges utiles sont les suivantes:
- *une expérience de télécommunications optiques de relais de données par laser, dénommée SILEX, assurant une liaison à haut débit de données avec des satellites en orbite terrestre basse ou géostationnaire;*
- *une charge utile de relais de données en bande S à accès multiple et haut gain, conçue pour faire la démonstration de la technologie*

Investigators (PIs) and Industry. After detailed technical discussions with the PIs, a revised resource allocation of mass and power has been agreed which, although above the selection baseline, is acceptable for the overall system. Careful monitoring and control of resources will be required during all project phases, since these system margins are not substantial.

At the third Science Working Team Meeting on 6 – 8 November 1989, IKI/Intercosmos presented the scientific and engineering aspects of Regatta. Discussions are still continuing between ESA and IKI/Intercosmos on potential scientific involvement between the Cluster and Regatta missions. A Workshop will be held in Graz, Austria on 20 – 22 February 1990 to define the scientific objectives of the coordinated mission.

Module intégrée de la charge utile d'ISO (MBB)

Integrated ISO Payload Module at MBB

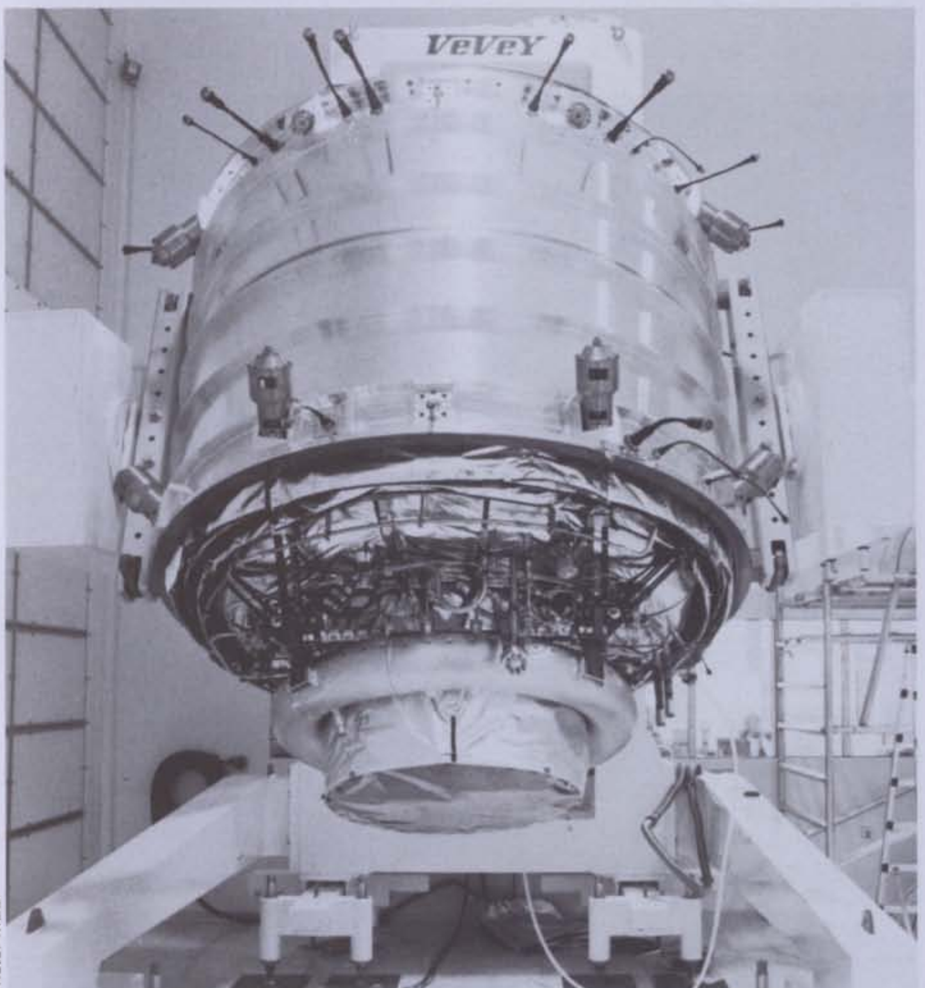


Photo: MBB

The next major milestones for Cluster are the spacecraft System Requirements Review at the end of Phase-B1 in the latter part of April 1990, and the Experiment Intermediate Design Reviews for each experiment during the summer.

ISO

The first hardware items for both the ISO Payload Module (liquid-helium cryostat) and the Service Module have been integrated. The Payload Module has been closed and evacuated, ready to be filled with liquid helium. The Service Module structure has been successfully static-load tested. Both modules will undergo parallel mechanical and thermal tests during the first half of 1990.

Breadboard testing of the electrical subsystems is largely complete, and most qualification units have been released for manufacture. A special effort is being made to accelerate work on the attitude-control subsystem to ensure that it will be delivered on time.

Now that thermal tests on the Service Module and the Payload Module will be performed in parallel, the scientific-instrument compatibility tests will be conducted in another cryostat from an earlier German national programme. This decision has technical advantages and it permits the test results to be available one year earlier. Advancing these tests makes for a healthy schedule for the planned May 1993 launch date.

The four scientific-instrument groups are making good progress in building their engineering-qualification models, which are due for delivery in the middle of the year. The ISOPHOT team is investigating means of advancing the delivery of its flight model.

PSDE

The Agency's Payload and Spacecraft Development and Experimentation (PSDE) Programme is a ten-year (1985 – 1995) programme designed to advance European communications technology.

The Technology Mission (Sat-2)
Preparatory studies of the Technology Mission, formerly known as Sat-2, have now been completed and a baseline payload configuration has been selected.

The payloads are:
- a laser optical data-relay communications experiment, SILEX, providing a high-data-rate link with satellites in low-Earth or geostationary orbit
- an S-band, high-gain, multiple-access data-relay payload, to demonstrate the technology needed by future data-relay services for medium data rates
- an advanced L-band land mobile services payload, using a large reflector to provide spot beams and test frequency re-use
- an on-board-processing payload for baseband switching of digital communications traffic between spot beams, as an optional payload
- a number of spacecraft-technology experiments, such as ion propulsion and nickel-hydrogen batteries, for improving platform capability.

Other experiments monitor critical payload interfaces and platform environment.

nécessaire aux futurs services de relais de données pour des débits de données moyens;

- *une charge utile de pointe en bande L pour le service mobile terrestre, avec un grand réflecteur capable d'émettre des faisceaux étroits et de travailler en réutilisation de fréquences;*
- *une charge utile de traitement à bord pour la commutation en bande de base du trafic de communications numériques entre faisceaux étroits, à titre de charge utile éventuelle;*
- *plusieurs expériences de technologie des véhicules spatiaux, comme la propulsion ionique et les piles nickel-hydrogène, afin d'améliorer la capacité des plates-formes.*

D'autres expériences sont conçues pour surveiller les interfaces critiques de charges utiles et l'environnement de la plate-forme.

Une charge utile de relais de données en ondes millimétriques, également à l'étude, en est au stade du montage sur table dans le cadre du Programme préparatoire.

A la suite du choix de Selenia Spazio (Italie) pour la maîtrise d'oeuvre du programme, la Phase-B2/1 de celui-ci a été engagée en juillet dernier. Cette phase comporte la définition détaillée et le montage sur table des charges utiles. SILEX a particulièrement progressé et la revue de conception préliminaire du système a eu lieu. Un modèle du système optique (banc d'essai système), intégré en montage sur table, fait l'objet d'essais de fonctionnement. Les études de configuration du satellite sont également terminées et, lorsqu'un choix aura été opéré entre les modèles de plate-forme Italsat et Eurostar, la Phase-B2/2 pourra commencer, sans doute vers le début de l'année.

Du fait que la Mission de technologie comporte un élément relais de données, une proposition de programme commun couvrant la Mission de technologie et le Système de relais de données a été soumise au Conseil qui l'a approuvée à sa session d'octobre 1989. On espère que la déclaration sera ouverte à la souscription en temps utile pour le démarrage de la Phase C/D de la Mission de technologie d'ici au troisième trimestre 1990 en vue d'un lancement en 1994.

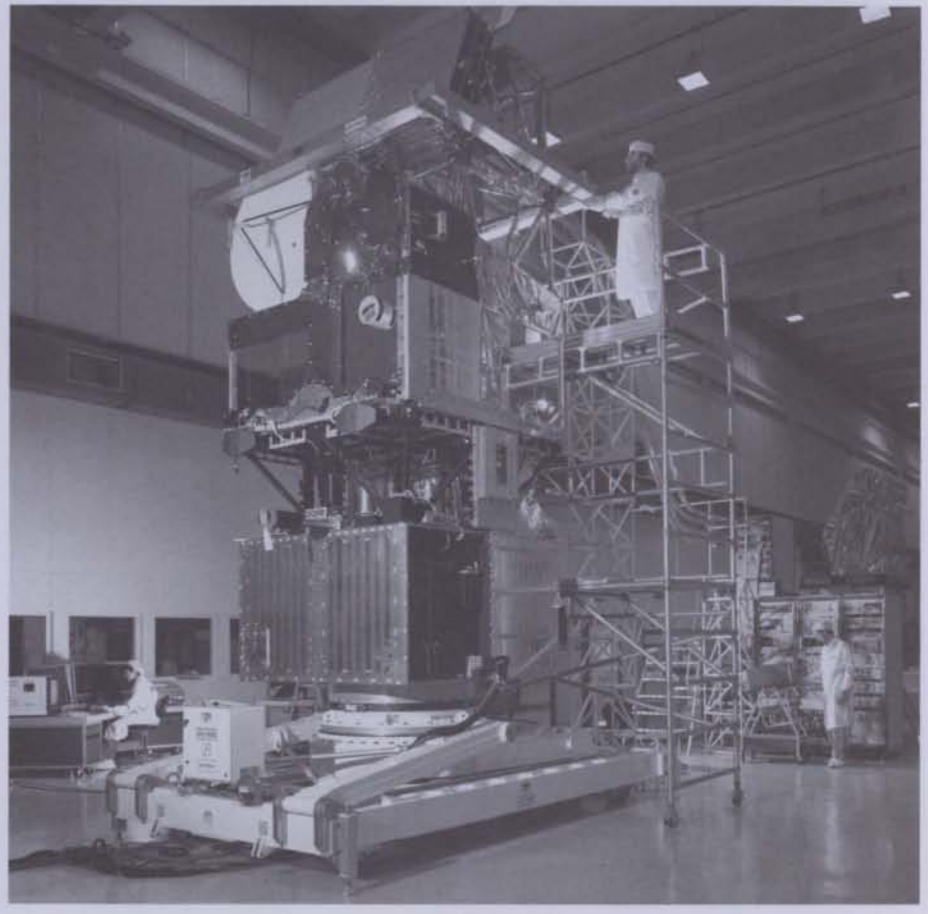
ERS

Après l'achèvement de l'équilibrage thermique du programme d'essais sous vide du modèle d'identification de la charge utile, une analyse détaillée a permis de confirmer la validité de la conception thermique d'ERS-1. Ce même modèle d'identification a été entièrement intégré avec le modèle de vol de la plate-forme et est en cours de préparation pour les essais de compatibilité radioélectrique qui auront lieu courant décembre dans la chambre anéchoïque d'Intespace à Toulouse. Une présentation du satellite, clou de la journée des médias spécialement consacrée à ERS-1, a été organisée à l'intention des délégués au Conseil directeur du programme.

Avec l'arrivée chez Fokker du détecteur actif à hyperfréquences (AMI) pour intégration début décembre, tous les modèles de vol des instruments ont maintenant été livrés. Certains points sont toujours à l'étude et pourront donner lieu à une amélioration ultérieure.

The ERS-1 spacecraft

Véhicule spatial ERS-1



Les activités relatives au secteur sol ont spécialement porté sur la préparation du lancement et du début de fonctionnement en orbite et sur les essais de la chaîne de traitement de données au moyen des données d'essai du satellite et de la charge utile.

Après le lancement, la phase de recette comportera de longues campagnes d'étalonnage et de validation au-dessus des zones côtières norvégiennes. Dans ce domaine, les travaux préparatoires sont en bonne voie.

Earthnet

L'acquisition, l'archivage, le traitement et la distribution des données de Landsat, MOS-1 et Tiros se sont poursuivis dans toutes les stations sol du réseau. A Maspalomas, on a procédé à la recette des chaînes de traitement des données de MOS-1 et de SPOT et les données de SPOT ont été régulièrement acquises et traitées.

ERS-1

Des progrès importants ont été accomplis dans le développement et la mise en oeuvre du secteur sol d'ERS-1.

A millimetre-wave data-relay payload is also undergoing breadboard development as part of the Preparatory Programme.

Following the selection of Selenia Spazio (Italy) as prime contractor, Phase-B2/1 of the programme was initiated last July. This includes the detailed definition and breadboarding of payloads. SILEX is particularly well advanced, and a preliminary design review of the system has taken place. An integrated breadboard model of the optical system (system test bed) is being subjected to performance assessment. Spacecraft-configuration studies have also been completed and, once the platform has been selected from the Italsat and Eurostar options, Phase-B2/2 will start early this year.

Due to the data-relay content of the Technology Mission, a joint programme proposal, covering both the Technology Mission and the Data-Relay System, was submitted to the ESA Council. This joint programme was approved by Council at its meeting in October 1989. It is hoped to open subscription to the Declaration in time to start Phase-C/D of the Technology Mission by the third quarter of 1990, aiming for a launch in 1994.

ERS

Following completion of the thermal-balance/thermal-vacuum test programme with the Engineering Model payload, detailed analysis has confirmed the validity of the ERS-1 thermal design. The Engineering Model payload has been fully integrated with the Flight Model platform, and is being prepared for radio-frequency-compatibility testing in the anechoic chamber at Intespace, Toulouse, in the course of December. The Programme Board Delegates have visited the satellite, which formed the main attraction of a special ERS-1 press day.

All flight instruments have now been now delivered, with the Active Microwave Instrument (AMI) arriving at Fokker for integration at the beginning of December 1989. Some aspects are still under investigation and may lead to later upgrade.

Ground-segment activities have concentrated on preparing for the launch and early-orbit phase and, using data from the satellite/payload testing, trials of the data-processing chain.

After launch, the commissioning phase will include extensive calibration and validation test campaigns centred around Norwegian coastal areas. Preparatory work for this is well advanced.

Earthnet

Acquisition, archiving, processing and distribution of Landsat, MOS-1 and Tiros data have continued at all network ground stations. At Maspalomas, the MOS-1 and SPOT processing chains have been successfully commissioned and SPOT data have been regularly acquired and processed.

ERS-1

Substantial progress has been made in the development and implementation of the ERS-1 ground segment.

Major milestones in establishing the fast-delivery processing chains for Fucino, Frascati, Maspalomas and Gatineau have been reached, with the successful acceptance of the Low-Bit-Rate (LBR) and SAR reference processing systems. Both of these are being installed at Frascati.

Development of the Processing and Archiving Facilities at Brest, Farnborough, Matera and Oberpfaffenhofen is going well.

EOPP

Aristoteles

The additional study on the Aristoteles Solid-Earth Mission, which commenced in May, has progressed well. It concentrates on the further definition of the primary gravity-measurement mission using the Gradio instrument addressed during Phase-A, together with an investigation of additional options related to the provision of a Precise-Positioning Mission, a magnetometer, and a Global-Positioning System receiver.

The System-Definition Review has successfully been completed with the selection of the baseline mission to be used for the remainder of the study.

The accelerometer pre-development has progressed, with the manufacture of the second laboratory model and improvement of the accuracy of the pendulum test bench.

Meteosat Second Generation (MSG)

Two parallel contracts for the study of missions and three-axis-stabilised satellites have been awarded to Aerospatiale and British Aerospace, respectively. The mid-term reviews of the companion studies of spin-stabilised versions of MSG were successfully completed in October 1989.

The related instrument studies are in various stages of definition or execution. A contract has now been placed with Aerospatiale for the High-Spectral-Resolution Sounder study. The High-Resolution Visible Imager Study initiated in early 1989 is progressing well. The Millimetre-Wave-Sounder Simulation and the Small-Optical-Package Studies have now been completed.

On completion of all these studies, proposals will be made for the preferred mission options to be covered, subject to Eumetsat's agreement, in the Phase-A study. Phase-A is planned to start in Industry at the beginning of 1991.

Polar-Orbit Missions

Phase-A of the first Polar-Orbit Earth Observation Mission, which includes studies on the candidate core instruments, is progressing well. The first review was held throughout November 1989, and the mid-term review is scheduled for January 1990.

Interface meetings continue with Eumetsat and the national consultancy groups who are studying the candidate Announcement of Opportunity (AO) instruments to ensure that the most up-to-date information is utilised in the Phase-A study.

The technology studies being conducted to support future polar-orbiting missions are progressing well. They cover microwave instrumentation (e.g. Synthetic-Aperture Radar, radar altimeter), optical instrumentation (e.g. evaluation of visible matrix detectors for medium- and high-resolution imaging spectrometers), as well as general-purpose items (e.g. active cooling systems).

En ce qui concerne la mise en place des chaînes de traitement des produits à livraison rapide à Fucino, Frascati, Maspalomas et Gatineau, des étapes importantes ont été franchies, avec notamment la recette des systèmes de traitement de référence des données à faible débit (LBR) et du SAR. Ces deux systèmes sont en cours d'installation à Frascati.

La mise au point des installations de traitement et d'achivage progresse normalement à Brest, Farnborough, Matera et Oberpfaffenhofen.

EOPP

Aristoteles

L'étude supplémentaire sur la Mission de Physique du globe solide Aristoteles, commencée en mai, a bien avancé. Elle porte essentiellement sur la poursuite de la définition de la mission principale de gravimétrie, à l'aide de l'instrument Gradio qui a fait l'objet des travaux de la phase A, ainsi que sur l'étude d'options supplémentaires comportant la fourniture de moyens de localisation précise, d'un magnétomètre et d'un récepteur GPS (système mondial de localisation).

La revue de définition système s'est achevée sur le choix de la mission de référence qui servira jusqu'à la conclusion de l'étude.

Les travaux de prédéveloppement de l'accéléromètre se sont poursuivis avec la fabrication du deuxième modèle de laboratoire et l'amélioration de la précision du banc d'essais pendulaires.

Météosat de deuxième génération (MSG)

Deux contrats parallèles portant sur l'étude de missions et de satellites à stabilisation triaxiale ont été attribués à l'Aérospatiale et à British Aerospace. Les revues à mi-parcours des études connexes de versions du MSG à stabilisation par rotation ont été menées à bien en octobre 1989.

Pour les instruments, les études correspondantes en sont à divers stades de définition ou d'exécution. Un contrat a été attribué à l'Aérospatiale pour l'étude du sondeur à haute résolution spectrale. Celle de l'imageur visible à haute résolution, commencée au printemps 1989, avance bien. Les études de simulation du sondeur à ondes millimétriques et du petit ensemble d'instruments optiques sont désormais terminées.

A l'achèvement de ces études, des propositions seront faites quant aux options à retenir, sous réserve de l'accord d'Eumetsat, pour l'étude de phase A. Celle-ci devrait commencer dans l'industrie au début de 1991.

Missions sur orbite polaire

La phase A de la première mission d'observation de la Terre sur orbite polaire, qui comprend des études sur les instruments candidats pour le noyau de charge utile, progresse normalement. La première revue s'est tenue en novembre 1989 et la revue à mi-parcours est prévue pour janvier 1990.

Les réunions de liaison se poursuivent avec Eumetsat et les Groupes de consultants nationaux qui étudient les instruments candidats dans le cadre de l'Avis d'offre de participation (AO) pour veiller à ce que l'on utilise les informations les plus récentes dans l'étude de phase A.

Les études technologiques menées en soutien des futures missions sur orbite polaire se déroulent bien. Elles portent sur les instruments hyperfréquences (par ex. radar à synthèse d'ouverture, altimètre radar) les instruments optiques (avec par ex. l'évaluation des détecteurs matriciels dans le visible pour les spectromètres imageurs à haute et moyenne résolution) ainsi que sur des domaines de portée générale (par ex. systèmes de refroidissement actifs).

Météosat

Programme pré-opérationnel

Jusqu'à la mi-octobre 1989, Météosat-3 (ex-P2), resté en attente à 3°W, a servi de renfort à Météosat-4 et contribué à l'expérience LASSO. Le satellite a ensuite été placé à 50°W, position qu'il a atteinte le 4 novembre. C'est en utilisant cette position privilégiée qu'Eumetsat prévoit d'assurer la couverture de l'Atlantique en plus du service de renfort qui se poursuivra jusqu'au lancement de MOP-2.

Météosat 2, lancé en juin 1981, est en train d'épuiser sa réserve d'ergols et sera éjecté de l'orbite géostationnaire dans quelques mois. Son système imageur est périodiquement mis en service et ne montre aucun signe de détérioration au bout de huit années en orbite.

Programme opérationnel

Météosat-4 (ex-MOP-1) continue à assurer ses fonctions de satellite principal.

Les essais d'ambiance du satellite MOP-2 ont été menés à bien dans les locaux de l'Aérospatiale à Cannes. Dans le cadre de la préparation de l'exploitation en orbite, les essais de validation-système ont été conduits en collaboration avec l'ESOC. Le lancement est prévu pour avril 1990 et le troisième modèle, MOP-3, sera lancé en septembre 1993.

A la demande d'Eumetsat, on prépare une proposition de prolongation du programme actuel (la proposition industrielle d'approvisionnement d'un satellite supplémentaire est déjà en cours d'évaluation).

Microgravité

Biokosmos-9

Biokosmos-9, lancé le 15 septembre 1989 par les Soviétiques, a été récupéré le 29 septembre. Les cinq expériences biologiques de l'ESA (env. 7 kg), emportées dans le cadre d'une coopération avec l'Institut de Recherches biomédicales de Moscou, ont fonctionné de façon nominale.

Vols paraboliques

La deuxième campagne de vols paraboliques sur une Caravelle du CNES s'est déroulée en octobre 1989. La prochaine est prévue au premier trimestre 1990.

Fusées-sondes

Les préparatifs des vols Texus 23 et 24 ont été menés à bien, en temps utile pour les campagnes de novembre et décembre, et la préparation de la campagne Maser-4 qui doit se dérouler au printemps prochain se poursuit conformément au calendrier.

Missions Spacelab

IML-1

Les charges utiles ESA de cette mission dont le vol est prévu en décembre 1990

Meteosat

Pre-operational Programme

Meteosat-3 (formerly P2) was on stand-by at 3°W as back-up for Meteosat-4 as support for the LASSO experiment until mid-October 1989. The spacecraft was then moved to 50°W, arriving at this new position on 4 November.

From this vantage point, Eumetsat plans to provide coverage of the Atlantic, in addition to the back-up service that will continue until the launch of MOP-2.

Meteosat-2, which was launched in June 1981, is running low on fuel and will be removed from geostationary orbit within the next few months. Its imaging system is exercised periodically and shows no deterioration after eight years in orbit.

Operational Proqramme

Meteosat-4 (formerly MOP-1) continues to operate as the primary satellite.

The MOP-2 spacecraft has now successfully completed environmental testing at the Aerospatiale facilities in Cannes. In preparation for in-orbit operations, system-validation tests have been performed with ESOC. The launch is scheduled for April 1990 and the third model, MOP-3, will be launched in September 1993.

At Eumetsat's request, a proposal for extension of the present programme is being prepared (the industrial proposal for procurement of one more spacecraft is already being evaluated).

Microgravity

Biokosmos-9

Biokosmos-9 was launched by the Soviet Union on 15 September 1989 and was recovered on 29 September. The five ESA biological experiments (approx. 7 kg) flown as a cooperative basis with the Institute of Biomedical Problems, Moscow, functioned nominally.

Parabolic flights

The second parabolic flight campaign with a Caravelle aircraft from CNES took place in October 1989 and the next campaign is scheduled for the first quarter of 1990.

Sounding rockets

The preparations for Texus 23/24 were completed successfully ready for the November/December campaigns and preparations for the Maser-4 campaign to be held this Spring are proceeding according to plan.

Spacelab Missions

IML-1

The ESA payloads on this mission scheduled for flight in December 1990 are the Biorack and the Critical Point Facility (CPF). The Biorack Integration Readiness Review was successfully held in September 1989 as was the first crew training session. A dry-run on the CPF Engineering Model to verify procedures with the investigators was also held in September.

D-2

The ESA payloads on this mission are the Advanced Fluid Physics Module (AFPM), Anthrorack and ESA experiments in multi-user facilities belonging to DLR. The mission is scheduled for March 1992.

IML-2

The IML-2 mission is planned for February 1993 and will last 16 days. The selected payloads are Biorack (reflight) and the Bubble Drop and Particles Unit. A decision on the Advanced Gradient Heating Facility is pending.

Eureca

Integration of the Eureca flight unit at MBB/ERNO in Bremen is progressing well. 13 of the 15 flight-unit instruments have been delivered to MBB/ERNO, and six have already been integrated with the carrier and have successfully completed interface tests with the Eureca system.

The Eureca work stations, consoles and other peripheral equipment have been installed in the Eureca-dedicated control room at ESOC. ESOC is connected via a Network Interface Unit with the Eureca Integration Centre at MBB/ERNO and can listen to and process telemetry data received from the spacecraft.

Radio-frequency interface tests between the Eureca and Shuttle on-board equipment and the ESOC ground-station equipment have been completed successfully.

Work related to the NASA Space Transportation (Shuttle) System is now proceeding very actively to finalise the Eureca to Shuttle interface, safety, and flight-operations documentation. NASA has nominated Claude Nicolier as mission specialist for Eureca flight STS-46 and he has started the specific familiarisation and training required for Eureca deployment and retrieval operations. Present NASA planning foresees the launch of Eureca by Space Shuttle Atlantis (flight STS-46) on 16 May 1991 and retrieval by Shuttle Discovery (flight STS-51) on 16 January 1992.

Space-Station Freedom/Columbus

The Columbus Space Segment industrial proposal was submitted to ESA on 4 September 1989. This proposal, comprising 375 volumes, has been under continuous evaluation over a period of three months by some 200 ESA staff.

The evaluation is currently expected to be completed by mid-January 1990; a delay of approximately 6 weeks with respect to the original planning. This delay has been caused primarily by the size and complexity of the proposal, the need to evaluate a number of unforeseen proposal updates, and the very late delivery of the required cost data. A preliminary Tender Evaluation Board (TEB) took place in early December, with the final Board planned for the latter part of January 1990.

Evaluation of the Polar Platform Option-A and -B proposals, which was initiated early in July 1989 to meet the October ESA-Council-decision milestone, was completed by the end of September 1989. The evaluation results, together with ESA's recommendations, were submitted for decision to the Council in October. The Council decided in favour of the Option-B proposal, with the proviso that ESA undertook to investigate, in consultation with industry, the possibility of merging the advantages of Options A and B by including, in particular, payload-growth capability in the Option-B design concept.

In October, in parallel with the ongoing industrial proposal evaluation, the Agency authorised the release of a number of configuration-independent tasks in industry under a Phase-C1 Preliminary Authorisation-to-Proceed *sont le Biorack et le Dispositif d'étude des phénomènes de point critique (CPF). La Revue d'aptitude à l'intégration du Biorack, tenue en septembre 1989, a donné de bons résultats, ainsi que la première session d'entraînement de l'équipage. La simulation de fonctionnement du modèle d'identification du CPF, destinée à vérifier les procédures avec les chercheurs, a également au lieu en septembre.*

D-2
Pour cette mission, les charges utiles ESA sont le Module de pointe de physique des fluides (AFPM), l'Anthrorack et des expériences logées dans des installations à utilisateurs multiples de la DLR. Le lancement est prévu pour mars 1992.

IML-2
La mission IML-2, prévue pour février 1993, durera 16 jours. Les charges utiles retenues sont le Biorack (nouvel emport) et le Dispositif d'étude du comportement des bulles, des gouttes et des particules. La décision relative au four à gradient de haute technologie est en suspens.

Eureca

L'intégration de l'unité de vol d'Eureca chez MBB/ERNO (Brême) se déroule de façon satisfaisante. Entre-temps, 13 des 15 instruments du modèle de vol ont été livrés à MBB/ERNO; six d'entre eux sont déjà intégrés sur le porte-instruments et les essais d'interface avec le système ont été menés à bien.

Au Centre européen d'Opérations spatiales (ESOC), les postes de travail, consoles et autres équipements périphériques d'Eureca ont été installés dans la salle de contrôle qui lui est affectée. L'ESOC est relié au Centre d'intégration d'Eureca chez MBB/ERNO via une unité d'interface de réseau et peut donc écouter et traiter les données de télémesure transmises par le véhicule spatial.

Les essais des interfaces en radiofréquences entre les moyens embarqués sur Eureca et sur la Navette et les équipements de la station sol de l'ESOC ont été menés à bonne fin.

En ce qui concerne le Système de transport spatial de la NASA (Navette), on travaille très activement à la mise au point définitive de la documentation relative aux interfaces, à la sécurité et aux opérations en vol Eureca/Navette. La NASA a désigné Claude Nicollier comme spécialiste mission (premier astronaute de l'ESA affecté à une telle fonction) pour la mission Eureca sur le vol STS 46; il a commencé les sessions de familiarisation et d'entraînement spécifique nécessaires aux opérations de largage et de récupération d'Eureca par l'Orbiteur. Le planning actuel de la NASA prévoit le lancement d'Eureca par la Navette Atlantis (vol STS 46) le 16 mai 1991 et sa récupération par la Navette Discovery (vol STS 51) le 16 janvier 1992.

Station spatiale Freedom/Columbus

A la suite de la soumission à l'ESA de la proposition industrielle du secteur spatial Columbus le 4 septembre 1989, l'Agence a immédiatement engagé le cycle d'évaluation de la proposition. Celle-ci comprend 375 volumes. Environ 200 agents travaillent donc à plein temps depuis trois mois à l'étude de ce dossier.

On pense actuellement que l'évaluation sera terminée d'ici à la mi-janvier 1990, soit avec un retard d'environ six semaines par rapport au planning initial. Ce retard est dû pour l'essentiel à l'importance et à la complexité de la proposition, à la nécessité d'évaluer un certain nombre de mises à jour imprévues et à l'envoi très tardif des données de coût demandées. Une réunion préliminaire de la Commission d'évaluation des offres (TEB) a eu lieu début décembre, la réunion finale de la Commission étant prévue pour la deuxième quinzaine de janvier.

L'évaluation des Options A et B de la Plate-forme polaire, qui a commencé début juillet pour respecter l'étape importante que constituait la décision du Conseil de l'ESA en octobre, s'est achevée fin septembre. Ses résultats, ainsi que les recommandations de l'ESA, ont été soumises pour décision au Conseil en octobre. Celui-ci s'est prononcé en faveur de la proposition de l'Option B, à la condition que l'ESA s'engage à étudier, en consultation avec l'industrie, la possibilité de combiner les avantages des Options A et B en introduisant notamment dans le concept de l'Option B une capacité de croissance de la charge utile.

Eureca flight unit instrument integration at MBB/ERNO

Intégration des instruments de l'unité de vol d'Eureca chez MBB-ERNO

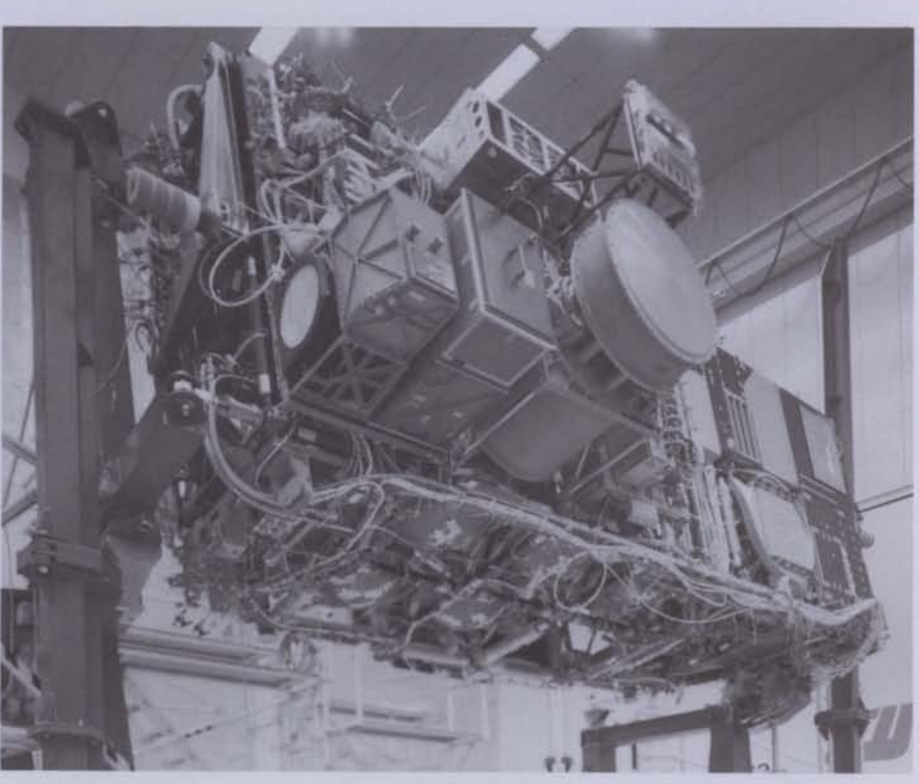
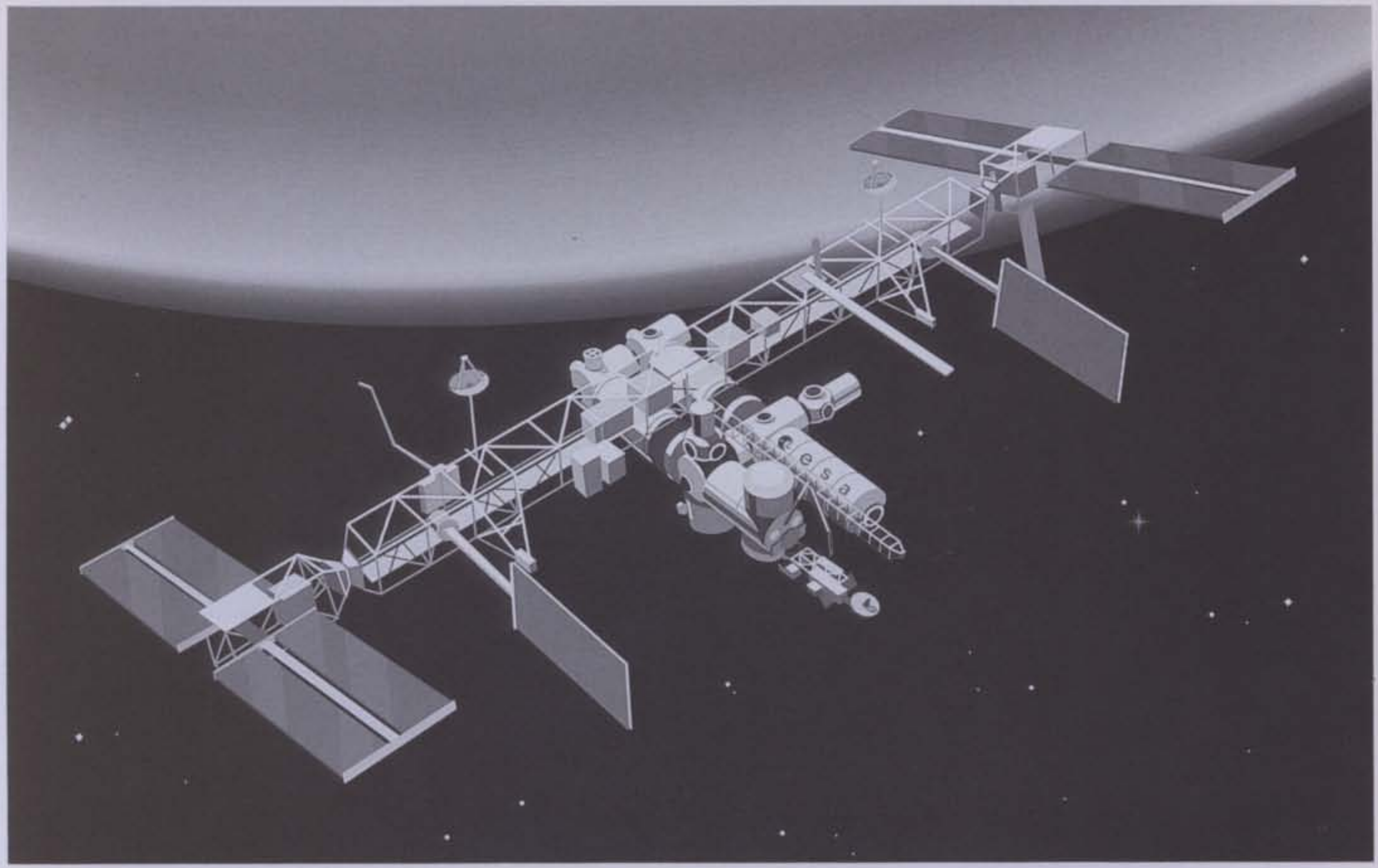


Photo: MBB



Vue conceptuelle récente d'une configuration de la Station spatiale Freedom

Artist's impression of the latest Space-Station configuration

(PATP). This PATP covers space segment industrial activities up to the end of January 1990, after which further authorisation is planned, as appropriate, based on the proposal evaluation results.

During August, NASA briefed their International Space-Station Partners on the proposed changes to Freedom's baseline resulting from the so-called 'Scrub 89' exercise. ESA expressed grave concerrns to the NASA-proposed 'rephased programme' baseline, and indicated the unacceptability of a substantial delay in launching the Columbus Attached Laboratory, the late availability of the full 75 kW station power capability, and the unclear situation with respect to the Station's ability to service the Columbus Free-Flyer.

Through a number of bi-lateral and multi-lateral meetings conducted with NASA and the other international partners during the period September to November, the Space-Station assembly sequence is being reconsidered so that the launch date for the Attached Laboratory could be brought forward and the earliest full servicing of the Free-Flyer could be advanced to fit the nominal launch date.

The ESA/NASA Level-1 Programme Co-ordination Committee (PCC) met in Paris on 2 November to review the overall status of the Columbus and Space-Station Programmes, with particular emphasis on the resolution of the issues related to the NASA rephased programme baseline. Joint documentation aspects, and other management and technical subjects such as the docking/berthing mechanism, were also discussed.

The Columbus Programme has continued to work closely with the Hermes Programme to define further the Columbus Free Flyer/Hermes spaceplane composite configuration and associated servicing mission. In particular, Columbus has participated in the Hermes Preliminary Design Review (RDP-A) and Hermes is supporting Columbus in the establishment of a common set of basic Space-Station interface requirements, applicable to both the Columbus Free Flyer and the Hermes spaceplane. The two Programmes have also worked together to develop a single ESA proposal to NASA for the potential joint US/European development of a standard docking/berthing mechanism for the International Space Station, Columbus and Hermes Programmes.

During the reporting period, the first phase of a Multilateral Utilisation Study supported by the four Space-Station Partners has been completed. The very useful results included analytical integration of a multilateral payload complement across the three laboratory modules, and an operatons analysis for the payloads accommodated. The task of streamlining the interfaces in the different modules to allow easier exchange of payloads between them has been given to a newly created 'Rack Steering Group'.

TDP

Experiments

Phase-2 of the Gallium-Arsenide (GaAs) Technology Experiment, using 2×4 cm cells with welded interconnectors, is progressing on schedule and the

Parallèlement à l'évaluation de la proposition industrielle en cours, l'ESA a autorisé en octobre l'engagement dans l'industrie d'un certain nombre de travaux indépendants de la configuration sous couvert d'une autorisation préliminaire d'engagement de phase C1. Cette PATP couvre les activités industrielles relatives au secteur spatial jusqu'à fin janvier 1990; elle sera suivie, le cas échéant, d'une autre autorisation en fonction des résultats de l'évaluation.

En août, la NASA a fait connaître à ses partenaires au programme de Station spatiale internationale des propositions de modification de la configuration de référence Freedom résultant de l'activité intitulée 'Scrub 89'. L'ESA a fait part de ses graves préoccupations au sujet de la 'configuration modifiée' proposée par la NASA et a indiqué qu'un retard important dans le lancement du Laboratoire raccordé Columbus serait inacceptable, de même que la disponibilité tardive de la pleine capacité de la Station (75 kW) et les incertitudes qui pèsent sur la possibilité d'entretien du Laboratoire autonome Columbus à la Station.

Au cours de plusieurs réunions bilatérales et multilatérales avec la NASA et les autres partenaires internationaux entre septembre et novembre, la séquence d'assemblage de la Station spatiale a été réexaminée pour que la date de lancement du Laboratoire autonome puisse être avancée, de même que la première visite d'entretien de ce Laboratoire, afin d'être en accord avec la date nominale du lancement.

Le Comité de coordination du programme ESA/NASA de niveau 1 s'est réuni à Paris le 2 novembre pour examiner la situation d'ensemble des programmes Columbus et Station spatiale en mettant particulièrement l'accent sur la solution des problèmes liés à la 'configuration modifiée' de la NASA. Les questions de documentation commune et autres questions relatives à la gestion et aux aspects techniques comme le mécanisme d'accostage/amarrage ont également été examinées.

L'équipe du Programme Columbus a continué de collaborer étroitement avec celle du Programme Hermès afin de définir plus précisément la configuration du composite Laboratoire autonome Columbus/Avion spatial Hermès et les missions de desserte associées. Les responsables de Columbus ont notamment participé à la Revue préliminaire de conception d'Hermès (RDP-A) et les responsables d'Hermès collaborent avec ceux de Columbus à la rédaction d'un dossier commun des impératifs d'interface de la Station spatiale, applicables tant au Laboratoire autonome qu'à l'Avion spatial.
Les deux programmes ont également collaboré à la mise au point d'une proposition unique que l'ESA soumettra à la NASA au sujet de la possibilité de développer en commun, aux Etats-Unis et en Europe, un mécanisme d'accostage/amarrage normalisé pour les trois programmes Station spatiale internationale, Columbus et Hermès.

Pendant la période considérée, la première phase de l'étude d'utilisation multilatérale à laquelle ont collaboré les quatre Partenaires a été menée à bien. Au nombre de ses résultats, très utiles, figurent l'intégration analytique d'un ensemble multilatéral de charges utiles exploitable dans les trois modules-laboratoire ainsi qu'une analyse d'exploitation des charges utiles embarquées. La tâche consistant à uniformiser les interfaces dans les différents modules afin de faciliter l'échange des charges utiles entre eux a été confiée au Comité directeur 'Bâtis' récemment institué.

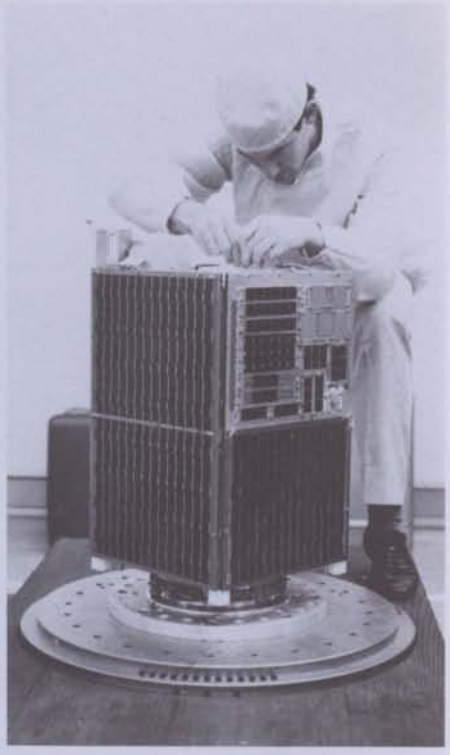
TDP

Expériences

La Phase-2 de l'expérience de générateur solaire à l'arséniure de gallium (GaAs), qui porte principalement sur des piles de 2 cm × 4 cm avec interconnecteurs soudés, se déroule conformément au calendrier et la revue de conception préliminaire aura lieu vers la mi-1990.

La Revue d'acceptation au vol du micro-accéléromètre à l'état solide s'est conclue en novembre 1989 et l'unité de vol est actuellement entreposée.

A la suite de la revue interne du mât à tube enroulable (CTM) à l'ESA, une phase-relais a été engagée préalablement à la Phase C/D au cours de laquelle se poursuivra la définition du système.



UoSAT-E with two TDP experiments onboard

UoSAT-E avec deux expériences TDP embarquées

L'Expérience de dépôt d'aluminium a été rebaptisée pour traduire l'élargissement de sa portée; elle intéressera en effet d'autres matériaux et sera désormais dénommée 'Expérience de dépôt de métaux en orbite'. Les travaux de développement de cette expérience ont déjà commencé.

L'Expérience de technologie de structures gonflables, rigidifiables dans l'espace (auparavant 'Antennes') a également été redéfinie et un mât gonflable va subir des essais à la place d'une antenne. Une demande de prix pour les phases A/B a été lancée en décembre 1989.

Sous-systèmes de soutien communs

L'unité de commande de la charge utile sera livrée d'ici à la mi-1990. Le simulateur du Hitchhiker-G sera livré au premier client au début de 1990.

Expériences en coopération ESA/NASA

Les accords relatifs à l'expérience de contaminattion en vol (IFCE) et à l'expérience d'interactions entre le module de générateur solaire et le plasma (SAMPIE) attendent le résultat de la phase-relais du CTM.

preliminary design review will take place by the middle of 1990.

The Solid-State Microaccelerometer flight acceptance review was successfully completed in November 1989, and the flight unit is now in storage.

Following an ESA internal review of the Collapsible-Tube Mast (CTM), a bridging phase, prior to Phase-C/D, has been initiated, during which the system will be further defined.

The Aluminium-Coating Experiment has been renamed to reflect the broadening of its scope to include other materials, and will henceforth be known as the 'Metal Deposition In-Orbit Experiment'. Development work on this experiment has already begun.

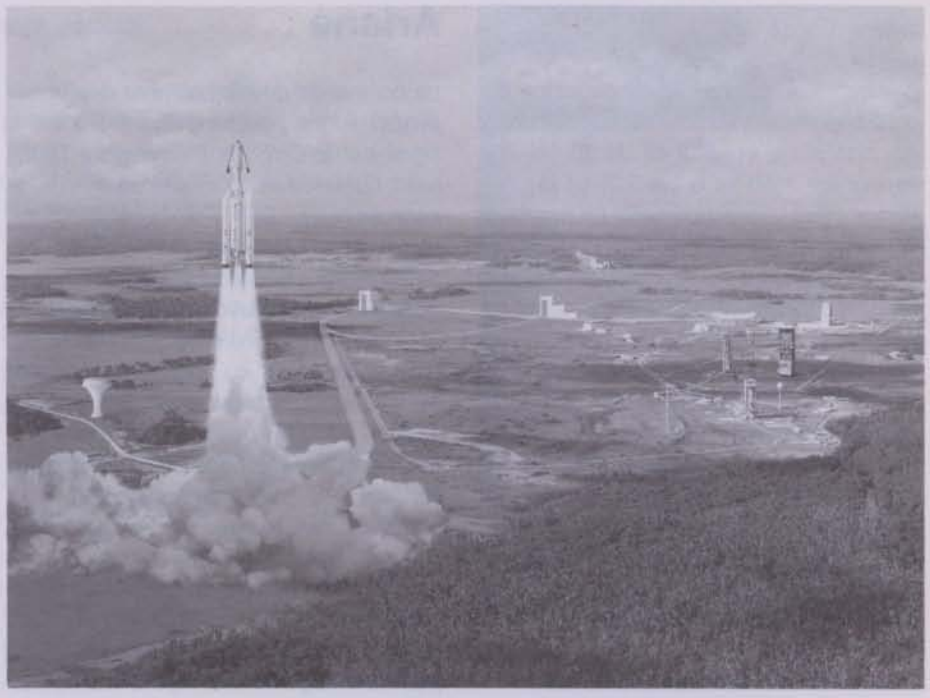
The Inflatable Space-Rigidised Technology (formerly Antenna) Experiment has also been redefined, and an inflatable boom will now be tested in place of an antenna. A Request for Quotations covering Phases-A/B was released in December 1989.

Common Support Subsystems
The Payload Control Unit will be delivered by the middle of 1990. The Hitchhiker-G simulator will be delivered to the first customer early in 1990.

ESA/NASA Cooperative Experiments
The In-Flight Contamination Experiment (IFCE) and Solar-Array-Module Plasma-Interaction Experiment (SAMPIE) agreements are awaiting the outcome of the CTM bridging phase.

Flight opportunities
The Hitchhiker-G experiments — Attitude Sensor Package and Collapsible-Tube Mast — are still scheduled to fly on 30 September 1991 (STS-49) and 22 February 1993 (STS-64), respectively. The Solid-State Microaccelerometer (G21) will now fly on STS-42, in August 1990.

The UoSAT-E launch on Ariane-4 as piggy-back to SPOT-2 was delayed from November 1989 to early January 1990 (for latest news see page 83). The TDP experiments on board are the Transputer and Single-Event-Upset Experiment and the Gallium-Arsenide Solar Panel with an experimental patch. The final choice of carrier for the Gallium-Arsenide Panel with larger cells (Phase-2) will be made early this year.



Vue conceptuelle d'un lancement Ariane-5/Hermès

Artist's impression of an Ariane-5/Hermes launch

Ariane

The development contract for Ariane-5's solid boosters was signed by CNES on 9 November 1989 with Europropulsion and its two parent companies SEP (France) and BPD (Italy). The contract includes the development and qualification of the booster as well as the provision of three pairs of boosters for the qualification flights of the launcher. These solid boosters, containing 230 t of solid material yielding a thrust of 600 t for two minutes, are the largest ever built in Europe.

Europropulsion is the main contractor, with SEP responsible for the nozzles and the structure and BPD for propellant-loading operations, thermal protection and the igniter. The contract also covers sub-contracts with MAN (Germany) for the structure and SNPE (France) for propellant loading. Regulus, a joint BPD/SNPE subsidiary in Kourou (French Guiana) is responsible for loading mechanisms for the central and aft stages. The 20 t forward stage will be manufactured by BPD in Italy.

Occasions de vol

Les expériences Hitchhiker-G — ensemble de détecteurs d'orientation et mât à tube enroulable — sont toujours inscrites sur le vol STS-49 du 30 septembre 1991 et le vol STS-64 du 22 février 1993 respectivement. Le micro-accéléromètre à l'état solide (G21) est désormais inscrit sur le vol STS-42 prévu en août 1990.

Le lancement d'UoSAT-E sur Ariane 4 en complément de SPOT-2 a été reporté de novembre 1989 au début janvier 1990 (voir page 83). Les éléments TDP embarqués sont l'expérience 'transordinateur et perturbations sous l'effet de particules élémentaires' et le générateur solaire à l'arséniure de gallium avec des plaquettes expérimentales. Le choix définitif du support du réseau à l'arséniure de gallium avec des photopiles de plus grandes dimensions (phase-2) interviendra en début d'année.

Ariane

Le contrat de développement des propulseurs à poudre d'Ariane-5 a été signé par le CNES le 9 novembre 1989 avec Europropulsion et ses deux sociétés-mères SEP (France) et BPD (Italie). Le contrat d'un montant total de 540 millions UC comporte la mise au point et la qualification du propulseur ainsi que la fourniture de trois paires de propulseurs pour les vols de qualification du lanceur. Ces propulseurs contenant chacun 230 t de poudre et délivrant 600 t de poussée pendant 2 minutes sont les plus grands propulseurs à poudre jamais réalisés en Europe.

La maîtrise d'oeuvre du développement est assurée par Europropulsion, avec la SEP pour la tuyère et la structure et BPD pour le chargement d'ergols, les protections thermiques et l'allumeur. Le contrat prévoit également des sous-contrats avec MAN (Allemagne) pour la structure et SNPE (France) pour l'étude du chargement. La production des chargements pour les segments centraux et arrière sera assurée par Regulus, filiale commune BPD et SNPE à Kourou en Guyane. Le segment avant de 20 t environ sera réalisé en Italie par BPD.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 13, No. 3:

CASSINI/HUYGENS ENTRY AND DESCENT TECHNOLOGIES
SCOON G ET AL

APPLICATIONS OF REMOTE SENSING TO LAND PLANNING IN THE VENETO REGION OF ITALY
DAINELLI P, PASQUALIN M & SPAGNA V

BIMETALLIC COMPATIBLE COUPLES
DE ROOIJ A

LARGE-SCALE PRODUCTION OF LIGHTWEIGHT MIRRORS
CONNOLLY A & EGLE W

HALO ORBITS FOR SOLAR SAILS – DYNAMICS AND APPLICATIONS
MCINNES C R & SIMMONS J F L

SIMULATION OF SPACE ADAPTATION SYNDROME ON EARTH
OCKELS W J, FURRER R & MESSERSCHMID E

MISSION PLANNING OPERATIONAL REQUIREMENTS TO SUPPORT USERS UNDER THE COLUMBUS SCENARIO
BIDDIS G T, DAVIDSON A & SCHMIDT K D

ESA Special Publications

ESA SP-296 (2 VOLS) // 1145 PAGES
PROC 23RD ESLAB SYMPOSIUM ON TWO TOPICS IN X-RAY ASTRONOMY (VOL 1: X-RAY BINARIES; VOL 2: AGN AND THE X-RAY BACKGROUND), BOLOGNA, ITALY, 13 – 20 SEPTEMBER 1989 (NOVEMBER 1989)
HUNT J J & BATTRICK B (EDS)

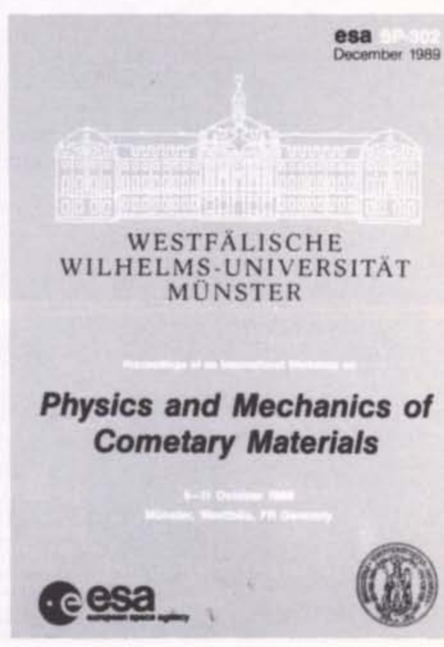
ESA SP-297 // 452 PAGES
PROC SECOND EUROPEAN IN-ORBIT OPERATIONS TECHNOLOGY SYMPOSIUM, TOULOUSE, FRANCE, 12 – 14 SEPTEMBER 1989 (DECEMBER 1989)
ROLFE E J (ED)

ESA SP-302 // 246 PAGES
PROC. INTERNATIONAL WORKSHOP ON PHYSICS AND MECHANICS OF COMETARY MATERIALS, MUNSTER, GERMANY, 9 – 11 OCTOBER 1989 (DECEMBER 1989)
HUNT J J & GUYENNE T D (EDS)

ESA SP-1122 // 70 PAGES
PROMOTION OF EUROPEAN SPACE TECHNOLOGY TRANSFER, PROC WORKSHOP, VERSAILLES, FRANCE, 9 – 11 MAY 1989 (NOVEMBER 1989)
GUYENNE T D & HUNT J J (EDS)

ESA Brochures

ESA BR-61 // 36 PAGES
WORKING FOR SPACE, THE 1988 SOCIAL REPORT (BILINGUAL) (OCTOBER 1989)
LANDEAU J & LONGDON N (EDS)



ORDERING OF ESA PUBLICATIONS

We regret to announce that, because of increasing problems with non-payment of invoices, we can no longer process orders for ESA publications until payment has been received.

The price for ESA publications is quoted in Dutch guilders in the ESA Bulletin and Journal and the yearly ESA Publications Catalogue. Within Europe no postal charges will be included in future. Publications to destinations outside Europe will ordinarily be sent by sea mail. If you live outside Europe and wish your order to be sent Airmail, please indicate this clearly and add 10% onto the price quoted. Please include a cheque or banker's draft in Dutch guilders (including the additional 10% where relevant) made payable to 'ESA Publications Division'.

Firms and organisations which place regular orders may like to take advantage of an arrangement by which they are billed retroactively every six months. For further details please contact the ESA Publications Distribution Office at ESTEC.

ESA Newssheets

EARTH OBSERVATION QUARTERLY // 6 PAGES
NO. 27 (OCTOBER 1989)
GUYENNE T D (ED)

ECSL NEWS N0 3 // 4 PAGES
BULLETIN OF THE EUROPEAN CENTRE FOR SPACE LAW, PUBLISHED TWICE A YEAR UNDER THE AUSPICES OF THE EUROPEAN SPACE AGENCY (JANUARY 1990)
GUYENNE T D (ED)

NEWS & VIEWS // 8 PAGES
ESA-IRS NEWSLETTER VOL 14 NO 4 (DECEMBER 1989)
LONGDON N (ED)

Procedures, Standards and Specifications

ESA PSS-01-11 // 16 PAGES
CONFIGURATION MANAGEMENT AND CONTROL FOR ESA SPACE SYSTEMS (MARCH 1989)
PRODUCT ASSURANCE & SAFETY DEPARTMENT

ESA PSS-01-40 ISSUE 2 // 75 PAGES
SYSTEM SAFETY REQUIREMENTS FOR ESA SPACE SYSTEMS (SEPTEMBER 1988)
PRODUCT ASSURANCE & SAFETY DEPARTMENT

ESA PSS-01-60 ISSUE 2 // 33 PAGES
COMPONENT SELECTION, PROCUREMENT AND CONTROL FOR ESA SPACE SYSTEMS (NOVEMBER 1988)
PRODUCT ASSURANCE & SAFETY DEPARTMENT

ESA PSS-O1-729 ISSUE 1 // 15 PAGES
THE DETERMINATION OF OFFGASSING PRODUCTS FROM MATERIALS AND ASSEMBLED ARTICLES TO BE USED IN A MANNED SPACE VEHICLE CREW COMPARTMENT (FEBRUARY 1989)
PRODUCT ASSURANCE & SAFETY DEPARTMENT

ESA PSS-03-108 ISSUE 1 (6 VOLUMES)
SPACECRAFT THERMAL CONTROL DESIGN DATA (NOVEMBER 1989)
THERMAL CONTROL & LIFE SUPPORT DIVISION

ESA PSS-04-106 ISSUE 1 // 73 PAGES
PACKET TELEMETRY STANDARD (JANUARY 1988)
STANDARD APPROVAL BOARD FOR SPACE DATA COMMUNICATIONS

EUROPEAN SPACE TRIBOLOGY LABORATORY

Tribology of Spacecraft

A two-day course to be held at Risley, UK

16 - 17 May 1990

All those involved in the design, development and testing of spacecraft mechanisms need an up-to-date knowledge of tribology. This course is specifically aimed at practising engineers and scientists in the space industries who face friction, wear and lubrication problems. The course is also relevant to those involved with mechanism applications for terrestrial vacuum environments.

The course assumes no prior knowledge of tribology and will cover the fundamentals, as well as the latest tribological advances and solutions available to the space industries.

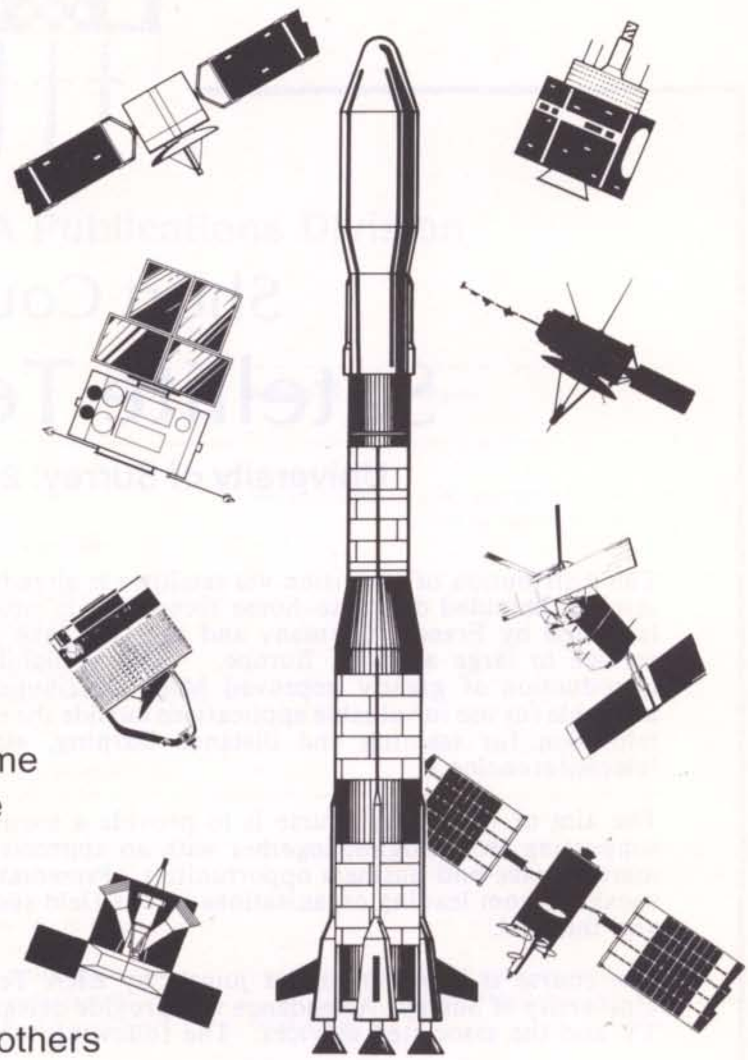
There will be 11 lectures covering the following subjects:

1. Tribology fundamentals for spacecraft applications
2. Fluid lubricants
3. Solid film lubricants
4. Polymer & composite applications
5. Bearings: types, materials & characteristics
6. Ball bearing behaviour & misbehaviour
7. Electrical contacts & connectors
8. Gear technology for spacecraft applications
9. Tribology for cryogenic applications
10. Thermal vacuum testing
11. Tribology & space mechanism design

The course will be held at the Main Lecture Theatre, AEA Technology, Risley, Warrington, UK. The course fee will be £375 + VAT and this includes luncheons and refreshments. Registration documents will be issued in March 1990. For further information, early registration or hotel details contact:

Mr Chris Barlow
National Centre of Tribology
AEA Technology
Risley, Warrington, WA3 6AT
UK
Tel 0925-31244, ext. 3232
Fax 0925-782579
Telex 629301 ATOMRY G

YOU have helped build
EUROPE'S PLACE in SPACE . . . .
. . . you are entitled to take advantage of technological know-how acquired through years of research and development!



YOU have also helped build
EUROPE'S PLACE IN ONLINE INFORMATION RETRIEVAL . . .
. . . ESA-IRS, the European Space Agency's own Information Retrieval Service, was born some 15 years ago to provide Europe with a service badly needed. Due to its R&D orientation in the context of the Agency's mandate, ESA-IRS is already operating in the future – where others just reached the present!

TO BE A LEADER – USE A LEADER!

Write or call us for more information on

- our over 120 databases & databanks
- how to use your PC to access ESA-IRS
- our electronic mail service
- how to create your own private file
- our DOWNLOAD facility
- how to order original documents online
- our software, our prices, and many other services

esa
european space agency

IRS
Online Services

Via Galileo Galilei
00044 – FRASCATI (ITALY)
Tel. (39/6) 94011
Twx. 610637 esrin i

Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Availability	Source
Periodicals				
ESA Bulletin	4	ESA's magazine	Free of charge	ESA Publications Division, ESTEC,
ESA Journal	4	ESA's learned journal	,,	2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly (English or French)	4	Remote sensing newspaper	,,	,,
ECSL News	4	Bulletin of the European Centre for Space Law (under the auspices of ESA)	,,	,,
Reaching for the Skies	4	ESA's Space Transportation Systems	,,	,,
Columbus Logbook	4	Space Station/Columbus newspaper	,,	,,
Microgravity News from ESA (English or French)	3	Europe's microgravity research programme	,,	,,
News & Views	6	ESA Information Retrieval Service's newspaper	,,	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Volumes on specific Conference subjects	Prices below	ESA Publications Division, ESTEC,
Scientific/Technical Monographs	(SP-xxxx)	Specific/detailed information on graduate-level subjects	,,	2200 AG Noordwijk, The Netherlands
ESA Brochures	(BR-xxx)	Summary of less than 50 pages on a specific subject	,,	,,
ESA Folders	(F-xxx)	'Folders' giving short description of a subject for the space-interested layman	Free of charge	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	Prices below	,,
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	,,	,,
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	,,	,,
Other Publications				
Contractor Reports	(CR-xxx)	Study reports from contractors: CR(P) given unlimited distribution CR(X) confined to certain ESA Member States	Prices below ,, ,,	ESA Publications Division, ESTEC 2200 AG Noordwijk, The Netherlands ,,
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	,,	,,
Technical Translations	(TT-xxx)	Translations of national space-related documents — (Microfiche or photocopy only)	Prices from ESRIN	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy, or ESA/IRS Office, 8-10 Mario Nikis 75738 Paris 15, France
Public-relations material		General literature, posters photographs, films, etc.		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

Charges for printed documents	E0	E1	E2	E3	E4
Number of pages in document:	1—50	51—100	101—200	201—400	401—600
Price (Dutch Guilders)	20	30	40	60	80

1. Cheques to be made payable to: ESA Publications Division
2. Prices subject to change without prior notice
3. Mailed free-of-charge (sea mail outside Europe). If airmail is required, please add 10% to prices indicated above.

Order Form for ESA Publications

(Must be accompanied by a cheque or banker's draft. For prices please see overleaf).

RETURN TO: DISTRIBUTION OFFICE, ATTN: F. DE ZWAAN
ESA PUBLICATIONS DIVISION
ESTEC, POSTBUS 299
2200 AG NOORDWIJK
THE NETHERLANDS

No. of copies	ESA Reference	Title	Price per copy, Dfl.	Total Dfl.

Airmail (outside Europe) ☐ yes Add 10% of total: ....

Total Amount enclosed: Dfl. ....

MAILING ADDRESS (Print carefully)

Name ....

Function ....

Organisation ....

Mailing Address ....

....

Town & Postal Code ....

Country ....

Customer's Ref. .... Signature ....

Date ....

ADDITIONAL INFORMATION

1. Publications are available in printed form (as long as stocks last), in microfiche and as photocopies.
2. Publications in the ESA TT series are not available in printed form.
3. Mailing free-of-charge (outside Europe sea mail). If airmail outside Europe is required please add 10% to total.

esa
european space agency
agence spatiale européenne

Member States	Etats membres
Austria	Allemagne
Belgium	Autriche
Denmark	Belgique
France	Danemark
Germany	Espagne
Ireland	France
Italy	Irelande
Netherlands	Italie
Norway	Norvège
Spain	Pays-Bas
Sweden	Royaume-Uni
Switzerland	Suède
United Kingdom	Suisse

European Space Agency / Agence Spatiale Européenne
8 - 10 rue Mario-Nikis, 75738 Paris Cedex 15, France